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Project ECO-EFFI Final Report

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PREFACE

Global shipbuilding is a highly competitive industry, and it has also been affected by the current economic crisis. Thus far, the European shipyards have been able to maintain their leading position due to their innovative technologies, although low-wage countries have gradually increased their share of the industry.

This study is part of the ECO-EFFI co-operation project, which has aimed to develop methods and tools to estimate a ship's eco-efficiency throughout its life cycle. ECO-EFFI is a subtask of a project called SEEE (Ship's Energy Efficiency & Environment), which is implemented under FIMECC's (Finnish Metals and Engineering Competence Cluster) EFFIMA programme (Energy and Life Cycle Cost Efficient Machines). The project is being implemented in cooperation with Turku University of Applied Sciences, VTT, ABB Marine and Turbocharging Oy, Deltamarin Oy and Napa Oy. Turku University of Applied Sciences' part in ECO-EFFI is to create basis for a transparent, measurable and comparable environmental performance indicator system for shipbuilding and ship recycling yards.

For the study, international and national laws and regulations concerning shipbuilding and dismantling were studied. Different environmental indicators, indexes and methods designed to measure environmental impacts of companies and industries were explored with the most useful presented in the report. Various experts were interviewed for the report in order to bring practical input and to analyse the literature reviews. Two bachelor's theses; "Environmental Impacts of Ship Dismantling – Screening for sustainable ways" by Juho Vuori and "Environmental Legislation and Regulations of Shipbuilding – Case comparing Finland and Spain" by Juho Pulli have been made for the project. This report is partly based on those theses while complementing them at the same time.

Three shipyard types – new building shipyards, repair and maintenance yards and dismantling yards – were identified as requiring their own environmental indexes: hence operations with the most significant environmental effects were identified. The need for a coherent and comparable environmental index in shipbuilding and especially in ship dismantling on international level became clear. Furthermore, a binding regulation mechanism is necessary in order to have all countries and shipyards abide by them.

The experts interviewed for the project, either in person or via email include Pentti Häkkinen and Anu Keltaniemi from Turku University of Applied Sciences, Matti Juhala from Aalto University, Jaana Hänninen from STX Finland, Jussi Mälkiä from Auramare, Hannele Tonteri from VTT and Henri Tuominen from Bureau Veritas. Additionally, Kiti Vihavainen and Marko Ulvila, assistants to the members of the European Parliament Sirpa Pietikäinen and Satu Hassi, respectively, provided an update to the project concerning the European Union's regulations. Our project personnel express their gratitude to all the experts for taking the time and sharing their expertise for the project.

This research was conducted within the Energy and Life Cycle Cost Efficient Machines (EFFIMA) research programme, managed by the Finnish Metals and Engineering Competence Cluster (FIMECC), and funded by the Finnish Funding Agency for Technology and Innovation (TEKES), research institutes and companies. Their support is gratefully acknowledged.

Turku, August 30, 2013

Juho Pulli & Jonna Heikkilä

ABBREVIATIONS

BAT	Best Available Technique
BREF	Best Available Technique Reference Documents
BREEI	Baltic Region Environmental Efficiency Index
CAP	Criteria Air Pollutants
CIESIN	Columbia University's Center for International Earth Science Information Network
DDT	Dichlorodiphenyltrichloroethane
DWT	Deadweight Tonnage
EEB	European Environmental Bureau
EEDI	Energy Efficiency Design Index
EFFIMA	Energy and Life Cycle Cost Efficient Machines
ESI	Environmental Sustainability Index
EPI	Environmental Performance Index
EU	European Union
FIMECC	Finnish Metals and Engineering Competence Cluster
GHG	Green House Gases
HKC	Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships
IACS	International Association of Classification Societies Ltd
IHM	Inventory of Hazardous Materials

ILO	International Labour Organization
IMO	International Maritime Organization
IPPC	Integrated Pollution Prevention Control
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
NORDIC-EPI	Nordic Environmental Performance Index
OECD	Organisation for Economic Cooperation and Development
PAH	Polyaromatic Hydrocarbon
PPRC	Pacific Northwest Pollution Prevention Resource Center
PVC	Polyvinyl Chloride
REACH	Registration, Evaluation, Authorization and Restriction of Chemical Substances
ROPAX	Roll-On/Roll-Off Passenger Ship
SPR	Ship Recycling Plan
TUAS	Turku University of Applied Sciences
UN	United Nations
US	United States
TBT	Tributyl Tin
VOC	Volatile Organic Compound
VTT	Technical Research Centre of Finland
SEEE	Ship's Energy Efficiency & Environment
WSR	Waste Shipment Regulation

1 INTRODUCTION

1.1 BACKGROUND

This study is the final report of the ECO-EFFI co-operation project. The purpose of the project is to develop methods and tools to estimate a ship's eco-efficiency. ECO-EFFI is a subtask of SEEE (Ship's Energy Efficiency & Environment), a project which is implemented under FIMECC's (Finnish Metals and Engineering Competence Cluster) EFFIMA programme (Energy and Life Cycle Cost Efficient Machines). The other co-operators in this project with Turku University of Applied Sciences are VTT, ABB Marine and Turbocharging Oy, Deltamarin Oy and Napa Oy. Turku University of Applied Sciences' part in ECO-EFFI has been the creation of a coherent environmental scale for shipbuilding and ship dismantling.

The aim of the environmental performance indicator system for shipbuilding and ship recycling is to be transparent and comparable between different shipyards. This has been challenged by the diversity of the shipyards; there are shipyards that are building new ships from prefabricated blocks or building from raw materials as well as shipyards that are repairing old ships and/or doing modifications on them. Furthermore, there are many different ship dismantling yards. Asian yards are most commonly just beaches where the ships about to be dismantled are driven or towed, and dismantled on the spot. The next step up from this would be for example Turkish yards, which have drydocks. The most environmentally friendly yards are the so-called "recycling yards", which have higher efficiency for material re-use and better environmental standards. Shipyards also possess different environmental effects, they may operate in very different localities, and they have varying numbers of subcontractors, which again have different environmental effects of their own. The timeliness of the research, especially regarding ship dismantling in developing countries and the need for consistent environmental scale has become clear, although defining the limits of the index clearly from the start was essential.

1.2 METHODS

This report is based on two bachelor's theses written for the project "Environmental Impacts of Ship Dismantling – Screening for sustainable ways" by Juho Vuori from the Department of Mechanical and Production Engineering and "'Environmental Legislation and Regulations of Shipbuilding – Case comparing Finland and Spain" by Juho Pulli from the Department of Sustainable Development. The first thesis reviewed the last part of the ship's life cycle – the dismantling. It created a comprehensive general view on the matter and also estimated the future of the dismantling process. (Vuori 2013.) The second thesis set out to compare environmental legislation in two countries, Finland and Spain, and compared the differences between them. The study also pondered upon whether these environmental regulations were enough to protect the environment. (Pulli 2013.)

The report is complementary to the "Calculations of Environmental Footprint for Shipbuilding" by VTT. Their study on the LCA (Life Cycle Assessment) for shipbuilding used one ship as the product, whose output and material consumption were calculated in order to review its impact on eutrophication, climate change and acidification. The study was finished in 2012. (VTT 2012, unpublished.)

From the abundant literature reviews used for this project, a few documents need to be acknowledged. In 2010, the Organization for Economic Co-operation and Development (OECD) produced a report titled "Environmental and Climate Change Issues in the Shipbuilding Industry". It describes very thoroughly the processes of shipbuilding and also the environmental effects of these processes. In addition to this, a report from Pacific Northwest Pollution Prevention Resource Center (PPRC) called "Environmental Impacts of Shipbuilding and Repair Operations" and International Labour Organization (ILO) document "Encyclopaedia of Occupational Health and Safety Fourth edition" list the processes and environmental effects of shipyards (PPRC 2008, OECD 2010, ILO 2013.) These reports were used as comparison for other references and as a basis for expert interviews. Furthermore, several different indexes and indicators were studied for the project. Most notable ones are listed in Chapter 5.

Literature findings were complemented by interviews with experts, whose practical knowledge was used to verify the literature reviews. The experts interviewed for the project, either in person or via email, include Pentti Häkkinen and Anu Keltaniemi from Turku University of Applied Sciences, Matti Juhala from Aalto University, Jaana Hänninen from STX Finland, Jussi Mälkiä from Auramare, Hannele Tonteri from VTT and Henri Tuominen from Bureau Veritas. In addition, Kiti Vihavainen and Marko Ulvila, assistants to the members of the European Parliament Sirpa Pietikäinen and Satu Hassi, respectively, provided an update to the project concerning the European Union's regulations.

2 LAWS AND REGULATIONS OF SHIPBUILDING AND DISMANTLING

2.1 SHIPBUILDING

2.1.1 International Laws

Shipbuilding is not regulated by one specific international law. The international organization working on ships and shipping is the International Maritime Organization (IMO), which is a specialized agency within the United Nations (UN). It is, however, focused on security of shipping and preventing marine pollution caused by ships rather than regulating shipyards. Apart from working under the law of the nation where the shipyard is located, larger entities control the nation's legislation and thus the shipyard's operations as well. For example, the EU directives are implemented straight into the legislation of a member state, so they influence the national environmental regulations of shipyards in the member country in question.

Currently, most of the environmental effects are produced in the operating phase and more environmentally friendly ships are promoted, whilst the production plant (shipyard) is overlooked. Globally, ship dismantling has received much more environmental attention than shipbuilding. This is most likely due to the fact that ship dismantling is performed in places where blatant abuse of both environment and health and safety regulations takes place. (IMO 2013a.)

2.1.2 EU Regulations

There are a few EU regulations that are important in the shipbuilding industry. These directives need to be followed by every EU member state and adapted into the existing national legislation, or new laws need to be created for them.

Integrated Pollution Prevention and Control, more commonly known as the IPPC, is perhaps the most important directive. It requires highly polluting industries, such as the shipyards, to prevent or reduce pollution emitted into the air, soil and water. The directive also establishes a procedure for environmental permits with the introduction of minimum environmental requirements and surveillance procedures for the authorities. The aim is to ensure high level of environmental and health protection. (Europa 2011a.)

One of the main ideas in the IPPC Directive is the usage of BATs, best available techniques. Industries and businesses above a certain size must obtain a permit for their activities using BATs for pollution prevention, waste disposal and energy efficiency. (Europa 2011b.) Environmental authorities, in co-operation with the industries, have produced documents called best available technique reference documents (or BREFs) in order to determine the BAT level for each plant for different sectors of industry. These documents can be found on the European Commission website. (Europa 2008a.)

The only BREF concerning shipyards is the "Surface Treatment Using Organic Solvents", which was created in 2007. The document includes detailed information about the BAT processes for surface treatment. For shipyards, the BREF addresses painting and other coating activities of ships and yachts. Main environmental effects of surface treatment are volatile organic compounds (VOC) emissions to air and water, waste being produced, noise and impacts on soil and groundwater. A review of the document is planned for 2014. (Europa 2008b.)

The "Surface Treatment Using Organic Solvents" BREF's section for coating of ships and yachts is divided into four parts:

- General information about the coating of ships and yachts
- Applied processes and techniques in the coating of ships and yachts
- Current consumption and emission levels in the coating of ships and yachts
- Techniques to consider in the determination of BAT for the coating of ships and yachts.

In the last part, different techniques for coating of ships and yachts are considered. Such different techniques include:

- Management systems – dock discipline
- Enclosure techniques
  - Open areas
  - Partially enclosed areas, windbreaks, spray curtains, etc.
  - Fully enclosed areas
- Surface preparation
  - Dry blasting – open system
  - Dry blasting – closed system, vacuum or shroud blasting
  - High pressure fresh water jetting or blasting
  - Wet or slurry blasting
  - Other surface treatments
- Coating materials
  - Conventional solvent-based coating materials
  - Replacement of solvent-based materials (substitution)
    - Water-based paints
    - High solid paints
- Additional corrosion protection – cathodic protection
- Paint application techniques and equipment
  - Airless spraying
  - Hot spraying
  - Integrated air extraction at the point of application
- Alternatives to antifouling paints based on biocides
  - Fouling release coatings based on silicones
  - Mechanical methods
  - Electrochemical processes
- Waste gas treatment
- Waste water treatment
- Waste management. (Europa 2007.)

Within the diverse techniques listed, the first one mentioned is the most widely used technique at the moment. With each of these techniques, the document gives a description of use and operational data and applicability. Environmental benefits achieved using the technique are also described, with cross-media effects, such as extra power needed, are also brought forward. Economic data, compared to the widely used technique, is also described, as well as the driving force behind the use of this particular technique. Example plants are detailed, if there are any. (Europa 2008b.)

When considering VOC emissions, which have been widely acknowledged as having the highest pollution potential in modern shipyards, the range of techniques available for coating need to be reviewed (PPRC 2008, OECD 2010, ILO 2013). The processes of coating techniques provide a valid example of the aim of the environmental performance indicator: a shipyard operating with the most environmentally friendly practice is graded higher than one operating with less consideration for the environment. When the processes with highest impact on the environment are reviewed along with defined weighting coefficients, a comparable environmental performance scale between the shipyards can be created. Registration, Evaluation, Authorization and Restriction of Chemical Substances (REACH) is a directive issued to control the use of chemicals. All chemicals that produce or use these chemicals must follow the directive. The aim is to have better control over chemicals, and to promote the replacement of dangerous chemicals with safer ones. (European Commission 2013.)

2.2 SHIP DISMANTLING

Ship dismantling was, for a long time, a completely unregulated industry. This loophole in international regulations created an undesired standard procedure for ship operators to dispose of their old vessels. Over the past two decades, awareness in the problems of the ship breaking industry has risen significantly and a need for development of environmentally sustainable ship dismantling is current. However, ship dismantling is a global issue, and therefore creating international rules and regulations is a very slow process. There are already agreements and conventions concerning the industry in place, but they are, for the time being, mainly advisory in nature, and surveillance is ineffective. (OECD 2010, 6.)

In 2010, the Basel Convention (on the Control of Transboundary Movements of Hazardous Wastes and their Disposal) came into force. The Convention does not address ship dismantling but rather generally controls the movement and dumping of hazardous waste in developing countries by companies from more developed ones. There are 53 parties that have signed the Basel Convention, including the EU. Apart from two countries, Haiti and the United States of America, all parties have also ratified the convention. (Basel Convention 2013a.)

In 1997, the European Parliament approved the Waste Shipment Regulation (WSR). In the regulation, the commission and the member states are advised to take certain actions immediately on the ship dismantling industry. In the aftermath, the Green Paper was published in 2007 by the European Commission on better ship dismantling. The Green paper states the Basel Convention to apply for ship dismantling as well. The Green paper presents possible actions with which the European Union could promote safe and environmentally sound processing of scrap ships globally, promotes all stakeholders in to open discussion on the challenges of ship dismantling and builds bases for the future EU policies on the industry. (Commission of the European Communities 2007, 9–10.)

In 2004, in order to improve the Basel Convention in relation to ship dismantling, IMO was invited by the members of the Basel Convention to draft binding requirements for environmentally sound ship dismantling (Basel Convention 2013c). As a result, the Marine Environment Protection Committee (MEPC), a sub-organization of the IMO, developed "Guidelines for the development of the ship recycling plan". The goal of the guidelines was to ensure all ships carry their own Ship Recycling Plan (SPR) in order to be prepared for proper recycling and safety. (Marine Environment Protection Committee 2011, 3.)

Furthermore, the Inventory of Hazardous Materials (IHM), also known as the "Green Passport", was introduced along with the new convention. The Green Passport is a vessel's individual documentation of all harmful materials on board, which is required for all newly built ships and also from the existing ones within a transition period. Regular updating of the IHM is required as well as the documentation of all repairs and conversions conducted on the ship. (International Maritime Organization 2009, 15–17.)

The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC) has been promoted by the EU and the parties of the Basel Convention (European Commission 2012, 4–5). The convention would include "the design, construction, operation and preparation of ships so as to facilitate safe and environmentally sound recycling without compromising the safety and operational efficiency of ships; the operation of ship recycling facilities in a safe and environmentally sound manner; and the establishment of an appropriate enforcement mechanism for ship recycling, incorporating certification and reporting requirements". The convention will come into force within 24 months, after 15 states, which represent 40% of major merchant shipping countries, have signed it (IMO 2010.)

3 SHIPBUILDING, MAINTENANCE AND REPAIR

3.1 BACKGROUND

There are a wide variety of shipyards around the world. As well as new building shipyards, repair yards and dismantling yards, there are some that include operations from all of these types. Thus the processes and environmental effects of a shipyard cannot be pinned down to one standardized example. Hence, the processes described here, as well as the environmental effects described in the Chapter 3.3, are portrayed in a broad way.

"For shipbuilding the processes include:

- handling of raw materials; fabrication and surface treatment of basic steel parts;
- joining and assembly of fabricated parts into blocks;
- erection of ship structures through the fitting and welding of blocks;
- outfitting of ships with electronic equipment; and
- preparation and installation of various fabricated parts that are not of a structural nature." (OECD 2010.)

The above mentioned are so-called "fabricated parts". The industry uses the term "prefabricated parts or sections" to describe the process whereby the superstructures of the ship are created elsewhere by subcontractors and then transported in parts to the actual shipyard for assembly. This has been a growing trend in shipbuilding, as opposed to building everything from raw materials at the shipyard. This plays a major role in the environmental effect of a shipyard, as the initial phases of shipbuilding, up till the prefabricated sections are assembled, are handled outside of the shipyard and thus their environmental impact appears elsewhere. (OECD 2010, ILO 2013.)

3.2 POLICIES WITHIN THE EU

The European Union has a strong drive to pursue environmentally friendly shipbuilding practices. The European Commission's website presents a collection of studies and projects for a greener shipbuilding future. (Europa 2013a.) One such project is the LeaderSHIP project. The first project was launched in 2013 as "LeaderSHIP 2015". It focused on the business aspect of shipyards, even more so after the financial crisis in 2008. On the other hand, the project had environmental aims for "Promoting Safer and More Environment-Friendly Ships" as well. As a result, it was recommended that existing and future EU legislation be implemented on an international level as well. EU-based shipyards have shifted further and further away from bulk crafting, into specialized ship crafting areas. This should be encouraged, and EU shipbuilding industry should continue taking the lead in the "clean shipping technology", where technological efforts to reduce energy consumption, air emissions and use of hazardous materials as well as the use of more environmentally friendly ship coatings and antifouling protection is promoted. (Eurlex 2003.) The same agenda appears in the 2020 version of LeaderSHIP. There, greening and diversification of shipbuilding have been recognized as "game-changers" in the short term. The barriers to these have also been discussed in the document. Lacking or insufficient financial return on investment and lack of investment certainty have been determined as the two main problems. (Europa 2013b.)

On the other hand, tightening environmental regulations can be an opportunity. This is stated in the "Green-growth opportunities in the EU shipbuilding sector"report, which was produced for the EU Commission in 2012 by a company called Ecorys. The study concentrated on forthcoming global and European regulatory changes to environmental issues like ballast water, sulphur and nitrogen oxide emissions, and what sort of market opportunities that could create for the European shipbuilding industry. The study states that green-market opportunities are market-based, but regulatory issues are also needed. "Balanced in terms of aims" is their statement, which refers to the aim of balance between environmental and economic objectives, rather than focusing on only one of them. According to the report, all varieties of legal policies should be used to achieve this, not just regulatory actions and taxes. (Ecorys 2012.)

It seems evident that know-how in green-building is going to be a huge asset, or a "game-changer", in the future when environmental regulations have advanced enough. According to these documents, it seems clear that the European Union aims to be at the forefront of green shipbuilding and shipping. For this to happen, environmental regulations and tools need to be up to date, and the environmental performance index is aimed at just that.

3.3 PROCESSES AND ENVIRONMENTAL EFFECTS OF SHIPBUILDING

Modern day shipbuilding is conducted primarily with prefabricated sections made by subcontractors, usually originating from all around the world. Due to the "gate to gate" definition, subcontractors are excluded from this review, while we concentrate on the activities and processes implemented at the shipyard. These include:

- Metal working activities
  - Thermal metal cutting
  - Welding and grinding
- Surface treatment operations
  - Abrasive blasting
  - Coating and painting
- Outfitting (installing parts and various subassemblies, e.g. piping systems, ventilation equipment, electrical components)
- Ship maintenance and repair activities.

These processes have the highest potential for environmental effects depending on how they are handled. (OECD 2010, 12.)

Metal working activities include using materials such as steel, aluminium, wood and composite materials such as fiberglass, and making the superstructures of a ship. As steel and other materials are usually already made into prefabricated blocks, most of the work is to do with thermal metal cutting and welding and grinding the various sections together. After the ship superstructure is completed, surfaces need to be treated with abrasive blasting in order for them to be ready for painting. Abrasive blasting operations focus on the ship's piping, steel plates and other steel elements used in the structural assembly of the ship. Coating and painting is done in order to protect the hull of the ship from external influences, such as weather and various plants and moulds. Anti-fouling paints are used to prevent fouling from occurring and to make the surface easier to clean in case fouling occurs. Outfitting can be started as soon as the steel structure of the particular block has been constructed. (OECD 2010, 13; ILO 2013.)

The environmental effects of the processes are varied. Metal working activities produce significant residual waste (metal shavings and chips), wastewater (cutting oils, lube oils, degreasing solvents), and hazardous air pollutants such as metal oxide fumes, greenhouse gases, "criteria air pollutants" (CAPs), which include ozone (O_3), particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and lead (Pb). (OECD 2010, 13–15.)

Surface treatment operations produce heavy metals, solvents, copper and hazardous or flammable materials, and are associated with emissions of lead, PM, volatile organic compounds (VOCs), zinc and other air pollutants. Noise is also produced from sources such as air discharge, air compressors, impact of the abrasives, exhaust ventilation systems, and blasting cabinets. (PPRC 2008; OECD 2010 16, 18.)

Abrasive blasting is part of the surface treatment, but it produces very varied emissions depending on variety of factors. Blasting creates large quantities of waste that consist of spent abrasives mixed with surface elements such as paint chips, oil and toxic metals, which may create runoffs to waterways. Toxic air contaminants depend on the materials used as abrasive agents, as well as on the surface that is being blasted. (PPRC 2008; OECD 2010, 16.) The potential air contaminants from dry-abrasive blasting are presented in Table 1.

TABLE 1. *Potential air contaminants from dry-abrasive blasting. (United States Department of Labor 2006.)*

Source	**Potential Air Contaminants**
Base material: (e.g. steel, stainless steel, galvanized steel, aluminium, copper-nickel and other copper alloys)	Aluminium, cadmium, chromium, copper, iron, lead, manganese, nickel, zinc
Surface coatings: (e.g. pre-construction primers, anticorrosive and antifouling paints)	Copper, barium, cadmium, chromium, lead, tributyl tin compounds, zinc
Abrasive blasting materials: metallic (e.g. steel grit, steel shot, etc.); slag (e.g. coal slag, copper slag, nickel slag); synthetic (e.g. aluminium oxide, silicon carbide); and natural oxides (e.g. silica sand)	Arsenic, beryllium, amorphous silica, cadmium, chromium, cobalt, crystalline, silica, lead, manganese, nickel, silver, titanium, vanadium

The so-called "fugitive emissions" from blasting operations also need to be noted. These runoff emissions migrate to other production areas, polluting them and causing harm to environment and workers. They can also end up outside the shipyard and have an effect on the health of the general public and the environment. (PPRC 2008.)

A ship's hull is prone to colonization by marine organisms and micro-organisms, such as algae, mussels and other fouling marine organisms. Fouling greatly increases vehicle drag, resulting in reduced vessel fuel efficiency and speed as well as possible damage to the ship. Hence, application of anti-fouling paints as part of the surface treatment is commonly used. Anti-fouling paints contain biocides that prevent the fouling organisms from attaching to the hull of the ship. (PPRC 2008; OECD 2010, 19.) A very common biocide used in the past is tributyl tin, more commonly known as TBT. TBT is highly toxic and remains in water environments and in sediments. This has complicated dredging of sediments and expansions of harbours, for instance. TBT interferes with biological processes and can accumulate in the food chain. TBT was banned in 1980's for small vessels under 25 meters long by the EU, the US and Japan. These initial bans were followed by a complete ban for the use of organotin compounds and a refusal of entry into port by any ship painted with TBT in 2008. (PPRC 2008; OECD 2010, 19) China, for example, uses DDT instead of TBT. It is estimated that 200 tons of DDT are used every year in anti-foulant paint production in China, and that 65 tons of anti-foulants are consumed in the country. This has caused emissions quite similar to those caused by TBT. (UNEP 2008; OECD 2010, 20.)

Alternative coatings and techniques have been created, which do not contain TBT. Such coatings include organotin-free anti-fouling paints and biocide-free non-stick coatings that create an extremely slippery surface to prevent fouling from occurring. Examples of biomimicry have also emerged, where nature is mirrored. When using shark skin as a model for an anti-fouling coating, the laboratory tests showed an 85% reduction in common algae. On the other hand, it was also noted that marine plants are highly adaptive, and that ships lack the shark's ability to move and flex their coating. (OECD 2010, 19–20.)

AkzoNobel, one of the world's largest paint and coating companies, has developed a biocide-free anti-fouling paint claiming it is not harmful to marine life. The company estimates that the product, Intersleek 900, can reduce fuel consumption and emissions by up to 6%. (WBCSD 2008.)

A Finnish company, DG Diving Group, has created a system which enables brushing and cleaning the hull of a ship while collecting potentially toxic particles, to prevent them getting into the marine environment. This is an alternative method to using anti-fouling paints. (DG 2013.)

In addition to these processes with the highest pollution risks, there are other operations with additional environmental effects that need to be noted. Incoming energy is used to power up the processes. If the shipyard has its own power plant, there may be outgoing energy as well (sold to the general energy grid etc.). Water is used in many processes, and wastewater is produced as a side effect of almost all processes. Air pollutants can also land in the water, causing pollution of nearby streams, rivers and the like. Storm water is a particular issue that needs to be handled with care in order to prevent toxic contaminants from being released into nature. A lot of waste is produced in the processes of the shipyard. This waste is then transported to landfill or recycling. Potentially hazardous and industrial waste is also produced. (ILO 2013.)

There are plenty of indirect environmental effects of shipyards. Water and air pollutants can act indirectly as mutagens, which may damage humans and nature by affecting reproduction. Using the life-cycle method, shipyards share an indirect responsibility for their material selection in terms of environmental friendliness. Steel is widely used as the main material for constructing ships, so shipyards affect the overall steel production and indirectly contribute to the environmental impacts that production causes. On the positive side, and continuing with the life-cycle theme, the shipbuilding industry is indirectly making shipping the world's most energy-efficient transportation method by using more and more cost-efficient and thus more environmentally friendly ships, engines and fuels. All of these developments, and many more, are the indirect effects of shipyards. They have not been covered in detail in this report, but it should be noted that they exist and that they potentially have a major impact on the environment.

3.4 PROCESSES AND ENVIRONMENTAL EFFECTS OF SHIP MAINTENANCE AND REPAIR

Typically these processes take place when the ship is outdated and in need of repair. The ship's hull is cleaned and abrasive blasting is applied to the ship's hull and interior tanks and spaces to clean the surfaces of contaminants such as old paint and coatings, rust, mill scale, dirt and salts. Then new coating and paint can be applied. Vessel cleaning can include oil and other hazardous material transfers. Servicing of machinery and other equipment and damage repairs are conducted, and then possible ship conversions are carried out. It is in the best interest of the ship owner to keep the maintenance time as short as possible, so the maintenance and repair is done under severe time constraints, which can lead to increased potential for environmental effects. (OECD 2010, ILO 2013.)

Many of these processes are similar to new ship construction. The potential impact on the yards' surrounding environment and ecosystems following from maintenance and repair services are therefore similar. (OECD 2010, ILO 2013.)

Typically, cleaning and servicing of mechanical, electrical, radiation and thermal equipment are carried out, as well as hydraulic and other pressure systems operating on air, gas and water. Emissions such as hazardous waste in the form of oil, hydraulic fluids, lubricants, thinners, acids and anti-freeze are created. Fuelling activities can also generate waste liquids, and vapours are released into the air. Some yards operate outside without indoor facilities, which increases environmental impacts. (PPRC 2008, OECD 2010, ILO 2013.)

Shipyards are sometimes also held responsible for the discharge of pollutants that are not produced by the yards themselves – for instance vessel cleaning, which can include the handling and treatment of a number of different forms of ship-borne pollutants, such as bilge water, ballast water, cargo residue and sanitary wastes. The provision of facilities for the handling of such pollutants is part of the MARPOL protocol, yet many ports still lack adequate reception facilities (IMO 2006). It should also be noted that maintenance and repair services can be seen as having a positive effect on the environment with increased performance and lessened accident risks on board the vessel. (PPRC 2008, OECD 2010, ILO 2013.)

3.5 HEALTH AND SAFETY ISSUES IN THE SHIPBUILDING, MAINTENANCE AND REPAIR INDUSTRY

Hazards to health and safety can occur in any part of the shipbuilding process. This applies to maintenance and repair work of ships as well. There is much manual work performed, most of the time in confined spaces, with many hazardous materials and chemicals and heavy machinery involved. Much of the work is done outdoors, which may increase hazards to both the environment and health. Both shipbuilding and repair industries are some of the most hazardous industries in the world. (ILO 2013, United States Department of Labor 2013). For example in South Korea, the second biggest shipbuilding nation in the world, the Ministry of Employment and Labor's statistics show that in 2012, the accident rate in shipbuilding was 1.2%. In 2009, the rate was 1.41%. This is more than double the average accident rate of all industries, which was 0.7% in 2009. (Ministry of Employment and Labor of Korea 2013.)

The risk is very real in shipyards, as noted also in a study conducted in Turkey 2010. Statistics from the Tuzlan area near Istanbul showed that in 2008 there were 86 shipyards in the area, with 34,500 employees. During 2008, fourteen accidents resulted in loss of life. (World Scientific and Engineering Academy and Society 2010.) The industry is said to be "among the top three most hazardous industries in the United States" (KMU-Harvard Alliance Foundation 2004).

These health hazards can be divided into three groups:

(ILO 2013; United States Department of Labor 2013; OECD 2010, 14, 17.)

Chemical hazards:

- asbestos
- fumes from welding, burning, soldering and brazing operations
- solvents
- paints
- fuels
- dust from abrasive blasting.

Physical hazards:

- noise and vibration
- heat stress
- electrical hazards
- ionizing and non-ionizing radiation
- outdoor working conditions (possible temperature & weather extremes).

Safety Hazards:

- fires
- confined spaces
- falls
- heavy equipment.

The most common accidents are usually slips, trips and falls, while toxic fumes and electric shocks are the biggest hazard concerns, as noted in both China and Turkey (World Scientific and Engineering Academy and Society 2010, KMU-Harvard Alliance Foundation 2004). Health and safety issues are of even greater concern for developing countries, where these issues have been overridden by the interests of business, marketing and engineering. According to a study conducted in Bangladesh, health and safety issues are not yet noted as important, and "the long term effects of safety, health and environmental measures are yet to be understood". (Bangladesh University of Engineering and Technology 2010.) Efforts to improve environment, health and safety around the world are in full demand at least on paper, as noted in news in China, Korea, Turkey and Bangladesh (Bangladesh University of Engineering and Technology 2010, Seabay Marine Corp 2010, World Scientific and Engineering Academy and Society 2010, KMU-Harvard Alliance Foundation 2004).

4 SHIP DISMANTLING

4.1 BACKGROUND

The average life cycle of a ship is approximately 25–30 years. Currently, 97% of ship dismantling is done by five countries: India, Bangladesh, Pakistan, China and Turkey. This is mainly due to economic reasons – labour costs and a higher demand for steel in developing countries, such as those in South Asia. Apart from China, where the dismantling mainly takes place at piers, operations are conducted in beaches. The pier facilities are more developed than beaches, but they still do not correspond to shipyard conditions, especially considering safety and environmental issues. (Commission of the European Communities 2007, 6–8.) Ship dismantling is an example of globalization where questionable issues rise between the western and the still developing world. The topic binds together environmental, social and political issues while economic benefits contradict the safety of humans and the environment as well as the misuse of developing world conditions. (Kumar & al. 2011, 1–2.)

In 2012, total of 57.5 million Deadweight tonnage (DWT) was dismantled worldwide. Currently, India is the biggest ship breaker (34%), followed by Bangladesh (24%), China (19%) and Pakistan (17%). Of the remaining 6%, nearly half of the industry takes place in Turkey. (Hellenic Shipping News 2013.)

Despite the dominance of southern Asia in ship dismantling, some progress in the industry has been seen in Europe during the past years. The public debate on the matter has promoted planning of recycling in the new building yards' operations (Martinsen 2009). For example in Denmark, there are three recycling yards operating, making it the one of the major ship recycling countries in EU (NGO Shipbreaking Platform, 2013a). While ship owners continue to be drawn to the developing countries for ship dismantling on financial grounds, regulations have been formulated by the EU. In April 2013, the establishment of a recycling fund from ships entering EU ports was mainly opposed (NGO Shipbreaking Platform 2013b). However in July, the new regulation of European list of recycling facilities and the inventory of hazardous materials (IHM) on board came into force, and both the NGO Shipbreaking Platform and the European Environmental Bureau (EEB) – representing over 160 environmental, human and labour rights organizations – have opposed the new law as insufficient and overlooking the current practice of re-flagging EU ships in order to avoid falling under the new law (Messenger 2013). Binding financial incentives have been declared as the most efficient way to control environmentally friendlier ship dismantling practices. The need for acknowledging this within the ship recycling industry with standardized certificate and audit systems has been demanded (Martinsen 2009).

4.2 PROCESSES AND ENVIRONMENTAL EFFECTS OF SHIP DISMANTLING

The processes and environmental effects presented focus on the five countries mentioned above. Due to the size of the ships and lack of proper facilities to handle the ships, dismantling takes place primarily outside. The ship about to be dismantled is driven or towed to the beach, where it is broken into parts and transported away. First any on-board gear is removed, then the actual hull is dismantled and cut into pieces. Toxic waste still contained in the ship is removed and usually burned at the site. (OECD 2010, 39–40.)

The dismantling sites in the developing countries usually have very poor environmental, safety and health regulations. Very few of them have proper containment to prevent pollution of soil and water, only a few have waste reception facilities, and the treatment of many hazardous and toxic wastes rarely conforms to even minimum environmental standards. Emissions into the atmosphere include asbestos, preservatives, cargo residues, thousands of litres of oil (including engine oil, bilge oil, hydraulic and lubricant oils), grease, tributyl tin (TBT), polyvinyl chloride (PVC) and paints. Emissions into the soil cause not only damage to the ground, but also runoffs into the water. This is caused by, for example, oil spills that float over large areas, which inhibit penetration of light into the water and reduce the growth of phytoplankton. Plankton is important for securing rich biological productivity in aquatic habitats, and when damaged, the whole food chain can be affected. (OECD 2010, 39–40.)

The environmental impacts that the ship dismantling industry has can be divided into three main categories. The emissions are transmitted into the atmosphere, marine environment and the soil of the ship breaking yards. Throughout the dismantling process, the formation of toxic gases is significant. Ship hulls are cut into pieces manually with oxygen torches, during which a variety of emissions are released in the atmosphere. Apart from formation of carbon and iron oxides, more hazardous gases and fumes are almost always produced during the cutting of the hull surface. Even though anti-fouling paints are currently strictly regulated, the ships that are scrapped now were built in the mid-eighties on average, when the use of toxic chemicals was less well regulated. Organotins are toxins that are nowadays forbidden but were widely used in anti-fouling paints in the past (Hossain 2006, 4, 18, 21).

Apart from uncontrolled fires at the dismantling site, combustion is used for example on cables in order to separate valuable metals from the insulation materials, such as polyvinyl chloride (PVC). When burning of PVC, dioxin, hydrochloric acid vapour and thick smoke is generated. (Basel Convention 2013e, 56.) After the ship has been beached during high tide, the dismantling is begun at low tide. Thereafter, every time the tide comes in and goes out, it sweeps a great deal of debris, heavy metals and toxic substances along with it. (Sarraf et al. 2010, 5–6.) According to the research on the contamination levels of the marine environment around the largest ship scrapping yards in southern Asia, the main pollutants found are primarily heavy metals, petroleum hydrocarbons and bacterial contaminants. The most serious pollutants were found to be the persistent heavy metals, mainly zinc, manganese and lead. (Reddy & al. 2003, 1–4.)

When soil samples were analysed in Alang shipyard in India, contamination of polyaromatic hydrocarbons (PAHs) was detected. PAHs are generated from several sources such as the cutting of the hull segments that are winched onto dry land in order to optimize the size and shape of the steel plates for reuse. The combustion process produces PAH emissions into the soil and the atmosphere. Burning waste increases PAH emissions as well as the use of oil, which is often used to keep up the fires. (Kumar 2011, 18–19; Vuori 2013, 18.)

4.3 HEALTH AND SAFETY ISSUES IN SHIP DISMANTLING

Apart from the insufficient regulation of environmentally friendly ship dismantling operations, health and safety implications for the workers in the dismantling facilities in the developing countries are severe. Due to the often prevailing poor working conditions, accidents are frequent and include toxic gas explosions and heavy metal plates falling from upper decks. Continued contact with hazardous substances cause both immediate and long-term harm to the workers. ILO generally considers ship dismantling to be one of the most hazardous professions in the world. One major cause of accidents during dismantling is explosions. Explosions occur when the ship's hull is cut by gas torches or when ship fuel or cargo tanks are not properly cleared of flammable gases and other flammable substances. (OECD 2010, 41.)

Workers in the dismantling facilities can be exposed to long-term impacts as well. Currently such substances are either banned or restricted in shipbuilding, although they were used in the vessels which are being dismantled at the moment. Since long-term impacts might take years to show, the connection to ship dismantling is very difficult to prove. (Vuori 2013, 20.)

Even though the environmental and health and safety issues cannot be overlooked, ship dismantling brings positive effects on local and regional level as well. The industry employs – directly and indirectly – large numbers of people, which brings about economic growth. Exact and reliable figures are difficult to obtain though, due to the unorganized labourers and the industry's high sensitivity to economic fluctuations. (European Commission 2007, 9–10.)

On the whole, the fluctuation of the industry and the insufficient labour legislation has led to weak status for the employees. The need for workers changes and causes national migration from poorer regions. (Sara et al. 2010, 1–3.) The situation is worsened by the neglect of the shipping industry, which instead of demanding stricter regulations, turns a blind eye to the issue by selling ships to dummy corporations without ensuring proper dismantling (Imowatch 2009).

5 ENVIRONMENTAL EFFICIENCY INDICATORS, INDEXES AND METHODS

During the project, many different environmental indicators, indexes and methods were studied. Benchmarking was conducted in order to examine the need for an environmental performance indicator, to compare the already created indexes and to assess whether some similar features could be used.

5.1 LIFE CYCLE ASSESSMENT (LCA)

Life Cycle Assessment (LCA) is a globally standardized (ISO 14040/44) tool to assess the environmental impacts of a product. LCA is based on "cradle-to-grave" thinking, where everything from raw materials to production and from usage to waste management is considered. LCA is perhaps the most common method for environmental evaluation of products, goods and services used in the world. The most commonly used LCA among the industries, however, is the more restricted "cradle-to-gate" approach. It starts similarly to cradle-to-grave, but ends at the exit gate of the production plant. (Sciencedirect 2009, SYKE 2011, 23–26.)

Originally in ECO-EFFI, the plan was to use LCA for creation of the environmental performance indicator as a cradle-to-grave consideration. Yet, due to the number of subcontractors in shipbuilding and their respective environmental effects, a consistent indicator with all direct and indirect impacts would have been unrealistic within the scope of the project. Furthermore in most cases, after finishing the construction the ship is handed over to a shipping company, after which the shipyard has no control over it. Hence, ship dismantling needs to be considered as a separate index from shipbuilding.

5.2 ENVIRONMENTAL SUSTAINABILITY INDEX (ESI)

Yale University's Center for Environmental Law and Policy and Columbia University's Center for International Earth Science Information Network (CIESIN), in collaboration with the World Economic Forum and Joint Research Centre, created an index which considered 21 factors of environmental sustainability. Although the index was meant for countries, the term country was used quite loosely, and the index could be used at a company level. This index was published from 1999 to 2005. (Ciesin 2013a.)

ESI was superseded by the Environmental Performance Index (EPI) in 2006. EPI has two focus points; reducing environmental stress to human health and promoting ecosystem vitality and sound natural resource management. Twenty-five indicators were used for this index:

- Environmental Burden of Disease
- Adequate Sanitation
- Drinking Water
- Urban Particulates
- Indoor Air Pollution
- Local Ozone
- Regional Ozone
- Sulphur Dioxide Emissions
- Water Quality Index
- Water Stress
- Conservation Risk Index
- Effective Conservation
- Critical Habitat Protection
- Marine Protected Areas
- Change in Growing Stock
- Marine Trophic Index

- Trawling Intensity
- Irrigation Stress
- Agricultural Subsidies
- Intensive Cropland
- Pesticide Regulation
- Burned Area
- Emissions Per Capita
- CO_2 from Electricity Production
- Industrial Carbon Intensity.

EPI has been published four times, in 2006, 2008, 2010 and 2012. EPI was designed to rank countries according to their environmental performance over the last decade. (Yale 2013, Ciesin 2013b, EPI 2012.)

Of the 25 indicators, most are only suitable in country-to-country comparison, but some could be considered on a company level as well (SYKE 2011). Even though some of the indicators can be adjusted to suit shipyard operations, and they demonstrate environmental comparison between larger entities, the emissions are expressed as estimates and in relation to capita or GDP, which does not support shipyard applicability.

5.3 EEDI – ENERGY EFFICIENCY DESIGN INDEX

Energy Efficiency Design Index (EEDI) is a tool designed to calculate carbon dioxide (CO_2) efficiency of ship transportation. It was developed by IMO and released in October 2008.

The EEDI index ranks ships according to their CO_2 efficiency, which is determined by the ship's CO_2 emissions divided by the amount of goods transported. The number is then multiplied by the distance travelled. The value reached is the ship's EEDI value. The smaller the EEDI, the more energy efficient the ship design in question is. EEDI was made mandatory for new ships in 2011 by IMO. Although EEDI is influential in IMO's strategy for marine vessels and measures environmental efficiency of the ship, it is designed for the operational phase rather than building and dismantling. (IMO 2013b.)

5.4 BREEI – BALTIC REGION ENVIRONMENTAL EFFICIENCY INDEX

The Baltic Region Environmental Efficiency Index for Marine Vessels was created for evaluating the environmental efficiency of marine vessels by calculating an efficiency index for them. With that index value, ships operating in the Baltic Sea can be ranked according to their environmental efficiency. (Haukilehto 2010.)

For the index, ships were divided into four groups:

- Cargo (cargo only)
- Cruise (passenger only)
- RoPax (cargo + passenger)
- Ferry (passenger + cargo for trips lasting less than two hours).

The emissions from these ships are analysed before they are divided into three main categories and graded according to ship type and impact on the environment. Minus points are given to the methods that are most harmful to the environment, whereas plus points are awarded to the methods that are the most rational considering the ship's operations and overall environmental efficiency. All the subcategories have been detailed with different possible techniques and grading has been carried out in estimation of how environmentally friendly they are.

The three categories with their subcategories are:

- "Potable water, waste waters and garbage"
  - Fresh water production
  - Black and grey water
  - Solid and food waste

- "Oil, ballast and special"
  - Deck machinery, underwater equipment and chemicals
  - Antifouling
  - Ballast water
  - Bilge water and oil sludge
  - Hazardous waste
- "Air emissions and fuel consumption"
  - Ice-Class
  - Fuel, SOx, NOx and PM emissions
  - Fuel consumption and EEDI
  - Shore-side power and incinerator.

The index is a so-called BAT based, which means that best available technology is the solution to be aimed for, at least for most of these problems. This creates a problem when technology and regulations evolve after the index has been released. Consequently, a "zero point" for the index was set to 1st October 1, 2010. Only the legislation in force and proven technologies that are currently available are taken into account. The regulations and technologies to be brought up in the near future are discussed briefly and the possibility of adding new, novel technologies to improve the ships' environmental efficiency are included in every group as a separate "Novel technologies, graded accordingly" paragraph. Grading has been set from -3 to 5 with bigger numbers being more environmentally friendly. The Baltic Sea Region's specific features, such as annual ice cover and winter navigation, eutrophication and sensitivity to nutrients, and the overall deteriorated environmental state were taken into consideration when designing the BREEI. (Haukilehto 2010.)

BREEI presents a fairly complete environmental scale for ships. It is notable that this scale was created purely for ships operating in one single sea region, the Baltic Sea. On the other hand, this depicts the importance of identifying different kinds of surroundings where operations takes place and the specific impacts on the environment in question. (Haukilehto 2010.)

5.5 ENVIRONMENTAL PERFORMANCE INDICATORS FOR SHIPYARDS – KVÆRNER FLORØ AS

In 1996, the Norwegian shipping company Kværner Florø AS produced a study called "Environmental Performance Indicators for Shipyards – Kværner Florø AS". The study was conducted as a part of the NORDIC-EPI project, which aimed to identify the relevant aspects of Kværner Florø AS's processes in order to evaluate the company's environmental performance.

Based on a questionnaire, Kværner Florø AS's departments were reviewed, taking into consideration their impacts on the environment. Three main areas of concern were identified: waste generation, waste handling and use of energy. Improvements within those areas were proposed and possible indicators were suggested.

In Table 2, the environmental indicators and parameters for measuring waste management and energy at Kværner Florø AS are presented. Even though the study is almost twenty years old, it is one of the few attempts we were able to find at creating an environmental index for shipyards. The table shows that many of the indicators have been tied to a specific issue, such as emission of dust, which is tied to the treated area.

TABLE 2. *Environmental indicators and parameters in the waste management and use of energy. (Kvaerner 1996, 23.)*

Indexes:			
Material usage	**External material protection**	**Waste handling**	**Energy usage**
Indicators:	**Indicators:**	**Indicators:**	**Indicators:**
• Material utilisation • Energy usage per unity of material • Environmental conditions at the supplier	• Emission of noise • Emission of dust per treated area • Emission of solvents • Material use per treated area	• Percentage of waste to land fill • Waste handling costs per tonne of waste • waste handling costs per month	• Energy usage per production hour • Energy usage per tonne product
Parameters:	**Parameters:**	**Parameters:**	**Parameters:**
• Percentage access material • Purchase of cut steel plates • Purchase of complete hulls • Transport of material (tonne*km) • Means of transportation from the steel works to the yard • Number of section suppliers • Building of hull at self owned hull yard • Price per kg material costs • Selection of steel work	• Number of complaints of noise from neighbours • Number of employees with reduced hearing • Measured noise emissions • Degree of covering when sand blasting or painting occur • Number of accidentally painted cars • Amount of generated dust per tonne spent blasting sand • Amount of dust in production hall (mg/m^3) • Calculations of thinner emissions from product data sheet • Usage of material associated with painting • Recycling of thinner	Measure the amounts, expenses and waste treatment for the sorted waste fractions for a period of time, e.g.: • Amount of metal delivered and the related expenses • Amount of oil and paint remainders delivered and the related expenses • Amount of mixed wastes delivered and the related expenses	Measure the used energy related to the different energy sources, e.g.: • Consumption of electric power during a period of time. • Consumption of fuel oil during a period of time.

5.6 OEKOM CORPORATE RATING

Oekom Research AG is a private company specializing in the social and environmental performance of companies, sectors and countries. It has created the "oekom corporate rating", which is their main tool in assessing social and environmental performance on a company level. The social and environmental performance is based on over 100 criteria, which are selected specifically for each industry. The end result is single rating, ranging from D- to A+, having 12 steps in total. (Oekom 2013a.) Shipping, shipbuilding and ship dismantling have not been assessed by Oekom.

The corporate rating for a company has been divided into 6 sections. Staff and suppliers, society and product responsibility, corporate governance and business ethics, environmental management, products and services as well as eco-efficiency all add up to one single grade. The strengths and the weaknesses of the company in the identified area are also identified. Input and output data on raw materials, energy, water, air emissions and waste are viewed. Additionally, greenhouse gas (GHG) emissions including HFC, PFC, SF6, NF3, on top of water consumption, waste production, emissions of water pollutants (BOD, COD) and air pollutants (NOx, SOx) are analysed. The suppliers to the company are included in the corporate rating as well. The indicators are presented by net sales of the company, which enables comparison on annual level of production. (Oekom 2013b.)

5.7 RUUKKI – ENVIRONMENTAL DATA MONITOR

Ruukki is a Finnish company which has specialized in steel and steel construction. The company employs approximately 9000 employees in 30 countries. Ruukki uses a tool called "Environmental Data Monitor" for collecting and presenting environmental information on the company. The sections include raw materials and products, energy, emissions, water usage and waste. All incoming material, such as iron ore, pellets, alloys, and zinc, is measured and presented on an annual level. Additionally, the amount of recycled steel is included. Apart from products, also energy consumption and the excess energy, which is sold forward, are calculated. Emissions to water and air, usage of water and production of waste as well as amounts of waste recycled and sent to the landfill are reviewed and compared on an annual basis. (Ruukki 2013.)

6 DESIGNING THE ENVIRONMENTAL PERFORMANCE INDEX

6.1 COMBINING THE ENVIRONMENTAL AND FINANCIAL ASPECTS

A fundamental aspect regarding the index is the connection between production and environmental effects. Shipyard A with no production has no (or at least considerably fewer) emissions, while shipyard B with full production has a lot more. Consequently, shipyard A might appear to be more environmentally friendly, but in reality it just has no production – and therefore no emissions. Thus, there needs to be a link between the environmental effects the shipyard produces and production figures. For example in the study "Environmental Performance Indicators for Shipyards – Kværner Florø AS" reviewed in Chapter 5.5, the indicators used are energy usage per production hour, energy usage per ton product or, for example, material used per treated area (Kvaerner 1996). This helps measuring shipyards that have continuously active production, and also enables differentiation from shipyards with gaps in their production rates. Without such a link, the environmental effects would not show correctly and they would not be comparable.

6.2 LOCATION AND DIFFERENT TYPES OF SHIPYARDS

Different locations of the shipyards are an issue that needs to be taken into consideration when designing the environmental performance index. The BREEIresearch, which is reviewed in Chapter 5.4, takes this into account. The study was conducted for the Baltic Sea region only, and the specific characteristics were considered in the making of the index, such as annual ice cover / winter navigation, eutrophication / sensitivity to nutrients as well as the overall deteriorated environmental state. (Haukilehto 2010.)

Since the environmental performance index is aimed at an international level, the differences between various locations need to be noted in the index. One option is to create different versions of the index for each operational area. The issue is complex and requires further investigation.

Another issue to be thought out for the index is different types of shipyards. Due to the different nature of the processes within the yards, it is likely that all the different yards require their own indexes. Regarding new building shipyards, there are at least two different kinds. Firstly, there is the traditional shipyard, where everything is built on-site from raw materials. Secondly, we have the modern shipyard, where ships are built using prefabricated parts, made away from the shipyard and then transported for assembly at the yard. If we look only at the environmental effects of the shipyard *per se*, the impacts are quite different in these two shipyards. If the yard is building from raw materials, all the environmental effects are shown at the shipyard. When using prefabricated blocks, substantial portions of the environmental effects are produced by the subcontractors, and the impact of the shipyard itself is decreased. Inclusion of these two different types of shipyards into the same index is difficult, and maybe even impossible, to accomplish.

The diversity of repair yards requires consideration as well. A ship might be in need of physical repair, or it might be undergoing a regular maintenance without the need of physical repairs such as welding. A ship might need modifications or conversions, which are undertaken at the repair yard. Like in new building shipyards, all these different repair, maintenance and conversion operations produce different environmental effects, and putting them into the same index is a challenge.

On paper, the dismantling yards have possibly the biggest variation in different shipyard types. Operations at modern recycling yards differ from dismantling beaches of the developing countries significantly. However in terms of the environmental performance indicator, they are manageable. Unlike in the shipbuilding yards, the unit to be dismantled is always a single ship, even though the processes and techniques vary the most of all shipyard types. The overall process remains coherent, and gathering the different dismantling operations into an index is predicted to be quite a straightforward process.

6.3 OUTLINING THE INDEX

When considering an environmental performance index for shipyards, the first relevant issue to consider is emissions. There are multiple ways emissions can be included in the index. An index could be created using a method where emissions into water, air and soil are calculated separately (VTT 2012, unpublished). As noted in the BREEI research, one way to include emissions in an index is to study each of the processes and different techniques applied to them, and then rate them based on their environmental impacts (Haukilehto 2010). Table 3 shows a simple model using this principle with some of the surface treatment operations given as an example.

TABLE 3. *A suggestive environmental rating model for some of the shipyard surface treatment operations.*

Surface Treatment Operations		**Environmental Rating**
Enclosure Techniques	**Surface Preparation**	
Fully enclosed areas	Wet or slurry blasting	AAAA
Partially enclosed areas	High pressure fresh water jetting or blasting	AAA
	Dry blasting: closed system	AA
Open areas	Dry blasting: open system	A

There are several issues that are not shown in the simplified model above. One of the most fundamental is weighting. The environmental rating has only 4 steps graded from A to AAAA. In the example, fully enclosed areas and wet or slurry blasting have been rated as the best methods or techniques in their respective areas. Even though they are the best techniques for their respective areas, their environmental impacts most likely do not have the exact same weighting. This could be done better with a numerical rating as the environmental rating. These numbers could be weighted according to what the real environmental effects are for the processes in question. However, this requires expertise in the area and is one of the issues that should be studied in the future.

Other important aspect missing from Table 3 is how to combine the environmental and financial aspects, as discussed in Chapter 6.2. The issues are of great importance, and this should be implemented for the index to be comparable between different shipyards.

The environmental index should be divided into categories. In Chapter 3.3, the processes of new building shipyards were studied. Metal working operations and surface treatment operations with their subcategories should be used as different categories, in addition to energy, water and waste as other categories of the index. Incoming energy should be weighted highly in the environmental rating, as both the metal working operations and surface treatment operations are high energy intense processes, and thus the chosen energy has a high impact on total environmental effects caused by the shipyard. Outgoing energy should be noted as well, as it is possible that the shipyard has a power plant of its own, which could be anything from a coal plant to wind power plant.

Water is a vital part of the building process. Incoming water should be noted in the index in addition to outgoing. Outgoing water is usually waste water, and the way it is treated is important. It is possible that some outgoing water can be re-used in some other process in the shipyard, which is an important issue to consider. Wastewater is a tricky issue, since it is commonly handled by the municipal wastewater system, which can be anything from a simple open stream to a sophisticated wastewater treatment plant. It can be that the shipyard itself has no power over how the wastewater is treated, so it is questionable whether they should be penalized for the issue at all.

The amount and state of the waste produced should be noted as well. There is a big difference between whether waste is taken to a landfill or if it is being recycled. What is done with industrial and hazardous waste is also a question of importance. As with water and energy, it needs to be considered how much weight is to be given to these issues and how much the shipyard itself has choice over these matters.

Health and safety issues were researched on a general level. Both shipbuilding and ship dismantling are two of the most hazardous industries to work in. With further research, it is possible to find processes and indicators for health and safety to be included in the index.

In ship maintenance and repair yards, servicing equipment, overhaul of the ship, damage repairs and conversions are the main processes. When considering these processes in detail, it can be seen that ship maintenance and repair use many similar or identical operations to new ship construction. Thus the environmental effects are similar – albeit on a smaller scale. (OECD 2010, 21.) The need for a different environmental performance index for ship maintenance and repair yards is thus in question, and it is possible that a completely different index for ship maintenance and repair is not needed. However, the processes in dismantling yards are hugely different, and using a same index as shipbuilding (and ship repair and maintenance) does not seem feasible. The main dismantling processes include the removal of on-board gear, the actual cutting of the hull and the handling of toxic wastes. The processes should be graded numerically, and weighed according to their impact on the environment. Similarly to the shipbuilding index, the dismantling index should include categories for energy intensity, water intensity and waste production and management. Furthermore, similarly to the shipbuilding index, the need for implementation of environmental and production linkage is crucial.

6.4 ENFORCEMENT OF THE INDEX

It has become clear during the study that the environmental performance index would be problematic in many ways, if it is introduced as a voluntary tool. It would lead to a situation where environmental forerunners of the industry would use it, and the ones who do not value environmental issues would discard it. In the worst case scenario, the index would be merely a cost to the shipyards using it, and give economical advantage to the shipyards that do not. Additionally, in order for the index to be a comparable tool for evaluating different shipyards, it needs to be widespread. In an ideal situation, it would be used by every shipyard around the world. For this to happen, some sort of non-voluntary method needs to be established.

6.4.1 Marine Classification

Very early on, it became evident that rules and regulations were needed in order for safe shipping to commence. The need to oversee this activity was also noted. As early as 1760 the Lloyd Register was formed, and the term we know now as classification society was born. Many others followed, and today there are dozens of different NGO registers for ships around the world. Thirteen of the biggest marine classification societies have formed International Association of Classification Societies Ltd (IACS), which covers 90% of all marine cargo transported around the world. (IACS 2013, Lloyd's 2013a.)

The aim of marine classification is to ensure that the ship is safe to operate, and that the standards set for that type of ship by the classification society are met. The standards and rules are set and monitored by the classification societies. These standards include technical and engineering data covering the entire life-cycle of ships from building, operating, maintenance and the eventual dismantling. The role of the IACS is to act as a forum for the member societies to discuss and determine maritime issues. The IACS promotes itself by saying that: "As an independent, self-regulating, externally audited, body, a Classification Society has no commercial interests related to ship design, shipbuilding, ship ownership, ship operation, ship management, ship maintenance or repairs, insurance, or chartering." (IACS 2011, IACS 2013.) Most probably that is why IACS has been given NGO-consultative status within the International Maritime Organization (IMO) (IMO 2013c).

The classification process made by an IACS member consists of:

- "A technical review of the design plans and related documents for a new vessel to verify compliance with the applicable rules.
- Attendance at the construction of the vessel in the shipyard by a Classification Society surveyor(s) to verify that the vessel is constructed in accordance with the approved design plans and classification rules.
- Attendance by a Classification Society surveyor(s) at the relevant production facilities that provide key components such as the steel, engine, generators and castings to verify that the component conforms to the applicable rule requirements.
- Attendance by a Classification Society surveyor(s) at the sea trials and other trials relating to the vessel and its equipment prior to delivery to verify conformance with the applicable rule requirements.

- Upon satisfactory completion of the above, the builder's/ship owner's request for the issuance of a class certificate will be considered by the relevant Classification Society and, if deemed satisfactory, the assignment of class may be approved and a certificate of classification issued.
- Once in service, the owner must submit the vessel to a clearly specified programme of periodical class surveys, carried out on-board the vessel, to verify that the ship continues to meet the relevant rule requirements for continuation of class." (IACS 2011.)

If we look at the issue broadly, all shipyards – for new shipbuilding, maintenance and repair and dismantling yards – are all part of the ship's life-cycle. There are some aspects of environmental issues which have already been addressed in standards and rules of the maritime classification societies, such as the Inventory of Hazardous Materials (IHM), which was formerly known as the "Green Passport". The IHM requires an inventory to be kept on the ship of all the hazardous materials on-board throughout the lifetime of the ship. The document is an invaluable tool especially in the end of the ship's life, as it is crucial to know what kind of hazardous materials are on board when the ship is about to be dismantled. (Lloyd's 2013b.)

Environmental effects of shipyards around the world are not addressed in standards and rules of maritime societies. Some elements, like the IHM, help these yards to be more environmentally friendly, but a standard with full coverage of all environmental issues does not exist on an international level. It was noted by one of our interviewed experts that marine classification system might be the best way to issue the index. In order for the environmental performance index to be of value, it needs to encompass all countries. Otherwise it is likely that the index would be used by a minority, while others ignore it like the environmental consequences of their operations. For example, ships without certification from a respective classification society such as the IACS are finding it difficult to get insurance for their ships or harbour at most international ports (Reuters 2012).

The marine classification would be a valid platform for the index to gain ground despite the voluntary nature of the classification. The classification societies have power in the maritime market and hence within the ship owners and operators. Classification standards are already established regulations within the shipping industry. Adding our indexes into the already existing standards could be the best way to publish the environmental performance indicator.

6.4.2 Other options for enforcement

International regulatory organizations, such as the IMO and the EU, are working on developing a more efficient legislation on ship dismantling. There are, though, different opinions as to whether the regulations should be tightly binding or more instructional by nature. The EU has more stringent approach that aims for statutory control, while the IMO's view is based more on voluntariness. Thus IMO might not be interested in the matter, as the index would work best as a non-voluntary measure. On the other hand, if the index were applied only in EU legislation, the consequence could be that rest of the world would not follow it. This could cause major problems, as discussed in the beginning of Chapter 6.6.

Consumer demand is one option – it could be the issue which would create enough political demand to take it further. Currently, much more interest is put into the finished product, the ship, and not into the production plants (shipyards). That is understandable since most of the environmental effects occur in the long operating stage, often lasting many decades. It does not mean, however, that the production stage should be ignored.

7 CONCLUSIONS AND RECOMMENDATIONS

As a result of our research on the environmental effects of shipbuilding and ship dismantling, an outline for the index was created. In Chapter 6.3, a simplified model is described with each shipbuilding production process used as a basis. Different techniques for these processes were then studied and the aim was to grade the techniques based on their environmental effects. Grading of the index is a rather complex issue, and should be further studied in future research. Furthermore, due to the similar processes, it was determined that shipbuilding and ship maintenance and repair could be included in the same index. In any case, this should be ensured in practice in future research. Regarding ship dismantling yards, which have completely different processes from shipbuilding, the index ought to be constructed with the same principles as the shipbuilding index, yet as a separate entity of its own.

Several key processes were identified as key indicators for the indexes. For the shipbuilding index, metal working activities and surface treatment operations were highlighted as the processes with the biggest potential environmental effects. For the dismantling index, removal of the on-board gear, cutting of the actual hull and handling of hazardous waste were highlighted as the key processes. Health and safety issues were discussed only on a general level during this report, but it seems clear that they should be included in the index.

Several issues need to be thought out before finalizing the environmental rating. Weighting is one of them. A numerical rating should be given as an environmental rating for different techniques in certain production processes. This rating should be judged and weighted in terms of how much overall environmental impact they have. The best techniques in process A and process B probably do have different environmental impacts in the overall picture, even though they ranked the same in the index. A numerical weighted environmental rating should offer a solution to this. The weighting process is complex and often a subjective matter. Also this process requires further research.

Combining the environmental and financial aspects is vital for the index. It is done in order to ensure comparability between different shipyards. Shipyard A with no production has no environmental effects, and shipyard B with full production has much bigger environmental effects. This causes shipyard A to show that it has no emissions, and thus it incorrectly has a much better environmental rating than it should. A link between the environmental effects and the production rates should correct this. A few examples, such as energy usage per production hour were given in this report. Due to the differences in labour hour costs between countries, emissions per production hour does not provide an equal indicator. Additionally, the location of the industry needs to be acknowledged as well, since different environmental effects can occur as more severe and on a bigger scale in more susceptible environments. Hence, localized indexes ought to be considered.

A tool for gathering information for the environmental index should be created. This tool ought to include data of raw materials, energy, water, waste, emissions and techniques being used in shipyards' processes. With the data collected and weighted accordingly, an environmental performance index for the shipyard in question could be constructed. This gathering tool should be field-tested in an actual shipyard to study further improvements and deficiencies.

How to publish the indexes and get shipyards to use them was also reviewed during the project. Promising avenues, such as the standards of the marine classification societies, were discovered. Also it was established that this type of environmental index would work best as a compulsory tool. A voluntary option was considered but decided against, as it would put shipyards on unequal footings.

Much political will is needed for international use of the index to be achieved. It has become clear during the project that the environment alone is not a sufficient selling point for the shipyards, or the ship owners. It is clear that the index would only work under strict surveillance in order to prevent abuse of the system. International co-operation is needed, as the index will only work if all the shipyards use it, while any loopholes would be eliminated.

Currently, much emphasis and publicity is being put into the actual product (ship) and less emphasis on the production plants (shipyards) and dismantling facilities. That is understandable as most of the environmental effects are caused by the operational phase of the ship's life-cycle. Regardless, the beginning and the end of that cycle demand sufficient environmental practices as well.

During the project, the need for a comparable environmental performance indicator system for shipbuilding and ship dismantling became clear. Currently, there are no international tools to compare the environmental effects of shipyards and ship dismantling yards. The environmental performance index outlined in the study, when further developed, could be a tool to make the comparison possible, bringing more transparency and better practices to the industry.

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