Circular Economy in the Maritime Industry

Class notation S.U.R.V. Sustainable Use of Resource Vessel

D. Delzenne

TU Delft

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by

D. Delzenne

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This thesis is confidential and cannot be made public until June 17, 2024.

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TU Delft

Preface

Writing this thesis has been a challenge and a pleasure from my point of view. It is the missing piece for acquiring my master of science degree at the TU Delft. The search for at topic resembled my time at the TU Delft very well. I contacted different companies with a large variety of topics in mind, looking for a match. Amongst others I contacted Boskalis Salvage, Dutch PI and Econowind. Eventually, recommended by a friend working at Bureau Veritas, I came in contact with Rik De Petter, Marine Offshore Chief Executive for Belgium Luxembourg. All I heard was that he had a topic for me. I went to the office in Antwerp which was situated across my high school. Basically I had passed this office hundreds of times before during another phase of my life. Due to busy schedules the meeting was short. It was hard not to notice the shear enthusiasm with which Mr. De Petter explained me his idea. It was contagious and by the time I was walking out of the building I had decided to embark on this project. It was an innovative idea an moreover touched on a very actual issue.

I want to thank Rik De Petter for entrusting and guiding me with and through this topic. I also want to thank him to be able to use his network for the interviews. I would like to thank my supervisor Dr.ir. JFJ Pruijn from the TU Delft, section Ship Design, Production and Operations. His academic guidance has helped me structure this thesis and he also provided me with contacts from his own network for more interviews.

I enjoyed working on this topic and acquired valuable skills in interviewing stakeholders for academic purposes. The topic itself became more interesting as the thesis progressed and I am positive that Bureau Veritas will put these conclusions to good use.

D. Delzenne
Delft, June 2022

Summary

This innovation can be seen and used as a beachhead technology for the implementation of new data management systems. It is hard to get stakeholders onboard using complicated new systems if the current way of doing things is known and efficient enough. Introducing new technologies can therefore best be done with completely new processes so there is no 'old way' on which actors can fall back on. If the new technology has subsequently proven its use, it will be much easier to implemented this new technology for improving current processes.

There is a consensus amongst all stakeholders that all stages of the value chain must be re-evaluated for improvements with regard to sustainability and circularity. By interviewing different stakeholders in the value chain of the ship building process, it can be concluded that a new class notation which specifies the amount of recycled steel used in a ship is technically and logistically feasible. Benefits differ for different stakeholders and some stakeholders see no benefit at all but nevertheless, they do acknowledge that they are part of a multi stakeholder industry and that when there is a demand in the market, they can be put in position to provide the supply.

D. Delzenne
Delft, June 2022

Glossary

9R	Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover
BIM	Building information model
BOF	Blast oxygen furnace
BV	Bureau Veritas
CE	Circular economy
CSR	Corporate social responsibility
EAF	Electric arc furnace
EEDI	Energy efficiency design index
EEXI	Energy efficiency existing ships index
EOL	End of life
ESG	Environmental, social and governance
GCBS	Green Building Certification Systems
GDPR	General data protection regulation
IHM	Inventory of hazardous materials
HKC	Hong Kong convention
LEED	Leadership in Energy and Environmental Design
LDT	Lightweight
OEM	Original equipment manufacturer
SDG	Sustainability development goals
SEEMP	Ship energy efficiency management plan
SRR	Ship recycling regulation
UN	United nations
UNESCO	United nations educational, scientific and cultural organisation
UNFCCC	United nations framework convention for climate change
YETI	Yacht environmental transparency index

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Introduction

The United Nations (UN) has put sustainability goals high on the agenda in recent years and aims to achieve tangible results by mid 21st century. In 2015 193 countries adopted the 2030 Agenda for Sustainable Development [41]. This agenda, consisting of 17 Sustainable Development Goals (SDG) [90] see figure 1.1, sets targets to, *inter alia*, eradicate poverty and achieve sustainable development in specified areas by 2030. Sustainable development is the overarching paradigm of the United Nations. The UNESCO (United Nations Educational, Scientific and Cultural Organisation) defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainability is thinking about the future for which environmental, societal and economic considerations are balanced in the pursuit of an improved quality of life [28].

Figure 1.1: The United Nations Sustainable Development Goals [86]

The UNFCCC secretariat is an entity from the UN tasked with the global response to the threat of climate change. UNFCCC stands for United Nations Framework Convention for Climate Change and is the parent treaty of the *Paris Agreement* [3]. The *Paris Agreement* is a universal, legally binding global climate agreement. It was adopted at the UN Climate Change Conference (COP21), held in Paris in December 2015 [88]. Its aim is to limit the average global temperature increase to 1.5 degrees Celsius. The biggest focus to tackle the environmental crisis is the Green House Gas (GHG) emission control, as this is directly linked to

climate warming [38]. The most recent EU nationally determined contributions to the Paris Agreement were adopted in December 2020, in which the EU updated its target to reduce emissions by at least 55% by 2030 from 1990 levels [24]. These targets are directly linked to SDG 13 (Take urgent action to combat climate change and its impacts), but also SDG 9 (Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation) which is closely related to SDG 13. Many companies refer to the SDGs in their mission statements. One of the challenges, however, is that the targets and indicators developed to monitor the implementation of the SDGs have a macro approach which makes their application at enterprise level difficult. Due to this macro approach, companies experience difficulty in evaluating and measuring their real contribution to the SDGs [47].

The shipbuilding sector, since it is land based, falls under the *Paris Agreement*. If the maritime industry is expected to decrease its carbon footprint, it needs to innovate faster and become more sustainable. In order for businesses to become truly sustainable, efforts regarding corporate social responsibility (CSR) are needed. CSR entered the economics playing field 50 years ago [34]. But it was from the 1980's and onward that businesses began to incorporate social responsibilities into their practices and only in the 2000's that CSR became essential strategies for multi-billion dollar enterprises like Coca-Cola, Walt Disney, Pfizer, etc. Opponents of CSR believe that priorities of companies should lie in optimizing operations and maximising profits, and that secondary processes, such as CSR, can distract from a corporation's core commercial activities. Furthermore it is hard to measure the financial returns that result from resources and money spent on CSR. The benefits associated with CSR are summarized by [50] and [49]. The most relevant benefits are enhancing the company's image and reputation, differentiation from competitors, anticipation of costs, stakeholder expectations, customer demands and future legislation, improvement of stakeholder communication, better risk management, improved innovation, creativity and efficiency, cost savings e.g. through eco-efficiency, and increased attractiveness to investors since the market for responsible investment is growing.

There are different ways for corporations to implement CSR. This can be done by engaging in charitable endeavors, improving labor policies or implementing environmentally friendly and sustainable business practices. Due to these developments, new organisations and businesses are profiting from sustainability for example by providing certification. One of those companies is B Corp. B Corp provides certification that measures a company's social and environmental performance. In return for a fee depending on the size of a company, B Corp will assess and evaluate how that company's operations and business model impact its workers, community, environment, and customers [40]. This includes an assessment of shipping methods used if applicable. According to Paelman et al. [78] 3900 companies are already certified by B Corp to date. They investigated the short- and medium-term growth rates for B Corp certified enterprises. They concluded that this kind of certification has a positive effect on turnover growth and that this effect increases over time. Kunnaala et. al [65] investigated CSR for shipping companies operating in the Baltic Sea. They concluded that CSR in shipping mainly focuses on environmental issues. Sectors that are closer to the consumer are generally more susceptive to these trends, for example passenger ships or the transportation of consumer goods by container ships.

Cargo owners can demand or prefer services to be provided by companies that showcase more corporate social responsibility or efforts to improve their sustainability [89]. Three conceptual approaches to sustainable development stand out since they discuss the interaction between environment, development and society. These three concepts are circular economy (CE), degrowth (DG) and green growth (GG) [41]. CE focuses on the replacement of linear production for circular production where waste becomes a resource. DG calls for smaller, even negative growth rates, to balance natural and economic systems. It is recognised as an alternative to the capitalist growth system and is therefore seen as controversial system by political and economical policy-makers. GG advocates economic growth by investing in activities that protect or restore the natural environment. CE and GG are increasingly important on policy agendas. In a bid to achieve progress with regards to SDG 9 (Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation), industries, including the maritime industry, are moving towards a CE and GG. CE and GG can be considered as concepts to reduce the environmental impact. A circular economy is defined by the Ellen MacArthur Foundation as "an economy that is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. As a result, the economy is restorative and regenerative by design" [31]. In this concept the entire life cycle of a product (or a ship in this case) is taken into account. Life cycle assessment of a product or an industry can be used as one method of evaluating their environmental impact. For a ship, a complete life cycle assessment consists of the raw material extraction, materials manufacture, product manufacture, the use

stage and the end-of-life (EOL) phase. Figure 1.2 represents and links these different phases. Once a ship reaches its EOL phase, the ship can be re-used or re-purposed. If it gets scrapped, the materials will be sorted and recycled if possible. Recycled materials find their way back to the material or product manufacturers and this creates the circular economy. This figure shows the different mindset needed to become more sustainable. Creating a market for recycled materials in ship building by certifying the use of them could be an incentive for more EU recycling yards to be created or extended.

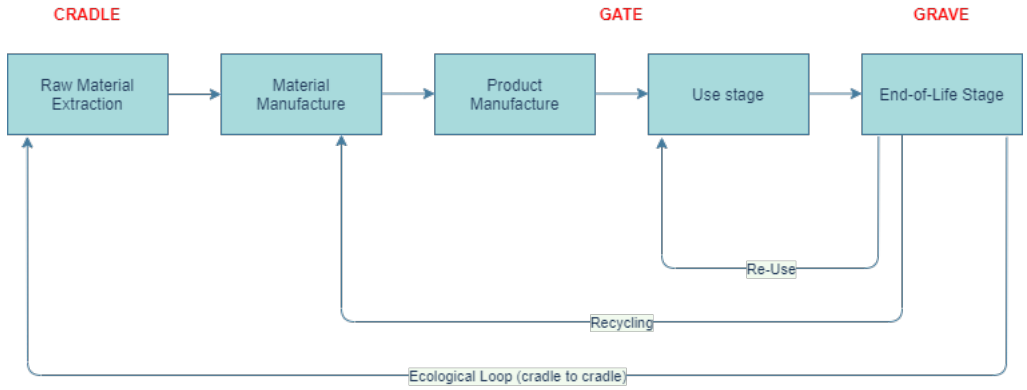

Figure 1.2: Life Cycle of a Ship

One aspect to a circular economy in shipping starts with designing with resource optimisation in mind and by promoting the reuse, remodelling, refurbishment of individual parts [97]. This can be achieved by creating elaborate material inventories of the vessels and a better traceability of materials during a vessels lifetime. With respect to the 9R framework, see figure 1.3, the ship building industry finds itself on different steps on the waste hierarchy ladder [63].

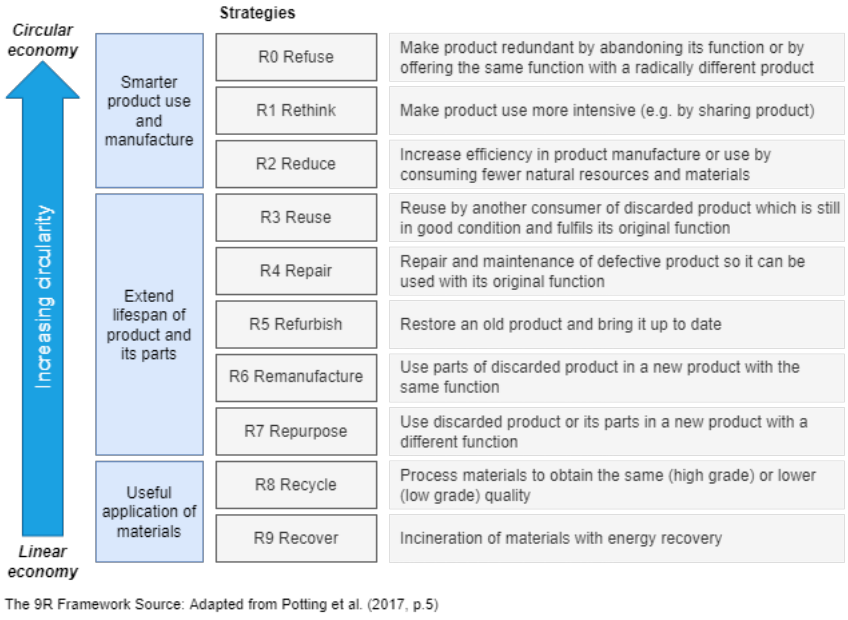

Figure 1.3: Waste Hierarchy

Figure 1.2 explains the different strategies that relate to a circular economy. The aim for every industry is to use a strategy with a low R number. Due to a ships long lifespan and its non standardized design and building process, the main R used for steel at the end of a ships life is recycling or repurpose (in case of rerolling). Rerolling happens because the EOL ship still contains high quality steel plates and beams and these parts find their way in construction industries after heat treatment and rerolling. This is a common practice is South-East Asia. Over 95% of a ships emissions during its lifetime currently can be allocated to the operating

phase. The industry is working hard to cut back on these emissions and the use phase is not a part of this research. The remaining 5% of emissions can be allocated mostly to the production phase. This includes scope 1, 2 and 3 emissions, with scope 1 emissions being emissions directly emitted by the operations of the company, scope 2 emissions can be allocated to the energy supply and emission from scope 3 are all third party emissions from transport and downstream stakeholders, see figure 1.4. Since ship building depends on many stakeholders working together to produce the final product, gathering information about scope 3 emissions is not an easy task.

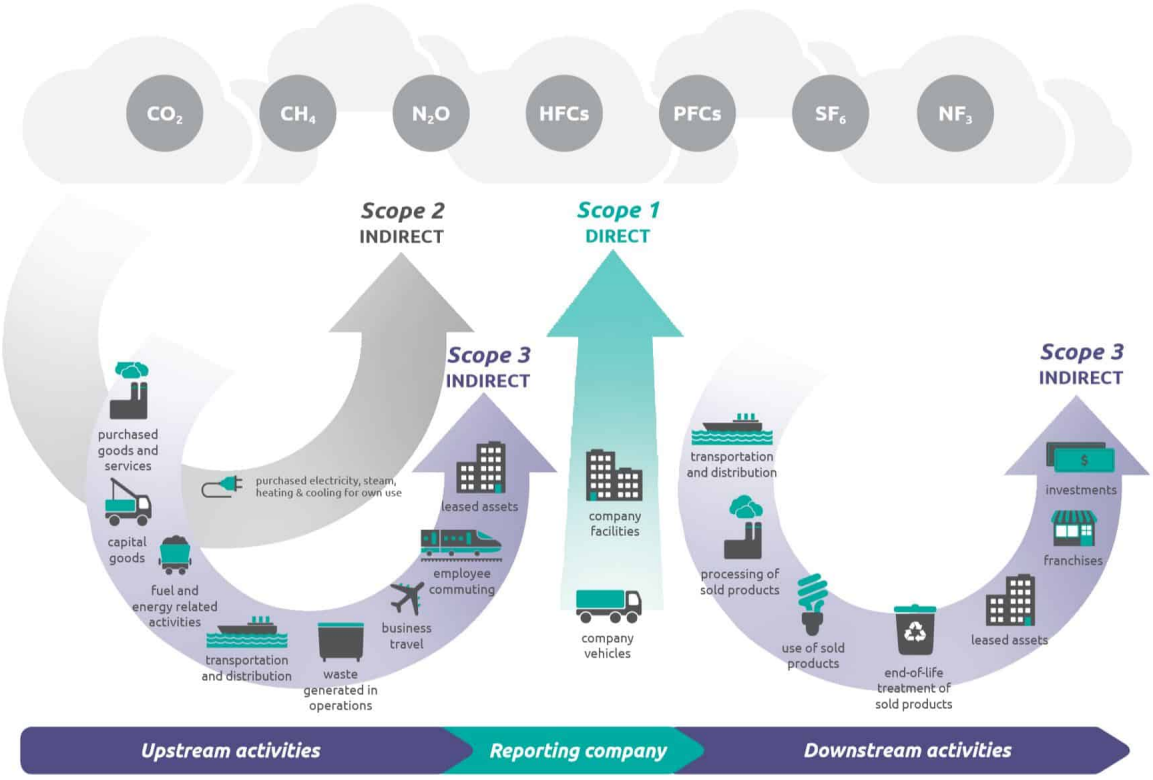

Figure 1.4: scope-1-2-3 Emissions [30]

The biggest reduction in emissions can be achieved in the use phase. To get an idea of the numbers, according to the Fourth IMO GHG study [52], voyage-based shipping accounted for a steady 2% of the global CO_2 emissions over the period 2012-2018. This averages to an annual 1000 million tonnes of CO_2 emissions. Significant work is being done in reducing emissions by improving ship propulsion systems with the goal of reducing fuel consumption, provision of onshore power supply, ferry electrification, the construction of larger RoPax vessels, the implementation of an energy-saving program that focuses on crew involvement and continuous training and cutting emissions during refitting [91] [44] [37] [79]. Alternative and low- to zero-carbon fuels are also being currently developed as well. AP Maersk created a market for green methanol by proactively ordering new ships that will run on green methanol [1]. Maersk also spent 1$ billion from 2015 to 2019 to retrofit 150 vessels in its bid to become carbon neutral by 2050. The second largest container line, Switzerland's MSC, achieved a 13% reduction in CO_2 emissions per tonne mile carried during 2015-18 [79]. The Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) are examples of global mandatory measures put in place to curb the emissions during the operational phase by regulations [87]. The emissions during the use phase or the operational phase of the ship will be outside the scope of this research. This leaves the 4 other phases of the life cycle: raw material extraction, material manufacture, product manufacture and end-of-life stage. These emissions are categorised as scope 3 emissions. These are emissions indirectly linked to the production or dismantling of the ship, see figure 1.4. These emissions are generated during the manufacturing of the ship but also include the emissions due to raw material extraction and material manufacturing.

Materials used in shipbuilding are ferrous metals, non-ferrous metals, plastics, wood and composites (polymer matrix reinforced with fibres). The main building material is steel, which on average accounts for

approximately 70-90% of all ship building materials [82] [57] [81]. Steel production, however, is among the world's most energy intensive industrial processes. The two most common methods for the production of steel are by blast furnace/basic oxygen furnace or by way of electric arc furnace. The former method accounts for about 71% of the world steel production [9]. This process uses virgin iron and coke. Coke is a material that is very high in carbon. Steel production in this manner is directly linked to greenhouse gas emissions. The latter process, that of the electric arc furnace, uses no coke and is, therefore, less environmentally damaging. However, this process is dependent upon the availability of scrap steel. Figure 1.5 gives a representation of both steel manufacturing routes. Although this is a simplified representation it is clear that virgin steel making needs more energy and processes to reach the final steel product.

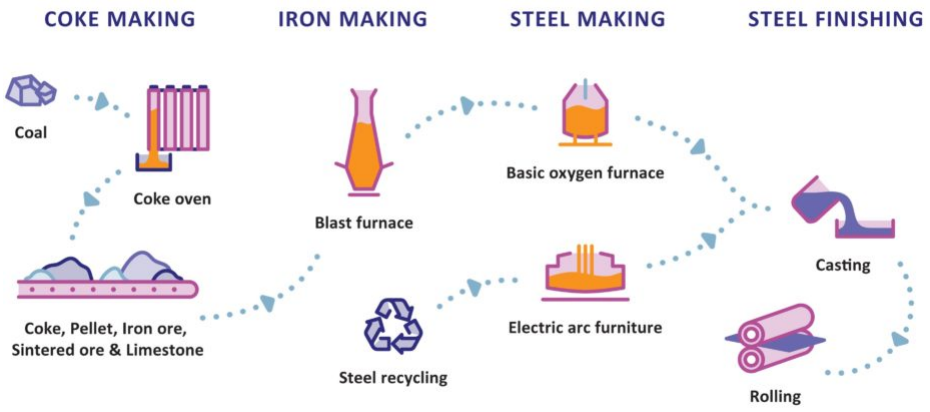

Figure 1.5: Steel Production [9]

The reasons for the selection of steel as the subject for investigation are twofold. First steel is the most used material in ship building 70-90% and second, if the case can be made for steel, it is assumed similar cases can be made for other materials as well. The language associated with steel products and sustainability changes quickly and different stakeholders use different terms interchangeably. Worldsteel has proposed the following definitions to provide clarity as to what the different terms mean [5].

Low-carbon steel: Steel manufactured using technologies and practices that result in the emission of significantly lower emissions than conventional production.

Zero-carbon steel: Steel produced without any CO2 emissions at all. This is a very high bar to reach, and it is difficult to conceive of a production technology that could achieve this in 2021.

Green steel: Due to the many different definitions used by different stakeholders, Worldsteel refrains from using this term. It is used in many situations as for marketing purposes and some of the definitions relate to steel manufactured using breakthrough technology, steel produced from scrap, reused and remanufactured steel, and conventional steel with emissions offset through the retirement of carbon units or allowances.

Net-zero or carbon-neutral steel: When a balance can be achieved between the greenhouse gases put into the atmosphere when producing steel and emissions taken out of the atmosphere by sinks.

Clean steel: Steel containing low levels of impurities, oxides, inclusions, or low or ultra-low level of carbon dissolved in the metal.

Decarbonisation: This is also a confusing term since it is the emissions resulting from reducing steel that need to be CO_2 free and not the product itself for steel without carbon is called iron.

Muslemani et al. defines sustainable steel as green steel that encompasses energy and resource efficiency, circularity and reduction of other pollutants [73].

Responsible steel is a not-profit organisation that has the aim of making the steel industry more sustainable in a bid to meet 2050's decarbonisation goals. They provide certification for steel making sites that can prove their efforts for producing steel in a sustainable way [2]. This shows the steel industry's

commitment to become more sustainable. The responsible steel certification looks at the emissions of the steel producers as a whole and not to the specified products.

Table 1.1 shows the average CO_2 consumption necessary for the production of steel by both routes. Despite often being attributed to lower labour and regulatory compliance costs, the main driver for the price for ship recycling is steel. In South Asia, rerolling mills produce reinforcing bars and other steel products for the construction industry by heating and reshaping plates from recycled ships. The rerolled steel does not reach its melting point and requires lower temperatures compared to making new steel. As the steel used for shipbuilding is certified by classification bodies, steel plates from recycled ships are considered high quality and therefore compete with billets as the raw material for South Asia's rerolling mills. Consequently, South Asia's recyclers have the advantage of commanding better prices for flat re-rollable steel compared to scrap steel destined for melting [71]. If recycled steel gets rerolled, only 0.23-0.31 tCO_2/t steel produced is needed. The figures for CO_2 consumption include only the emissions produced at the steel mill. The World Steel Association indicates that on average, 1.9 tonnes of CO_2 are emitted for every tonne of steel produced. Melting scrap steel in Turkey, for example, can result in roughly three times fewer emissions depending on electricity source. If steel is not melted but re-rolled, CO_2 emissions could be reduced by up to six times.

Table 1.1: Comparison BF-BOF/EAF

	BOF (Blast Furnace or Basic Oxygen Furnace)	EAF (Electric Arc Furnace)
average CO_2 emission	1.85 tCO_2/t steel produced	0.4 - 0.6 tCO_2/t steel produced[14]

Due to the growing awareness of the impact of ship recycling on human health and the environment, regulations have been made to improve these effects. The most important ones influencing the ship recycling industry are the Basel Convention, the Hong Kong Convention and the EU Ship Recycling Regulation.

The Basel convention entered into force in 1992 and its objective is to protect human health and the environment by prohibiting the transboundary movement and disposal of hazardous waste. 188 of the United Nations' 193 members are parties to the convention [25]. The Waste Shipment Regulation implements the Basel Convention and the Basel ban within the EU [82].

The Hong Kong Convention, which has not yet entered into force. So far 17 countries ratified the convention, representing 29.77% of the world's merchant shipping tonnage [36]. The represented tonnage needs to reach 40% for the convention to enter into force. The HKC has as an objective that ships, when reach their end-of-life phase and get recycled, do not pose any risks to human health, safety and the environment. Classification societies are nonetheless already certifying recycling facilities as HKC-compliant [35]. Bureau Veritas also adopted the Inventory of Hazardous Materials (IHM) in its Green Passport certification [42].

In 2013 the European Commission has adopted the Ship Recycling Regulations. These rules provide the requirements for ships and recycling yards so that ship recycling takes place in an environmentally safe and sound manner. They also restrict the installation and use of hazardous materials, such as asbestos or ozone-depleting substances. EU rules also require the IHM on board EU ships (both existing and newly build), EU ships going for dismantling and third-country ships stopping in EU ports [84].The EC also created a list of approved, certified recycling yards. However, according to Solakivi et al., 2021 [81], the current capacity of the certified European shipyards will not meet the anticipated recycling demand for the coming decade, so the European List (list of EU approved recycling facilities) will need the capacity of approved yards outside the EU.

Global ship recycling volumes are expected to double by 2028 to 14 million LDT and quadruple by 2033 to 28 million LDT. Adding to this expectation, due to a rapidly changing regulatory landscape, inefficient new tonnage could be phased out before their EOL increasing this recycling forecast to even larger quantities [29]. This will provide potential for new entrants including EU approved recycling facilities. Recycling is the lowest step up the hierarchy 1.3 as it is focused on the processing of materials to obtain a similar or lower quality material. Future designs should do more to incorporate the higher steps of this hierarchy into the life cycle of a ship, namely the refurbishment and reuse steps. By doing so even resources will be used adding to the sustainability of the design. For recycling purposes the deterioration of the ships hull due to corrosion should be taken into account [18].

Literature on certification of recycled steel products is hard to find. Steel producer Sandvik claims their

products consist of 84% recycled materials on average. Since 2019 they also started showing the exact amount of recycled steel in percentage per product on the materials certificate sent to customers [20]. ResponsibleSteel is a non-profit organisation with the aim to create a global standard and certification program to ensure businesses and consumers that the steel they use, is sourced and produced in a responsible way. ResponsibleSteel wants to enhance the responsible sourcing, production, use and recycling of steel by providing a platform for stakeholders to build trust and achieve consensus. Furthermore, they want to develop standards and certification and related tools to maximise steel's contribution to a sustainable society [2]. This type of non-profit organisation already exists for other industries like the aluminium, concrete, stone and other aggregate industries. The concrete industry has the Concrete Sustainability Council (CSC) which has as one of its goals the recognition by sustainable certification systems and the financial valuation in green procurement government policies. Studies show that in Germany for example, every fifth euro is being invested in green buildings. Certified companies clearly benefit from a competitive advantage here [32]. Nespresso, Rio Tinto Alcan, AMAG, Amcor Flexibles, Constantia Flexibles, Constellum and Tetra Pak founded the Aluminium Stewardship Initiative (ASI) in 2012 and claim that certifications are likely to create a premium market for responsible sourced aluminium [16]. Currently, there are no means of tracing these recycled or reused steel products. Increasing regulations regarding climate change and increasing demand for green brand image, both due to CSR and CnSR, can make the circular economy concept a valuable addition for companies in the maritime sector. Certifying recycled steel could therefore potentially facilitate new ventures in the ship building and recycling industry. Furthermore, while Europe is the world's third largest steel manufacturer it surprisingly lacks the necessary raw materials. Scrap steel availability is increasing [13] [10].

Another important factor needed to realise the CE in shipping is a combination of regulations and multi-stakeholder collaboration. The shipping industry works with an embedded network of different stakeholders. Without transfer of data and knowledge and a common willingness to change the industry, it will be hard to realise a significant change. No single stakeholder is able to risk the burden by himself. A more sustainable ship building industry requires all stakeholders to do their part. Regulators, financial institutions, manufacturers and owners all have a common interest in the long run to make this shift happen. Figure 1.6 Represents the different stakeholders and their relation to the 5 phases of the Ship's life cycle. The stakeholders under the green rectangle are related to more phases or have no correlation to a specific phase of the life cycle diagram. Downstream and upstream directions in the supply chain of the ship building process are depicted as well, Currently, stakeholders have to work together with parties directly left or right from their own position. It is key to change this and make sure all stakeholders have an idea to what happens in the entire ship building process. The easiest way to provide information throughout all stakeholders is if the products they produce contain all the necessary information. This information needs to be traceable, trustworthy and transparent. Classification societies are the perfect stakeholder to perform this activity. The aim of this research is to find an answer to the feasibility of a new class notation that specifies the recycled steel content of new build ship. This research will therefore mainly focus on the certification process and the influence of each of the stakeholder affected by this new class notation.

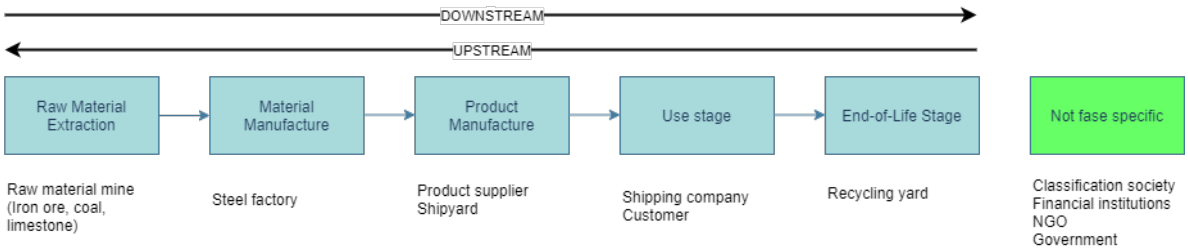

Figure 1.6: Stakeholders

Ship building has always been an industry that depends heavily on large quantities of data and calculation. With the digitisation of industries and a constant need for efficient data collection, sharing and evaluation, new technologies and smart solutions are being implemented worldwide in all industries. Application of blockchain technology for example is finding its use more and more in supply chains worldwide [43] [23] [60]. As stated earlier, in order to increase sustainability in the ship building process will require an increase in data sharing between the different stakeholders as well. It is key to come up with digital solutions that are safe and efficient [60].

To implement certification of recycled materials and incorporate new technologies in data sharing and processing is a task well suited for classification societies. Classification societies are private institutions that will investigate if a ship or maritime construction is in compliance with the relevant technical standards. They will issue a classification certificate and will carry out surveys in fixed time frames to make sure the vessel stays in compliance with this certification over the years. Each classification society applies its own rules regarding construction, propulsion, material properties, the piping system etc. Classification societies explicitly disclaim responsibility for the safety and seaworthiness of the vessel, but they do verify the vessel is in compliance with their classification standards. Certification is present in the design, building and operating phases of a ship's life. First, recycled steel is not currently certified as against the percentage of scrap steel that is used to manufacture new steel. Secondly, the last certification which the classification societies perform before the ship gets scrapped, is the 'ship ready for recycling certificate' [84]. After ship breaking materials are presumably reused and recycled and consequently continue their way into other industries and markets.

The first research gap is the certification of recycled materials and their traceabililty with respect to the shipbuilding industry. Although recycled materials are already used in shipbuilding through the supply of steel originating from EAF steel manufacturers, the percentage of scrap steel is not specified as of yet and therefore this information is lost in the process. Looking at the increased interest in ESG reporting (ESG is similar to CSR in the sense that they both indicate how a company deals with environmental, social and governance aspects of its operations. CSR, however, relates to the intentions of the organisation while ESG relates to meeting those intentions through the use of measurable criteria [6]) and in data analysis through the entire maritime sector, this information about the allocation of recycled steel could potentially be very valuable for different stakeholders, even if it is only a small percentage. A second research gap is the lack of exchange of data between different stakeholders over the life cycle of a ship in favor of the circular economy concept. What kind of data exchange can improve collaboration between stakeholders and lead to synergies and is the certification of recycled products a tool, aiding in this process?

This research will investigate the potential viability for a business case wherein sustainably recycled materials become certified before they enter the shipbuilding process, see Figure 1.7. In this way, materials can be reused and certified for building new shipping projects. Current certification activities are depicted by the green block in figure 1.7. This means that these activities correspond to the material manufacture, product manufacture and use stage. New certification activities are presented by the red blocks and by the red arrow labeled with 'recycling'. These new activities have something to do with the use of recycled materials. This research will find which new activities possibly can arise by implementing this innovation. What are the barriers and potentials for such a certification from the viewpoint of key stakeholders in the life cycle process of a ship or maritime structure. What kind of data or which specifications are important in this procedure? How does the certification of recycled materials impact the circular economy. More specifically, can certification provide the traceability, trust and transparency that is needed to improve the collaboration between the different stakeholders in favor of a more circular economy concept in the maritime industry? Steel will be looked at as it is the main building material for ships. Next to a viability analysis based with respect to the ESG performance (in this case the Environmental aspect and governance aspect are prevailing) the possible direct/indirect reduction in CO_2 emissions will be looked at. The reason behind examining both the input of recycled materials in the building process as well as the output of materials at the end of life phase, is that the classification society, in this way, provides certification for all the different phases of the life cycle of a ship. This creates opportunities to provide additional certification of circularity. Does an overall outlook of a ships performance with respect to sustainability, over its entire life cycle, with an in depth traceability of the materials used, add value (positive or negative) to all or any of the stakeholders? The result of this research will lead to a procedure that can be used by a third party (in this case classification society Bureau Veritas), to map these material flows. This certification will differ from the responsible steel certification in the way that this research looks at the specific steel product coming from the steel manufacturers and what this means for the life cycle of a ship. A possible solution to make a certification procedure more efficient and therefore the viability of this business case could be the use of blockchain methodologies [62]. Blockchain methodology will be qualitatively assessed as a solution to improve the traceability, trust and transparency of certification procedures.

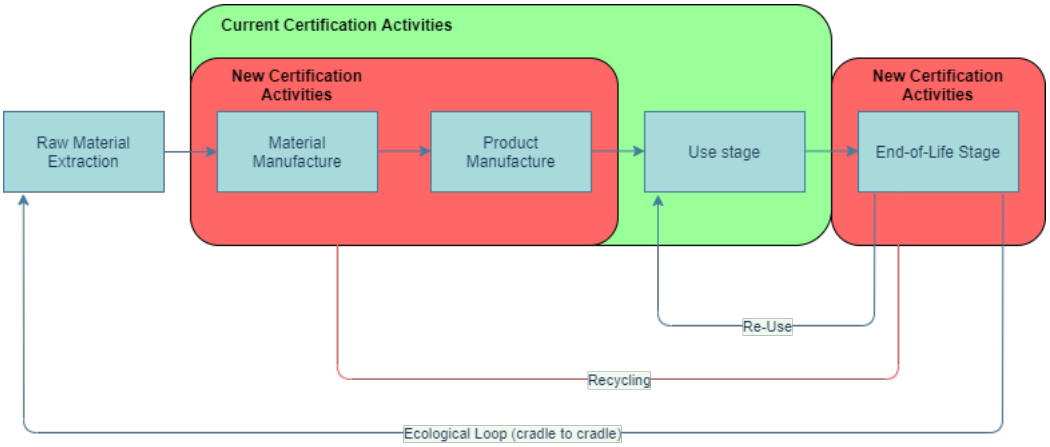

Figure 1.7: Certification activities

1.1. Hypothesis

A circular economy, where recycled materials from 'end of life' ships are traced and used for new ships has added value (financial, regulatory and environmental) for the shipyards and shipowners.
How can certification help to improve trust, transparency and traceability of a circular economy in the shipbuilding industry?

1.2. Research Questions

1. What is the potential for and what are the barriers to the certification of Building materials provided for the construction of ships or other floating maritime structures?

2. What is the potential for and what are the barriers to the certification of material flows from a recycled 'end of life' ship?

3. Who are the different stakeholders in this process and how can they benefit from the circular economy concept?

4. What should a certification procedure look like?

5. What are the potential impacts (economic, social and environmental) of such a certification protocol on newly built ships?

   This investigation is performed in collaboration with classification society Bureau Veritas. Just like any other industry increasing sustainability is high on the agenda of classification societies. Because of their unique position in the market they can not only improve their only footprint, but through certification innovations help to improve the sustainability of the maritime industry.

1.3. Methodology

The methodology used for this research will be both a thorough literature review of scholarly articles and the interview of relevant parties involved in each step of the process/ procedure. The determination of those parties (key informants) that need to be interviewed will follow from question 1, but, in any event, will include companies active in ship recycling, steel manufacturing, shipbuilding, shipping and classification. In addition, companies that are not directly linked to the maritime sector will be interviewed such that similarities and differences between the industries can be determined and compared. A salient example of such a comparison will be as between engine manufacturers. Questions 1, 2 and 3 will mainly be answered by the literature review and validated by qualitatively interviewing key informants. Questions 4 and 5 require information from the interviews. The interviews are semi-structured interviews. The resulting transcripts will be coded to cross link the different topics to the topics found in the literature. This views of the different stakeholders can be matched and compared. To answer question 5, 2 procedural models will be qualitatively assessed and discussed. The models will be a conventional certification method and then a more technologically advanced blockchain method. The effect of a new certification procedure for the use of recycled materials will be assessed by the STAR method on the different stakeholders.

1.4. Plan of Approach

Table 1.2: Plan of Approach

Step	Methodology	Relevant research question
Background & Problem definition	Literature review	1
Stakeholder Identification	Literature review / Ranking of barriers and potentials	1, 2 & 3
Material Selection	Literature Review / Stakeholder Interviews	1, 2 & 3
cStakeholder Interviews	Stakeholder Interviews	2 & 3
Problem Solution	Analysis of literature review and stakeholder interviews	4 & 5
Validation of the problem solution	Limited* Stakeholder Interviews	6
*Limited stakeholders selection approved by R. De Petter		

The stakeholders are identified in chapter 2. Barriers that those stakeholders encounter are also described in this chapter. Chapter 3 looks at the technical proces of steel production and explains why this material has been chosen. This chapter also looks at the scrap steel availability and possible future innovations in steelmaking. Chapter 4 explains how the interviews have been done and how they are processed. The results of the interviews are described here and they follow a similar lineup of topics (barriers) presented in chapter 2. Chapter 5 describes the certification procedure. Which new possible certifications are there compared to the existing ones and how is this certification procedure a solution to the challenges, are presented here. The solution is being evaluated in this chapter by the STAR method. This chapter ends with a section about future innovations and solutions. This part looks at the use of Blockchain technologies as a possible way to introduce new certification opportunities. The thesis is closed with conclusions and recommendations.

2

Stakeholders

A new class notation for the use of recycled steel in maritime structures touches on two areas. On the one hand it is about the 'use of recycled steel', this is part of the greening process of the industry in general. Secondly, it is about 'recycled steel'. The latter part touches on the subject of the supply chain of the ship building industry. Both routes present barriers and/or opportunities. Similar barriers and opportunities can be found in other industries.

Greening of the industry has to do with the circular economy concept. According to [63] the CE concept has momentum now, but needs consensus as to what is its correct definition. Kircherr et al. defines CE as an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers. Kircherr et al. identified different barriers to CE in the European Union. They found that the technological issues are not the most pressing ones. The barriers they identified are categorised into four categories: cultural, regulatory, market and technological. They can be found in Table 2.1.

Table 2.1: Barriers to the CE [64]

Cultural	Lacking consumer interest and awareness
	Hesitant company culture
	Operating in a linear system
	Limited willingness to collaborate in the value chain
Market	Low virgin material prices
	High upfront investment costs
	Limited funding for circular business models
	Limited standardization
Regulatory	An absence of enabling legislation
	Lack of global consensus
	Limited circular procurement
Technological	Limited circular design
	Too few large-scale demonstration projects
	Lack of data, e.g. on impacts
	Ability to deliver high quality remanufactured products

The implications of these identified barriers is that it becomes clear that to implement the concept of CE, there needs to be a change in mindset amongst all stakeholders in the supply and value chain. It is not a quick win but a long-term undertaking. Many participant to this study portrayed the government as a key player to

facilitate efforts into increased sustainability by addressing the barriers of low virgin prices and high upfront investment costs.

The iron and steel industry is the largest coal consumer and the most GHG intensive industry. 7% of global energy supply and 7-9% of global GHG emissions can be adhered to the iron and steel industry [61] [92]. Figure 2.1 shows steel use per sector in the EU for 2019-2020 [13]. The maritime industry falls under other transport. If divided into hull and machinery, the machinery parts falls under the mechanical engineering. Only a small part of the total steel consumption is therefore allocated to the maritime industry. CO2 reduction efforts will have the most impact on the largest consumers, being the construction, the automotive [76] and the mechanical engineering industry.

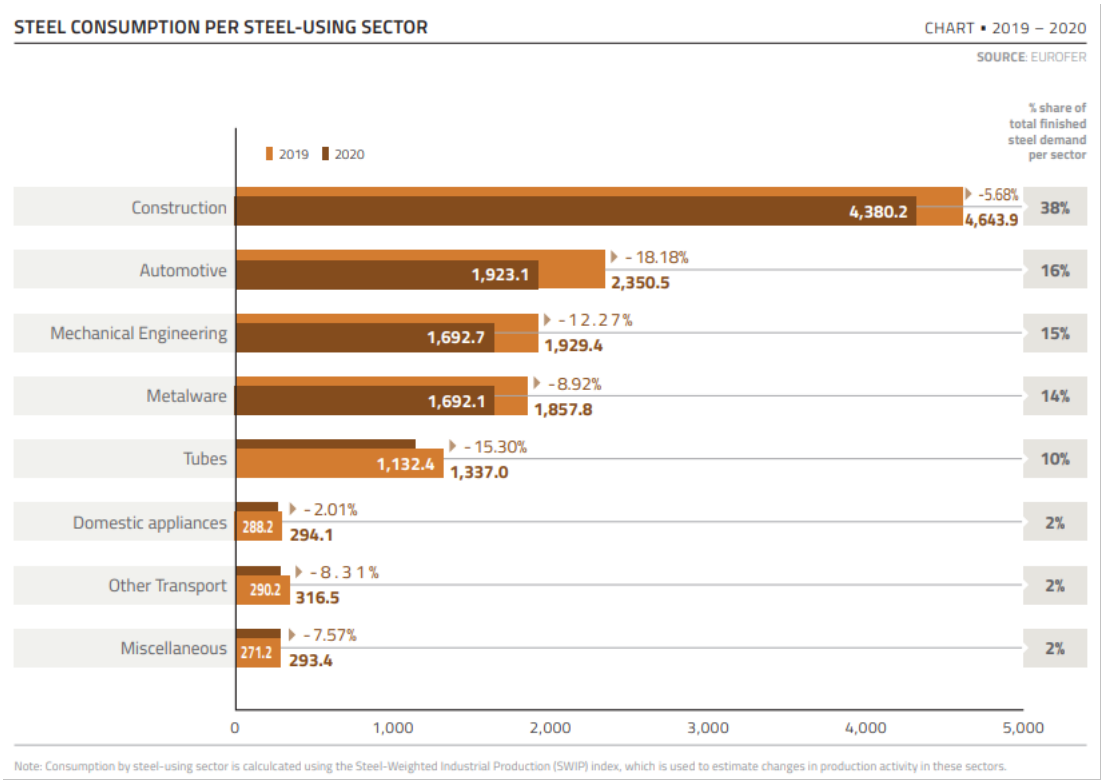

Figure 2.1: Steel consumption per steel-using sector [13]

Over the years, most steel consuming industries saw an increase in attention to the sustainability of their sector and felt the pressure to reduce their carbon footprint on the environment, mostly in terms of reduced emissions. Different industries have responded (willingly or forcefully) to this increased attention. The transportation industry has implemented remanufacturing as one of their EOL recovery strategies [72]. OEMs in the aerospace and aircraft industry are heavenly involved in the remanufacturing process. High performance parts even undergo remanufacturing up to six or seven times [85]. The aerospace industry has been identified as the largest single practitioner of remanufacturing by value due to the high value of the complex systems used. The automotive industry is world's largest remanufacturing sector. This is because the automotive sector produces vehicles *en masse* and many parts are standardised. Policies are also implemented to achieve this level of remanufacturing. In Europe, clear targets have been set through the EOL directive (2000)/53/EC. This states that Member States are required to meet rates for reuse and recycling of 85% and for reuse and recovery of 95%, by an average weight per vehicle [12]. Contamination, mainly by copper is an important barrier for the recycling of end of life vehicles [76]. Remanufacturing and refurbishment are usually not associated with ships. Retrofit and refit are more used with shipowners to upgrade their ships. With remanufacturing, the ship needs to be taken back at EOL and it needs to be reused, or partly reused, by new users [59] [22]. The biggest barriers for remanufacturing are cost associated and that products are not designed for the EOL. The cost aspect is decreasing with the increase in costing policies for carbon footprint. Hourly labour costs and accumulating lost revenue of downtime make it more economic to buy new parts [72]. European policies like closing the loop [8], the ETS [11], the CBAM [7], and

national policies like the CO2 performance ladder system [80] increase the potential for remanufacturing of ships. External factors such as market mechanisms in shipping influence the EOL of ships as well. Ships can be scrapped well before their actual EOL if the market situation causes this to be the more economical option. In this case policies could also influence this decision. Compared to the automotive and airline industry the maritime industry faces numerous challenges with this CE concept. These challenges are: no standardisation, labour intensive, no design for remanufacturing, logistically challenging to ship parts from and to everywhere in the world, lack of specialised skills and labour force, one-off large ships (no standardisation of ship components), waste infrastructure missing to take back ship components, time consuming to repair and maintain, high tax on labour, finding a suitable customer for the reuse of components, customer preferences [72]. Potential opportunities for profitable remanufacturing are: creating standards, approval by environmental policies, better reputation, better waste infrastructure for collection and reuse, favour design of ships for modularity, encourage the use of environmental product declarations, reduce tax on labour, reduce vat for repaired (second-hand) and remanufactured components, mandatory national targets for reuse/preparation of reuse in the maritime sector, more information to customers that remanufactured components are as good as new. External factors can influence this mechanism as well. before the financial shock of 2008 new ship engines order took 2 years to be fulfilled, remanufacturing only took a few months. the Suez canal blockade and the shortage of resources also made OEM take action to rethink their supply chains. The conclusion for remanufacturing of ship parts according to Milios et al. [72] is that the most effective way forward would be a global effort to coordinate and regulate under the umbrella of the classification societies and according to international conventions on maritime affairs. National policies might be only of limited use, as the industry has a global outreach. The certification of recycled steel in ship building is therefore only a small part of the story but nevertheless a crucial part that sets the industry on a path in the direction to a more sustainable industry.

The construction industry is the largest steel consumer, accounting for approximately 50% of total world steel consumption [26] [27]. The most well known certification in construction is LEED, It stands for Leadership in Energy and Environmental Design. LEED uses a embodied carbon calculation method that estimates the quantities of GHGs released into the atmosphere during building materials manufacturing processes as well as during construction, material replacement, and end-of-life treatment. The main goal for LEED is to provide ratings for green buildings in terms of design, construction, operation, and maintenance [70]. The LEED community acknowledged shortcomings of LEED regarding verifiable environmental outcomes [48]. THis creates a barrier for justifying the use of certifications regarding sustainability. This can be solved with LCA methods. The International Organization for Standardization (ISO) has 2 leading standards for Life Cycle Assessment. These are ISO 14040 and ISO 14044 [55][56]. They focus mainly on the process of performing an LCA. ISO 14404 [54] was developed by the World Steel Association (worldsteel) for application to iron and steel making. The standard focuses on CO2 emissions, rather than all GHG emissions, on the grounds that 93% of an operating company's GHG emissions are in fact related to CO2 ISO 14044:2006 is commonly used with an LCA framework to calculate the embodied carbon [56]. Pre and post consumer recycled content is used to define the total recycled content. This is based on general data and is accessible in LCA documentation. Following formula is used to calculated the recycled content, to be used for impact assessments.

$$R = R_1 + \frac{R_2}{2}$$

R_1 = post consumer waste material

R_2 = pre consumer waste material

The exact recycled content as a measure for the sustainability of steel products is, according to the steel industry not a good measure [39]. Because EOL steel products get turned into scrap steel almost entirely, British Steel argues that providing the percentage of recycled content would distort the market and increase the cost of steel products for consumers. This view is a barrier to the certification of recycled steel. Steel producers are a major stakeholder in the ship building process. Policies regarding carbon costing are asking companies to investigate and control their scope 1, 2 and 3 emissions. Recycled content information of steel products will therefore be crucial information. On the other hand the industry is correct that the recycled content is not solely responsible for the sustainability of the steel products. The energy supply is another major factor. Battery powered ships or vehicles are only as green as the supplied energy is green [58]. Figure 2.2 shows the energy mix (%) for electric generation for 36 countries. This is important information to determine the carbon footprint of a steel manufacturer. The barrier for the recycled content of steel is that it needs additional information of how that steel is produced.

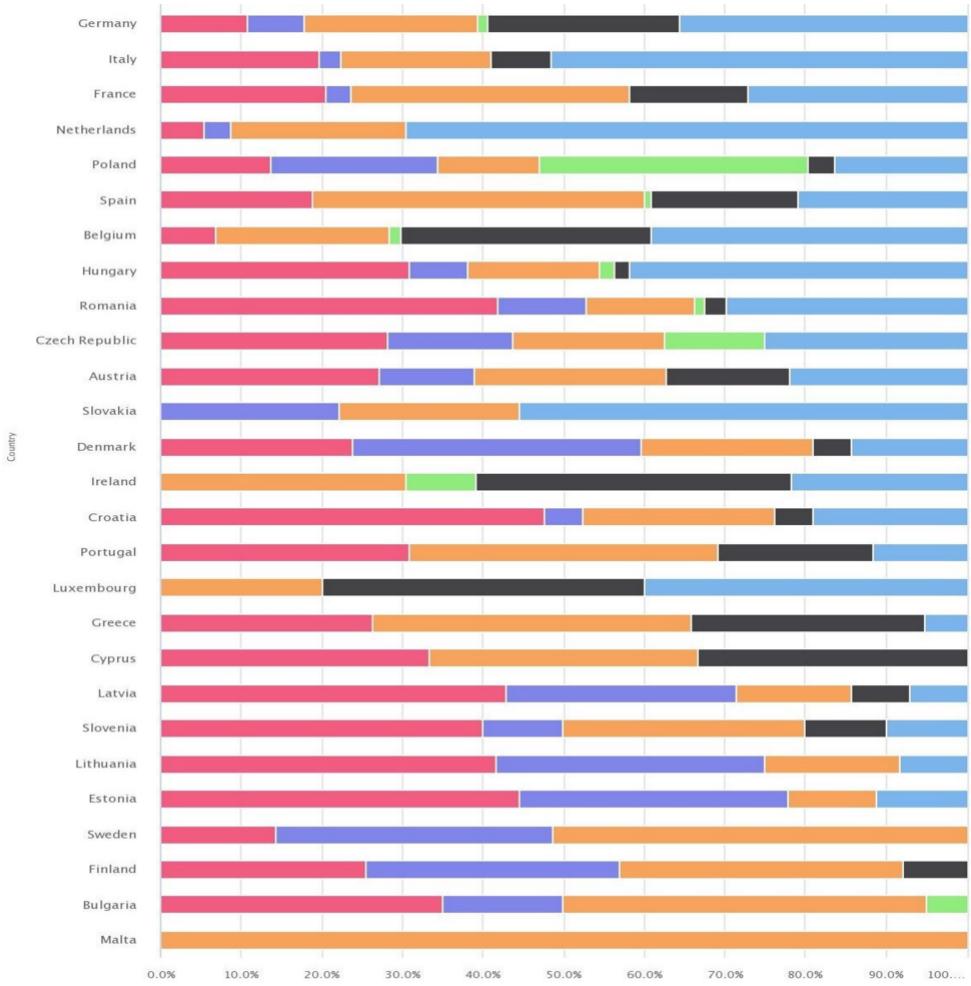

Figure 2.2: Energy use by energy carrier across EU-27 countries. Blue = gas; orange = electricity; red = renewables; purple = district heat; black = oil; green = coal, source: Irena.org

The contamination of steel scrap by undesired tramp elements such as copper is a barrier to the use of scrap steel. These contaminations are often introduced during the steel lifecycle, for example copper wiring is often attached to the chassis of an EOL car. This adversely affects the quality of some recycled steel products. Unlike other elements, copper can't be removed to slag when scrap is re-melted. Design for EOL recycling is one of the solutions for this case. According to a report from MaterialEconomics [17] Europe is capable of increasing the use of scrap steel from the current 50% to a level of 70% given that total scrap availability increases, scrap contamination is reduced and EAFs are more widespread. Shipping industry has the advantage that its scrap is less contaminated and of a high grade. This report also looked into the different carbon reduction routes.

The Fast Track LCA method can be used to determine the life cycle impact of a product. It is a simplified version from the rigorous LCA method [96]. The fast track method uses "lookup tables" like the sort of www.ecocostvalue.com. The 5 steps to perform a LCA are: 1) establish the scope of the investigation, 2) establish the functional unit and boundaries, 3) quantify materials, use of energy, etc in the system, 4) enter data in calculation sheet and 5) interpret the results and draw conclusions [15]. Previously discussed values for the recycled content for steel production are used here. In the EU in 2018 the recycled content was about 56%, see figure 2.3.

Figure 2.4 shows that mainly scrap from in China is increasing significantly over the coming 30 years. This is because their economy had a large influx of steel from the year 2000 and on wards [26]. Scrap availability is one of the challenges when it comes to the scrap-based steel making process. This figure shows the expected scrap availability. This can be predicted because of the average lifespan of steel products being 30 years, see Figure 2.5. Steel produced today will enter the market as scrap steel around 2050. The

CRUDE STEEL PRODUCTION AND STEEL SCRAP USE IN THE **EU-28** (MILLION TONNES)

	2014	2015	2016	2017	2018	% 2018/ 2017
Crude Steel Production	169.3	166.1	162.0	168.5	167.7	-0.5
of which						
Share BOF of Crude Steel in %	**61.0**	**60.7**	**60.5**	**59.6**	**58.5**	
Share EF of Crude Steel in %	**39.0**	**39.3**	**39.5**	**40.4**	**41.5**	
Total Steel Scrap Use	91.6	90.61	88.4	93.6	93.8	+0.2
Ratio Steel Scrap / Crude Steel in %	**54.1**	**54.6**	**54.6**	**55.5**	**55.9**	

BOF – Bacic Oxygen Furnace
EF – Electric Furnace

Source: worldsteel and EUROFER

Figure 2.3: Crude steel production and steel scrap use [13]

increase in demand for steel is gradually declining which means that enough scrap will be available the coming decades. However, to replace the total demand for primary iron with scrap is not possible due to the contamination. Next to that studies predict that primary steel production will still be the dominant route [75]. Regulation from China could prevent the scrap steel from being exported to other areas in the world. Although there would be enough scrap available, the scrap steel market keeps on being a volatile market.

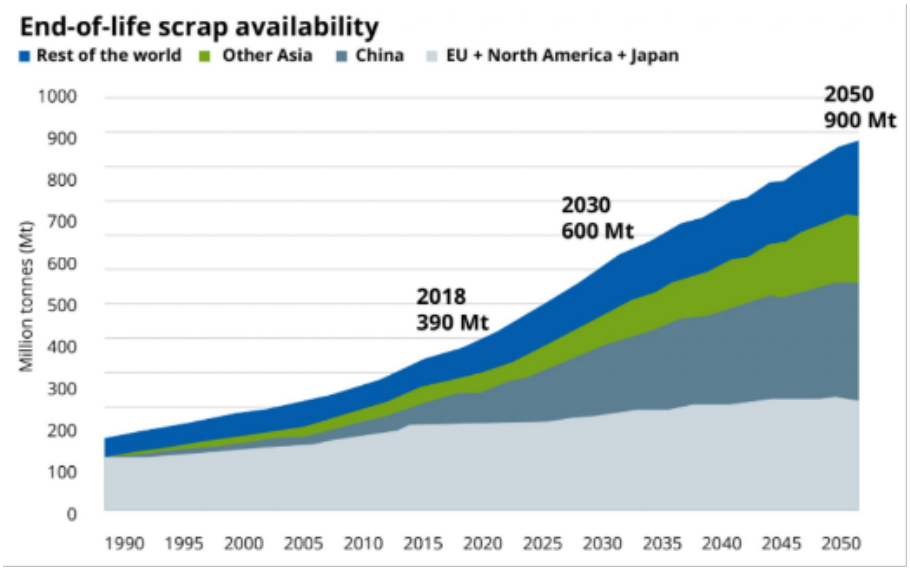

Figure 2.4: Scrap steel availability [5]

Category no.	Typical market category	Lifetime duration [y] Average (standard deviation)		Market share [%]	
		Europe, CIS, America, Africa	Asia, Oceania, the Middle East	Europe, CIS, America, Africa	Asia, Oceania, the Middle East
1	Civil engineering	67 (29)	34 (14)	18%	23%
2	Buildings	67 (29)	31 (13)	19%	28%
3	Machinery and appliances	20 (9)	17 (7)	22%	27%
4	Transport (vehicles, buses, trucks, and trains)	17 (7)	15 (6)	34%	15%
5	Shipbuilding	30 (13)	30 (13)	0.5%	1.5%
6	Others	20 (9)	15 (5)	6.5%	5.5%

Figure 2.5: Assumed lifetime of steel products [75]

The policies in place (global, continental and national) are focused on target setting. Information about scope 1, 2 and 3 emissions are therefore necessary for all stakeholders upstream or downstream in the supply chain. To reach the fifth stage of the Dutch CO2 performance ladder for example, accurate emission data of upstream and downstream stakeholders is required [80]. The fourth industrial revolution, also called industry 4.0 makes this demand for information between all stakeholders possible. Dependencies of stakeholders in the life cycle of products are revolutionised this way. In the construction industry building information modeling or BIM is a well known concept [93] [45], see figure 2.6. Many activities or processes can be incorporated in this BIM model. Next to being very helpful during the building phase, the BIM model creates a digital twin that can be updated through its entire lifetime. Incorporation of ERP and other procurement systems is another major advantage. Amongst similar lines, a collaboration between four important maritime companies, being Boskalis, Van Oord, Damen and Royal IHC, started the project called One Maritime Data Standard or OMDS [21]. 2BA has created a platform and database with the aim to facilitate more efficient procurement possibilities. The difficulty with applying these innovations in the maritime sector is to agree on common standards. The maritime sector relies on and needs the collaboration of stakeholders and suppliers worldwide. Research into stakeholder collaboration is abundant [74]. Barriers are similar to the following challenges that were identified and reviewed amongst contractors in the building industry [45]. These barriers are lack of standardisation, legal and contractual problems, cost of implementation, data protection and cybersecurity, lack of investment in research and development, unclear benefits and gains, resistance to change, lack of labor force, fragmented and project based nature of the industry. The use of BIM to support green building certification systems GCBS has been studied for the construction industry [77]. They see a significant increase in the interest in this topic but the major barrier is the lack of a unified approach for BIM and GBCS integration and interoperability. Form all construction related certification methods, LEED certification has the best integration level of BIM into GCBS.

Mello et al. investigated the sustainability challenges in the ship building supply chain with respect to digitisation and the implementation of industry 4.0 [69]. Table 2.2 gives an overview of the challenges they identified. All these barriers are relevant in the scope of this study except for the product use ones.

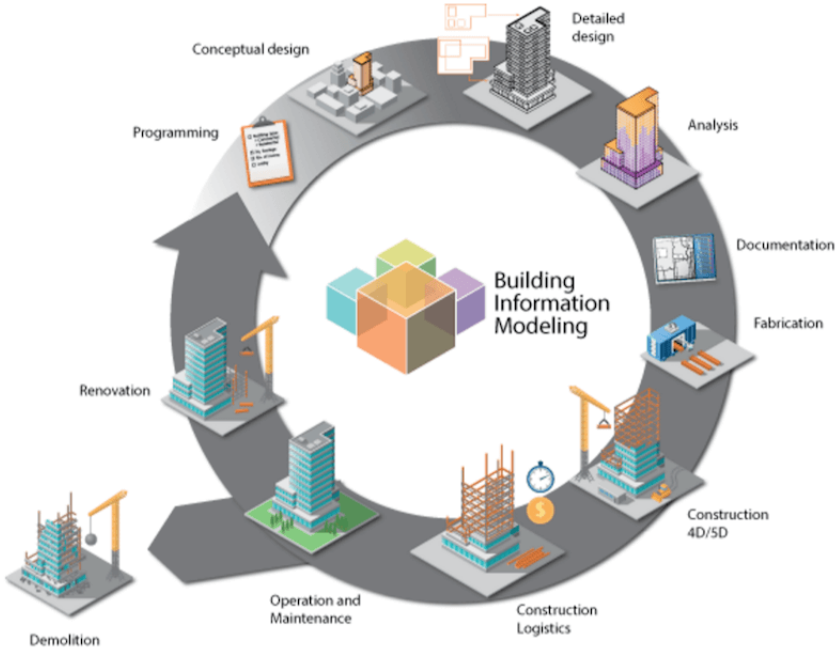

Figure 2.6: BIM

2.1. Classification society

Certification of recycled steel products has the potential for the societies to expand their business activities. By including certification for the destination of scrap steel at the EOL phase, the entire material stream related to a ship can be traced. In this way, societies have certification documents related to the entire life cycle of a ship, see figure 1.7. This provides the opportunity for extra certification related to the level of circularity of the ship. In this way, they can improve their assistance towards shipowners and help them in meeting their sustainability obligations and commitments. As mentioned before, the function of certification is to provide transparency and traceability and subsequently create trust between different stakeholders. In a quickly evolving shipping industry, where data acquisition, processing and sharing is generating a competitive advantage for those companies who are proactively tackling current shipping issues, opportunities for societies lie in facilitating this flow of data between the different stakeholders.
Recycled steel, as a commodity, is prone to greenwashing, which can be prevented by certifying recycled steel products. Another way in which societies can provide trust is in the overall ESG data used agencies to evaluate companies. The ESG ratings can depend on the agency performing the assessment. The lack of transparency and standards in this field can be an opportunity as well. Barriers to certifying recycled steel are the allocation of sufficient funds and resources to make this certification happen and since it is an innovative field of work, the results are not guaranteed. There is the chance of regulation being issued obligating companies to incorporate recycled steel in their operations, and possibly making this kind of certification obsolete. Another barrier is the uncertainty of how the scrap steel market will evolve, which in turn can influence the demand for recycled steel products.

2.2. Financial institutions

In their role as financing companies in the maritime industry, banks can influence decision-making in favor of sustainable shipping. Financial institutions increasingly show interest in ESG investments. They want to mitigate the investment risks when it comes to environment, social and governance aspects of companies and therefore, look into the ESG ratings of these companies. The 'Poseidon Principle' is an initiative where eleven banks, representing $100 billion of the global shipping portfolio [53], have agreed to integrate CO_2 emissions in their decision-making process when it comes to providing loans to shipping companies. "ING (a member of the initiative) and other leading ship-finance banks have a strong preference to finance more

Table 2.2: Overview of the identified sustainability challenges and the related case study evidence [69]

Shipbuilding supply chain phases	Sustainability challenges	Case study evidence
Design	Impact on ship's environmental performance during ship operation	Ship design prioritizes operational cost-efficiency over-improving environmental performance
	Inefficient and fragmented flow of information	Poor integration between design systems and those of other disciplines
Suppliers and logistics	Global sourcing (low proximity between actors)	Global sourcing (low proximity between actors)
	Complex and inefficient flow of information between actors	Several different IT systems used internally and between actors
Manufacturing and assembly	Working conditions.	High amount of manual labour, awkward and unsafe motions required by shipyard operators and a lack of supporting tools
	Productivity and cost-efficiency	Vast yard site with a poor of overview of materials, time spent searching for and retrieving materials and information
Product use	Emissions and energy-efficiency	Shipbuilding company does not monitor ships in operation and the status of its sub-systems
	After-sales services, maintenance and repair	Spare parts production and stock-keeping disrupts normal production
Product end life	Ship recycling	Unsatisfactory end-of-life handling of ships produced in the supply chain

environmentally friendly vessels which in turn should encourage shipyards to continue to improve vessel design and efficiency," ING's Fewster said. [79]. Therefore, financial institutions can be seen as enablers of CE. The purpose of interviewing financial institutions is to find out how they look at CSR, CE and ESG. Do these institutions see CSR, CE and ESG as factors influencing their decision process for approving financing? How do they value the risk of competitiveness of recycled steel products? Does certification of recycled steel products add value or increase chance of receiving financing?

2.3. Consumer

Consumers in this context are a broader concept. Examples of consumers are people who buy household products that were shipped half way around the world, passengers on a cruise, brands that use shipping in their supply chain, ports or countries that hire dredging companies for port maintenance, etc. Consumers play a vital role in this whole process. If enough consumers decide to buy products or receive services only from those companies that engage in environmentally sustainable business practices, they will automatically force the industry to move towards more environmentally friendly practices. This is why they are enablers in this matter. The purpose of interviewing consumers is to find out about willingness to pay for more sustainable companies. Are they aware of the current market developments regarding CE and ESG? Do they base their decision making on environmental aspects as well or do they only focus on the cost perspective? Are consumer aware of the recycling of steel and the possible environmental impacts recycled steel products can have?

2.4. Steel manufacturer

Steel producers are challenged as well to decarbonise emissions in their industry. The potential for steel producers in a more sustainability demanding climate lies in recycling and the increased value that can be appointed to recycled products. Steel factories have the ability to decrease the CO_2 emissions from their downstream supply chain by providing their customers with recycled steel products. The barriers they face

is the availability of scrap steel. Steel products have a lifespan of about 30 to 40 years. The availability of scrap steel can become an issue of demand as it grows and could potentially increase the price of this commodity. Furthermore, looking at their own production processes, barriers for steel manufacturers are the technological advances, high capital investments and a long timeframe to convert current steel fabricating processes to more environmentally friendly processes. An extra incentive is the carbon trading system implemented by the EU. In early May 2021, Carbon traded at about €50 per metric ton on the EU Emissions Trading System [68]. Steel manufacturers are interviewed because they manufacture the steel products. They are responsible for the input of recycled steel in the market. They can provide information about the percentage of scrap steel used. The steel manufacturer can provide insights in the steel and scrap steel market. If the demand is created or desired by the enablers (consumers and financial institutions) the steel manufacturers are making this process possible by providing recycled steel products and reporting on the relevant information about the recycled steel products.

2.5. Shipping company

Shipping companies in this process are also part of the consumer group that was mentioned above, depicted as customer in figure 2.7. Shipping companies can differ in sustainability according to their own business strategies or in how close their relationship is towards consumers. Therefore, it is important to determine the opinions concerning environmental sustainability, CSR, CE and ESG from different companies. Already a lot of effort is being done in reducing the Scope 1 emissions. For shipping companies this means the emissions resulting directly from their operations. These Scope 1 emissions are being reduced by using alternative fuels, more efficient propulsion systems, improved designs according to the EEDI, better and more efficient management of the fleet and operations (SEEMP), etc. By using ships that are being built with certified recycled steel products, shipping companies also have a potential to reduce their upstream Scope 3 emissions. This results in a greener company profile and increases competitiveness on this respect. Companies that have operations close to the consumers, have a higher chance of being chosen over companies with a less green image. The barriers for shipping companies are an increased investment from which the return on investment may be hard to justify. Their competitiveness could also be a barrier in case market fluctuations cause recycled steel to become more expensive than regular brown steel. Increased effort on CSR can have a positive effect on the company's image but these effects might need time to manifest themselves. On the other hand, companies contracted by government should get a substantial advantage when they can prove their efforts to become more sustainable (green procurement from governments).

2.6. Ship designer

Ship design can be part of a shipping company. Figure 2.7 shows a rich picture of possible scenarios during a ship building project. It shows the complexity that can already exist between only two stakeholders [69]. Different scenarios are being depicted in this figure with the corresponding consequences or dependencies. This represents the barrier of collaboration that can exist between two stakeholders already. This barrier becomes even more complex when certified recycled materials are added in this mix. Using certified recycled materials requires a shipyard and designer to spent extra resources on material procurement,

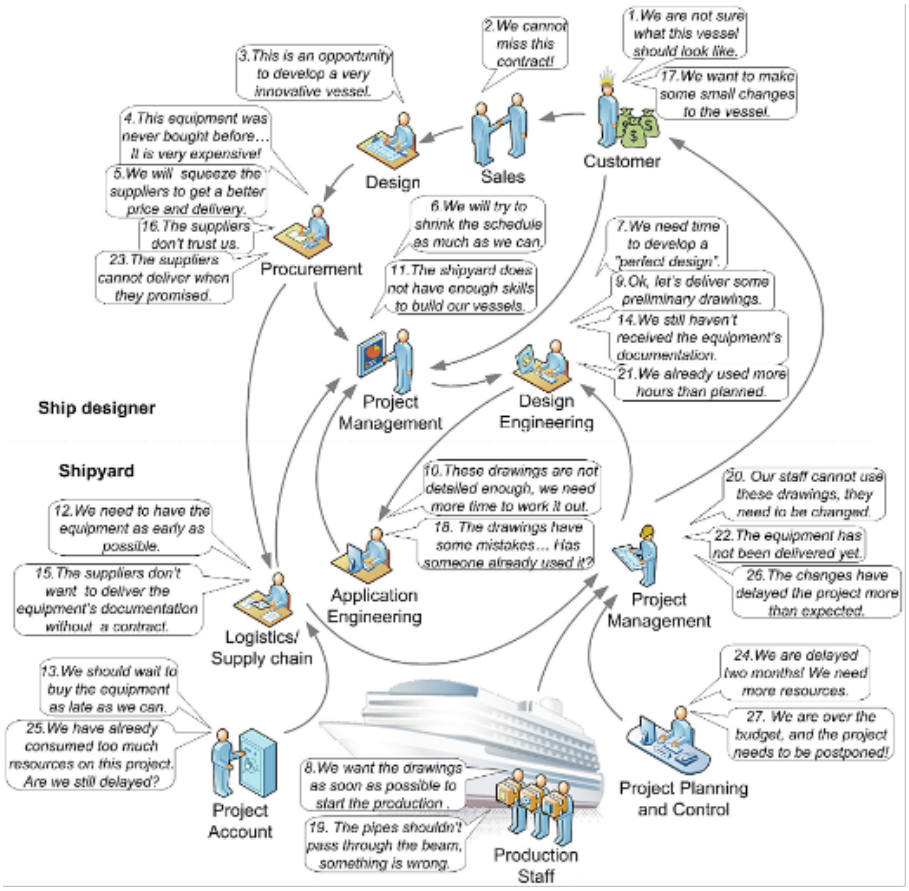

Figure 2.7: Rich picture of the project behaviour [69]

2.7. Shipyard

Shipyards can choose to use recycled steel over 'virgin' steel products. They are, however, dependent on the requirements of their clients. The potential for shipyards regarding the use of certified recycled steel is that they can charge premiums for ships being built with this material. In doing so, this will also boost their sustainability outlook towards the community and increase their competitiveness as against other shipyards that do not provide this option. The barrier for a shipyard is the extra investment of capital and resources to make this process possible. This requires two stockpiles of the same steel product and a thorough bookkeeping system to document the parts of the ship where the recycled steel parts are used. If no premium can be charged the benefit of using recycled steel products will only show in the company's CSR and results can only become visible over time. As the manufacturer of the ship or maritime construction, the shipyard has the difficult task to meet the demands of their customers with an efficient and cost effective design/product. They have to source the materials according to specs and manufacture the product according to the clients wishes. It is therefore interesting to find out in what way the shipyard is looking and perhaps influencing the ESG performance of both upstream and downstream stakeholders. How do they find the balance between these three aspects of sustainability (environment, social and governance)? Furthermore, they are an important stakeholder when it comes to connecting different parties with respect to the CE in the maritime industry. They posses experience and know-how with which they can devise new business models, aiding the CE.

2.8. Original Equipment Manufacturer

Product suppliers can increase their competitive advantage by embracing more measures to reduce their own impact on the environment. Product suppliers can also influence their upstream supply chain by choosing steel suppliers that show more effort in sustainability. The barriers for product suppliers arise from the considerations to be made when sourcing their supply of materials. Cost and impact of transportation

and customer demands need to be taken into account when making decisions about their upstream supply chain. Product suppliers are similar to the shipyards in the sense that they have to source the materials according to specs and manufacture the product according to the clients wishes. The difference is that they usually have their products ready to go on the shelf or their products can be ordered from a catalogue. The advantage for the original equipment manufacturer (OEM) is therefore that they are less dependent on clients wishes when it comes to selecting materials for building their products. Nonetheless they have to follow the market closely to stay competitive. Similar to the shipyard, it is interesting to find out in what way the shipyard is looking and perhaps influencing the ESG performance of both upstream and downstream stakeholders. How do they find the balance between these three aspects of sustainability (environment, social and governance).

2.9. Recycling yard

The recycling yards break up ships into waste streams. Scrap steel can reduce the emissions in producing steel products significantly. In this way, scrap steel is a valuable commodity and its value can be expected to rise over time, compared with virgin steel products as long as the same quality can be guaranteed. The potential for ship recycling yards is in improving their efficiency and their practices for quickly and safely dismantle ships. This includes collaboration up until the design phase where strategies can be determined and implemented to ensure more efficient ship breaking. The barriers for ship recycling yards include the market fluctuations for EOL ships and the tough competitiveness between yards geographically. Recycling yards are tasked with dismantling ships in a sustainable way. Yards, approved by the regulations according to the SRR have to find ways to be competitive with yards that do not work under the same regulations. Their competitiveness is an important subject of investigation. Signs are abundant that the steel scrap market is growing. More and more steel plants are built and converted with the EAF route, which uses steel scrap in its process. A growing market is a positive sign for the recycling yards but how do they see this market evolving? Is steel scrap becoming a valuable commodity?

2.10. NGO

NGOs play an important role in increasing awareness for issues that may not get a lot of attention otherwise. NGO's lobby for their issues to try to influence governments, companies, consumers, media and investors to change business practices and policies. NGOs related to this subject have potential to obtain more backing than before due to the shifting attitude towards sustainability. Therefore, they have a higher chance of achieving their goals. For example, the attention to improve ship breaking practices of SE Asian yards that still primarily use beaching, are highly significant to European and global regulators. The barriers the NGO's face are not specific to this subject but to the nature of their existence. NGOs are usually selectively tolerated guests and have limited leverage to enforce their findings or beliefs on business practices or policies, except for media pressure and moral persuasion. [4].

2.11. Government

Governments set the goals for the industry concerning sustainability and decarbonisation and, additionally influence the industry by implementing the applicable regulations. When sending out tenders for projects, government institutions have the moral obligation, if they back the SDG's in their policies, to take sustainability into account as a determining factor. Recycling is one of the key steps for the EU in achieving their flagship initiative a resource efficient Europe [83].

Concluding this chapter gives a number of barriers to the certification of recycled steel in the maritime industry. Different categories can be identified. Table 2.3 gives an overview of the barriers described in this chapter and categorises them under different topics. These topics will be discussed in Chapter 4.

This table shows that the certification for recycled materials touches on many different topics and it clearly becomes a multi-stakeholder problem to solve. Identifying these topics are the first step to find a fitting solution and to evaluate this solution afterwards. Four major categories can be identified, they are: 1) Sustainability and CE, 2) Steel or material production, 3) Steel market, and 4) Data and standardisation.

Stakeholders see the problem from their own point of view and therefore the importance or the weight of the different sustainability challenges is different depending on who is being asked. Table 2.3 will be used to evaluate the solution presented in Chapter 5.

Table 2.3: Barriers to certification of recycled steel

Topic	Sustainability challenges
Sustainability, ESG and CE	Lacking consumer interest and awareness
	Limited circular procurement
	Limited circular design
	Too few large-scale demonstration projects
Conservative character of the maritime industry	Hesitant company culture
	Operating in a linear system
Customer willingness to pay	
Regulations and policies	Obstructing laws and regulations
	Costing policies for carbon footprint
Demographic differences	
Enabling stakeholders	
Incentives and selling points	
Steel production	Scrap availability
Information about recycled content	Providing the percentage of recycled content would distort the market
	Control their scope 1, 2 and 3 emissions
	Energy supply is another major factor
	Fast Track LCA uses lookup tables
Greenwashing	Fast Track LCA uses lookup tables
Material sourcing and yard logistics	Labour intensive
	Global sourcing (low proximity between actors)
	Productivity and cost-efficiency
Implementation of certification	Complex and inefficient flow of information between actors
EOL phase	Cost associated and products are not designed for the EOL
	Ship recycling
Steel market	Low virgin material prices
	Scrap availability
Demand for recycled steel	Costing policies for carbon footprint
Green investments	High upfront investment costs
	Limited funding for circular business models
Contamination of scrap steel	Contamination of steel scrap by undesired tramp elements such as copper
	Ability to deliver high quality remanufactured products
Data and standardisation	Limited standardization
	Lack of data, e.g. on impacts
	Lack of global consensus
	Shortcomings of LEED regarding verifiable environmental outcomes
	Agree on common standards
Collaboration between stakeholders	Limited willingness to collaborate in the value chain
	Fragmented and project based nature of the industry
	Inefficient and fragmented flow of information
	Complex and inefficient flow of information between actors

3

Material Streams

Materials used in shipbuilding are ferrous metals, non-ferrous metals, plastics, wood and composites (polymer matrix reinforced with fibres).

In shipbuilding, there is no obligation to provide ship owners with a detailed breakdown of the material composition of the ship. Some weight estimates can be found in the stability manual, but, since the purpose of this manual is to provide the master with insight into the stability of the ship, no specific data of the different material components is provided. Furthermore, this is not a standardised document. The IMO says in paragraph 2.1.2 of its resolution MSC.75(69) [51]:

"Each ship should be provided with a stability booklet, approved by the Administration, * which contains sufficient information to enable the master to operate the ship in compliance with the applicable requirements contained in the Code. The Administration may have additional requirements. On a mobile offshore drilling unit, the stability booklet may be referred to as an operating manual. The stability booklet may include information on longitudinal strength. This Code addresses only the stability-related contents of the booklet."

Ships materials can be divided in the following material streams, table 3.1 according to the DNV study from Andersen et al. (2001)[46]

Table 3.1: Material streams, Source: Jain et al. (2015)[57]

Code	Material Streams
W01	Ferrous scrap
W02	Non-ferrous scrap
W03	Machinery
W04	Electrical and electronic equipment
W05	Minerals
W06	Plastics
W07	Liquids, chemicals and Gasses
W08	Joinery
W09	Miscellaneous

Jain et al. (2015)[57] made a methodology, based on the ship's stability manual, to estimate the material composition of EOL ships. The goal of this research was to create a tool for ship recycling yards to estimate the material composition more accurately. The authors proved that the material streams of a specific Handymax bulk carrier can be quantified with an accuracy of 88% by using the ships stability manual. They recommended, however, that detailed work breakdown structures having weights and centers, known to a shipyard in the design and building phase of a ship, should be preserved and kept on board during a ship's lifetime. Five of the most accurate of nine available studies on the material quantification of ships were

reviewed by Jain et al. (2015)[57] and are summarized in table 3.1 The weight losses, well over 10% in some of the studies, are caused by margin errors or misdeclarations. From these studies it can be seen that the largest material streams consist of ferrous scrap (64.5-85%) and machinery (6-19%).

Steel products used in shipbuilding are, amongst others, plates, hot rolled coil, pickled hot rolled coil, engineering steel [95]. These products are fabricated predominantly by two process routes, the basic oxygen furnace and the electric arc furnace route (BOF and EAF routes respectively). The integrated steelmaking route, which combines iron ore, coal, limestone, and recycled steel as raw materials, is based on the blast furnace (BF) and basic oxygen furnace (BOF), see figure 3.1. To make 1,000 kg of crude steel, this route uses an average of 1,370 kg of iron ore, 780 kg of metallurgical coal, 270 kg of limestone, and 125 kg of recycled steel. The electric arc furnace (EAF) route, see figure 3.2 uses primarily recycled steels and direct reduced iron (DRI) or hot metal, and electricity. On average, the recycled steel-EAF route uses 710 kg of recycled steel 586 kg of iron ore, 150 kg of coal and 88 kg of limestone and 2.3 GJ of electricity, to produce 1,000 kg of crude steel.

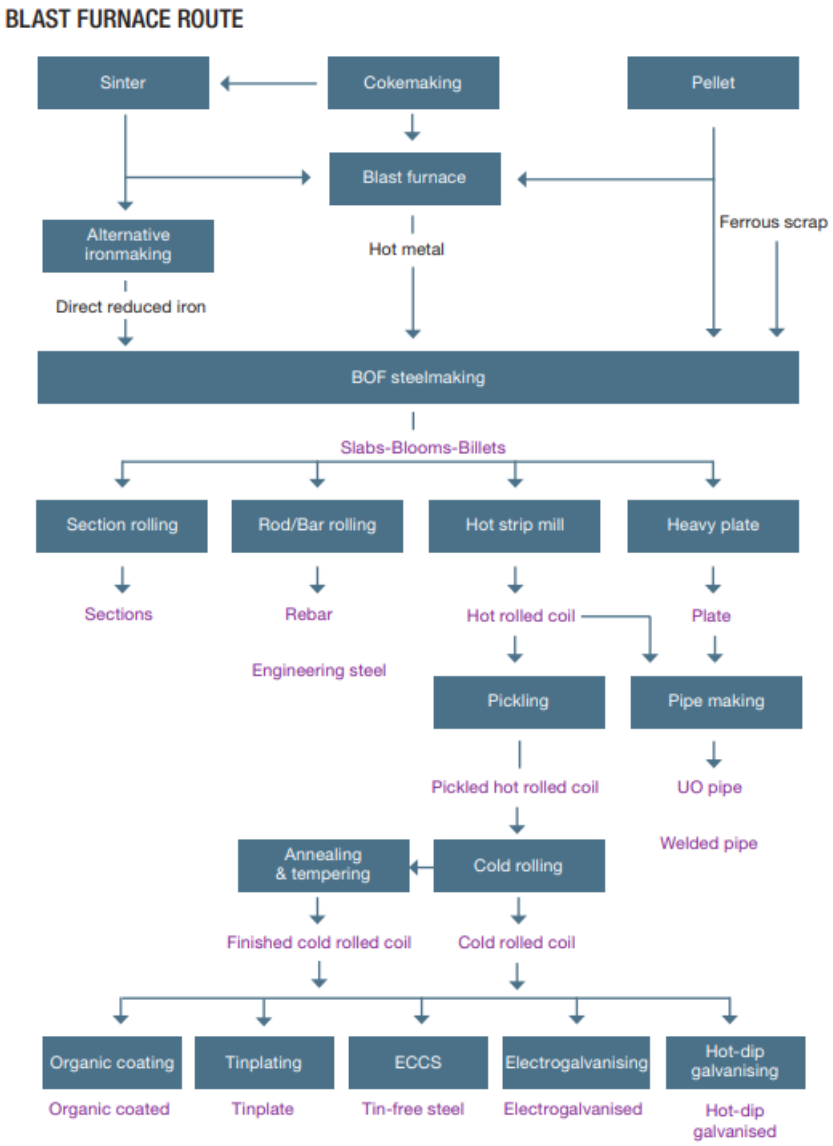

Figure 3.1: Blast Furnace Route [94]

To Decarbonise the steel industry, there are three possible routes: 1) Decarbonise primary steel production, 2) Increase the use of Scrap-based steel production and 3) Increase steel use efficiency.

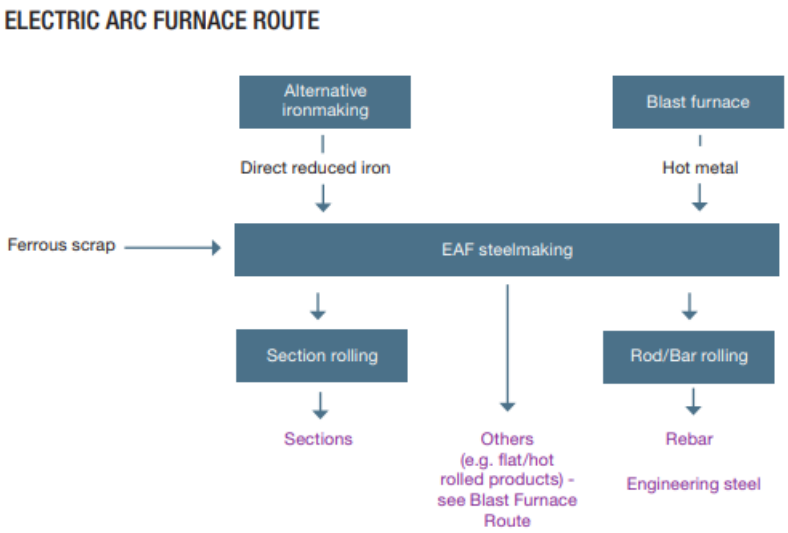

Figure 3.2: Electric Arc Furnace Route [94]

Upgrading the BOF route is possible so it can take up 30% to 50% of scrap steel [92]. According to a study from McKinsey [67] [33] the route with BOF using DRI and green H2 is a viable option for the future. Currently the prices for H2 are high but once the production can be scaled up it this will drop over time, see figure 3.3.

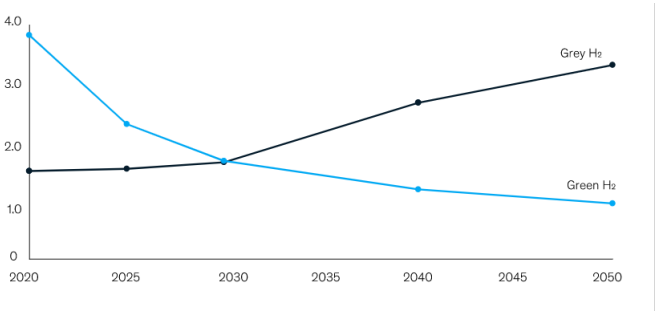

Figure 3.3: H2 price development, Germany, EUR/kg H2 [33]

The conclusion from this chapter is that the technological innovations for steel making are being developed as we speak. In the future the two major production routes BOF and EAF will still exist with the necessary adaptations to become more sustainable. Due to the high capital cost of steel production plants it will take a number of years before a new innovations will take over as the prime production method. The availability of scrap is another issue that will prevent the worlds steel production to completely jump to EAF. Green H2 is promising source of energy for carbonfree steel production but it will take time to scale up the H2 production so it becomes a viable alternative to current energy sources. In the meantime, while all the new innovations are being developed, sustainability improvements could possibly be achieved by picking the low hanging fruit. Certification of recycled materials is a possible incentive for companies to improve their carbon footprint.

4

Interview Results

To investigate the challenges and opportunities associated with the use of recycled steel in ship building and the certification of such recycled steel products, in-depth semi-structured interviews were held with key industry stakeholders. Since the literature on this subject is limited, the interviews offered the combination of breadth and depth into the subject. In this way primary data was collected which provided valuable insights into the beliefs of the interviewees. The semi-structured interviews allowed for key topics to be covered as well as topics more specifically related to the field of expertise of the interviewee. The key topics included in the interviews are: 1) the interviewee's definition of CSR, CE sustainability and ESG, 2) opportunities and barriers to the use of recycled steel in ship building, 3) possible support mechanisms for certification of recycled steel. The choice of interviewees is based on the stakeholder identification in Chapter 2. Table 4.1 gives an overview of all the stakeholders chosen for the interviews, including the contact persons. The questions were open so the interviewees had the opportunity to elaborate on the matter and follow-up questions were possible. This setting allowed for a more detailed view of the experts on the matters at hand. Questionnaires differ for the different stakeholders based on their field of expertise. Questionnaires were provided to the stakeholders well in advance of the interview and the interview procedure and data processing is in accordance with the GDPR (General Data Protection Regulation) guidelines. The first part of the questionnaires is the same for all stakeholders. After a short introduction about the subject, in which is stated that all questions are asked with respect to the maritime industry, they are asked about their perception of CSR, CE and ESG and what it means to them or to their specific part of the maritime industry. The rest of the interview is tailored to their specific field of work and area of expertise. The questionnaires (see Appendix A) represent the questions that have been used to give structure to the interviews. The questionnaires are dependent on the stakeholders. The full transcripts of the interviews can be found in Appendix B. In these transcripts the questions are printed in bold with David (my name) given as the interviewer. The company names are stated as the replier since the interviewees presented the views of the company for which they work for. Whenever they presented personal views, this was explicitly stated.

The subject of this research is of confidential matter. The goal of this research is to provide an answer to whether the classification society Bureau Veritas should pursue the development of a new class notation regarding the use of recycled steel. Since the idea originated with Mr. Rik De Petter and to maintain competitive edge, the choice of interviewees was discussed together with Bureau Veritas. Most of the interviewees are customers of Bureau Veritas, and were approached by using the network of Rik De Petter. The two stakeholders, representing financial institutions, were approached through the network of my promoter Jeroen Pruyn and EDR Antwerp Shipyard was approached through my own network. All interviewees were eager to share their view and expert opinion on the matter. Only one shipyard and one financial institution refrained from participating with the interview. The shipyard in question stated that they themselves are working on similar projects and argued that the questions asked, were touching on matters that they preferred not to share with outsiders. Although this interview did not happen, the reason for not accepting is only showing the state of the art character of this subject.

Table 4.1: list of interviewees

Stakeholder	Company
Financial institution	ABN AMRO
	Nesec
Shipping company/B2B	Compagnie Maritime Belgique
	DEME
	Jan De Nul
Steel factory	Arcelor Mittal
Shipyard	Damen
	EDR Antwerp Shipyard
Original Equipment Manufacturer	ABC Engines
Recycling yard	Galloo

Each stakeholder was presented with a concept version of the solution in advance of the conversation. The solution is presented in more detail in chapter 5. The concept was explained as follows:

"The idea is to come up with a new class notation that specifies the amount of recycled steel used in the building process of a ship or maritime construction. It will be divided into two parts being hull and machinery. The machinery part consists of specific components and can easily be accounted for. The hull part is the difficult part and the traceability is the main barrier here. It is the aim of this research to find out what this innovation means for the different stakeholders in terms of possible advantage or disadvantage and in terms of feasibility."

The first step of processing the interviews consisted of writing out the full transcripts. Most of the interviews were held in Dutch so they also had to be translated into English when transcribing them. Next the transcripts have been coded to structure the different opinions and insights of the expert views. A summary of the interviews and of the lessons learned is given next in this chapter.

The dynamic of this innovation can be seen in the figure 4.1. This new class notation is not using any new technology. It creates new opportunities over the value chain of ship building by providing or making information accessible between stakeholders. This information is valuable in the current sustainability climate. Therefore, it is seen as a technology push towards a commercial product. The market pull is in play as well, but far less important in this innovation. The market pull exists in the way that there is a hunger in the market for innovative measures that can reduce emissions in any way at every stage of the value chain or increase efforts for more sustainability in those stages. The process from idea generation to commercial product is of course similar as other innovation developments. The development of the idea, feasibility study and marketing and sales all need to be thoroughly investigated for a successful implementation of the new innovation.

Next the discussion follows with the views of all stakeholders that were interviewed. The discussion is structured according to the topics presented in table 2.3 in chapter 2.

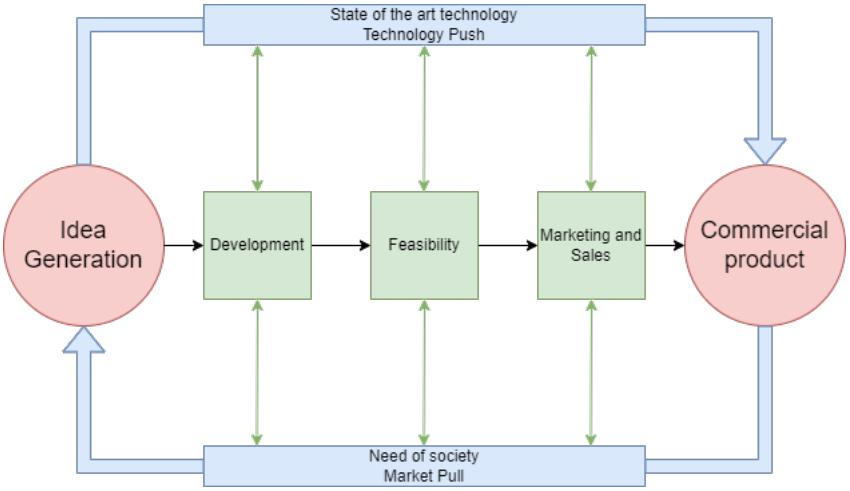

Figure 4.1: innovation market relation

4.1. Sustainability, ESG and CE

Awareness for sustainability, ESG and CE was present with all interviewees. The implementation in their own field of work differed. Shipping companies were well underway in incorporating sustainability into their corporate strategies and were busy with turning sustainability in active working programs based on the SDG's. On the subject of becoming green, both shipping companies saw the value, have the feel they need to be frontrunners and certainly do not want to miss out when sustainability has become part of daily operations. When presented with the option to choose for ship made with recycled steel, they would take it into consideration if their customer would pay for it. They both saw the added value for such a ship when responding to public tenders. The competitive advantage would be a significant.

One shipping company makes the interesting comparison with the implementation of safety standards. At the time it was time consuming and companies had to make big investments. Safety culture was difficult to implement with workers. But now it is well implemented and has become a second nature in all companies. They expect the same to happen with sustainability. Lack of standards and a transparent scoring and evaluation scheme is an issue at the moment.

The ship repair yard thinks the sustainable incentive will become very important very soon. the goals set by Europe are very ambitious and the deadline will be closing in fast.

The OEM (engine manufacturer) tries to buy back their old engines. They remelt the cast iron part (80%) and sent remaining steel parts for recycling. This, however, was decided due to external factors like material shortages and cost reduction. In terms of sustainability they are active in developing new engines for alternative fuels. They look into the SDG's of their customers and work only with European suppliers to have less transport cost.

For sustainability purposes the EAF route is gaining popularity amongst steel producers. New innovations and modifications are investigated to also reduce the carbon footprint of the BOF route.

The steel manufacturer feels that the way forward is to make primary steel production more sustainable since there will always be a need for primary steel.

Next to looking at improving their own processes in terms of ESG, the shipyard is also looking into providing information about the circularity of their products. New business models are even investigated like leasing constructions so the yard keeps ownership and can better track what happens with the vessel or buying back the ship at EOL stage to better control the circularity. During the design phase more integration of the circularity principles are incorporated such as reuse of materials, standardisation, design for EOL. Also when choosing suppliers they try to incorporate circularity into the decision making process.

The breaking yard works on highly accurate recycling and sorting to keep their wast as low as possible. This does not necessarily create more income. However, in the scrap market the economical aspect is still very dominant over the ecological.

One financial institution is part of the Poseidon Principles. They feel this is a good initiative because it is based on actual measurements and it creates awareness for the maritime industry. It is used for keeping track of the greenhouse gases of ships and fleets during their use phase.

For the financial sector, sustainability risks have only become more important over the last few years. On the short term the focus is mainly about the energy transition. For the long term one financial institution mention they are putting their entire portfolio through a climate stress test.

4.2. Conservative character of the maritime industry

One shipping company agrees with the fact that the maritime industry is conservative. This gives us even more incentive that we need to correct data and facts to increase the awareness for sustainability practices. To change this around we need first movers, companies that are not afraid to make statements like this.

One financial institution agrees to the conservative character of the industry and expects the major change to come from companies at the consumer side that are gaining more information about the entire product supply chain.

4.3. Customer willingness to pay

The OEM believes customers are not ready to accept a big increase in cost solely for environmental reasons.

The shipyard does not believe customers are willing to pay more for sustainability at this moment. This could change when CO2 costs are increasing.

One financial institution does believe customers would be willing to pay more, but not too much, if it's being sold with the right arguments.

4.4. Regulations and policies

The views on policy differs substantially depending on who is being asked. It is clear that concerning the evaluation of greening efforts of companies there is still no consensus. One company likes the CO2 performance ladder, the other finds it too complex and misses the comparative aspect of such a policy. According to the first shipping company, this CO2 performance ladder creates a level playing field and incentivises companies to increase their efforts in reducing their carbon footprint. Only it is often not possible to influence our scope 3 emissions since we don't have design responsibilities for those.

Both shipping companies and the repair yard see the possibility for the national or European subsidy to support the use of recycled steel, similar to the subsidy for the renewable energy (wind) sector.

One shipping company also expects policies obligating some percentage of recycle steel content.

Government interventions are welcomed by the OEM as long as the policies have a positive impact, are easy to interpret and do not pose a competitive disadvantage on the global scale.

The ship break yard does not see the positive effects of the SRR they anticipated. They say that still 80% of European tonnage to be scrapped, was still illegally scrapped in South-East Asia. It is a good policy measure but the enforcement is the responsibility of the member states, so if they don't feel the necessity to act on breaches then the policy has limited results in the end. Generally, breaking yards in South East Asia offer 4 times more than European yards. Europe also has plans for an export ban of scrap steel but this has been delayed for three years. Such a policy would significantly reduce their export market and the breaking yard does not see this as a good evolution for the industry.

One financial institution prefers a uniform, clear and general approach from the EU on the matter of sustainability.

4.5. Demographic differences

The breaking yard feels that there is a big difference between North and South European countries when it comes to sustainability and recycling. Scandinavian countries are far ahead. Southern countries do not have this mindset yet and are also not forced to do so by the EU.

One financial institution sees the difference in taking up responsibility regarding sustainability. North-West European companies will proactively pick up new innovations to improve sustainability. Southern countries will be much more conservative and reluctant to change.

4.6. Enabling stakeholders

One shipping company sees an important front running role for themselves in this matter by creating a strong vision as a company. They believe this will also lead to a competitive advantage. Governments are usually late to the party but once they embrace innovations their policies can increase the speed of the implementation.

The OEM believes the financial sector plays an important role and can be an enabler by providing financing for greener projects.

The shipyards finds it is the responsibility of the client in the end to choose which vessel they buy. They also agree that financial institutions have the ability the influence how green shipping will become by giving better loans for greener projects. Governments in their turn have to provide a framework.

One financial institution does not see it as its responsibility to force shipping companies to improve on their sustainability. They feel this is the responsibility of the shipping company and if we. the society as a whole, decide this should change, we need to transform this into regulations.

4.7. Incentives and selling points

One shipping company mentions that clear, and tangible information is needed to make the recycled content certification economical. This can be for example the proven reduction in CO2 emissions due to the use of recycled steel. The other shipping company says that sustainable collaborations with stakeholders leading to more innovations are equally important than just CO2 reduction.

The ship repair yard would have no interest in buying this kind of steel, unless it is a specific demand form their customer. they also don't think shipowners would be interested in new ships with recycled steel content at the moment, perhaps if there would be some kind of a subsidy.

The OEM says their incentives are client dependant. If the client asks for recycled engines, they will provide. They do not initiate the process. So far they have not noticed their clients were interested in the recycled content of the engines as a selling point. They hope they can gain commercial advantage from this in the near future.

The OEM thinks that the information about recycled parts is very valuable for its customers. This information can be used to increase their chances to receive financing due to the greenness of the projects.

The steel manufacturer is already offering certified energy mixes to their customers. This is the selling point for offering carbon neutral products.

The shipyard sees a big increase in the interest of their clients into sustainability so they feel that information about the circularity of the vessels is an excellent selling point. The recycled content would be a competitive advantage and they are also trying to monitor the EOL phase.

Due to the low financial risk, one financial institution sees potential in the innovation that would track and trace the use of recycled steel in maritime projects.

4.8. Steel production

The steel manufacturer acknowledges the two major routes BOF and EAF and confirms EAF can be fed with 100% scrap steel. This route can also be fed with DRI. Most EAF routes also use 100% scrap steel worldwide.

Steel manufacturers are developing the concept that uses green hydrogen and DRI. This method can be used for the BOF route. This process would be completely CO2 free and only produces water as a by product.

4.9. Information about recycled content

The information about the use of recycled steel could have a substantial impact according to one shipping company. They were under the impression that it is not offered by steel producers because it would be a quality issue. Presenting windmill parks for example, that are made with recycled steel would have a huge potential from a sustainability perspective. If it is proven and certified by a third party we want this information. Tenders in different countries already demand efforts into sustainability, these will have to become quantifiable so this information would surely help.

The other shipping company noted that they were already looking into the recycled steel content but so far were not able to get the exact data, so they report conservative data. They too see this information as an untapped potential and could refine their scope 3 reporting if the data would be available. Because of

these scope 3 emissions and 70% of our bought goods our steel products,it matters that we know whether it is recycled steel or not. Also buying this steel from European suppliers makes a difference.

The ship repair yard said the recycled content is not mentioned because it is not in the interest of the steel producers. This would result in an unwanted price differentiation. They will only do this if everybody in the market starts demanding for this.

The OEM does not know their own advantage in terms of reduced CO2 emissions due to their recycling business model. If we can prove this with a clear and transparent calculation we could benefit from it, now that CO2 taxes are introduced everywhere. We do know the exact data from our own foundries.

Historically the steel manufacturers have not seen the benefit for sharing the recycled content of steel products. On the contrary they even expected it to have a negative effect on their business. When two different routes produce the same product it is in the interest of the steel producer to keep the prices equal, no matter which route is being used. These days however, they see the increase in interest sustainability from their customers and that carbon footprint is becoming a very important issue. When making steel from steel scrap, the steelmakers can accurately state 97% of the steel is recycled content. This could be clearly checked and this would happen based on weight inputs and weight outputs. To order steel with a specified recycled content is tricky. EAF is already 100%. They do feel that they would have to accommodate this if the market asks for it. This one steel maker has one BOF plant producing steel plates for ship building and it uses about 20% of scrap steel. The shipyard confirms that steel makers are not given the recycled content data even when they ask for it, they only manage to receive an estimation.

4.10. Greenwashing

The shipyard is mitigating this risk in both reporting and sourcing.

Financial sectors are verifying their data though the use of classification societies. One financial institution believes in general most companies are aware of their moral responsibility. Public opinion these days are on top of things and expose greenwashing quickly. That being said, they do feel the necessity for classification societies to independently certify projects using recycled steel. It needs to be proven and verified to be able to get financing for this purpose.

4.11. Material sourcing and yard logistics

Yards source their steel from different yards for logistical and financial reasons.

One financial institution mentions the sourcing part and the impact on sourcing is high on the agenda for many companies. This creates opportunities for the use and the tracing of recycled steel.

The ship repair yard sees logistical issues in working with recycled steel for logistical reasons. In their business model they keep a large amount of steel in stock in different grades. It will be very costly (activa and space at the yard) to keep extra steel on stock that meets the recycled content requirement for each of the different grades. The ship repair yard mentioned they had about 73 different types of steel on stock.

Depending on the yard, the shipyard orders steel per project and keeps the different grades separated, both physically as documentation.

The breaking yard currently is sorting 260 different steel grades. This is highly accurate sorting. Better sorting leads to less waste end they can sell more material overall. The car industry currently also recycles 92-93% of their cars.

4.12. Implementation of certification

The shipyard says its possible through the use of CAD programs to determine accurately the amount of recycled steel if this information is used as input in the CAD program.Full inventory lists should then also be available. The intention is there to know the recycled content of all materials used on board. They already have the ships' material breakdown and can evaluate the recycleability of the ship but it is not yet possible to see what materials are virgin and non-virgin.

4.13. EOL phase

One shipping company mentions that they want to know where and how their ships end up at their end of life. It is important that this happens according to the regulations. To know that the circle is closed does not lead to an economical advantage, it would be nice selling story though.

The break yard says that reasons for scrapping are also due the shipping market cycle and in some cases even to protect technology.

One financial institution mentions customers are not looking into the EOL phase of a ship when ordering new built ships.

4.14. Steel market

One shipping company expects recycled steel products to be more expensive at first but the CO2 emissions are getting more expensive as well so at first recycled products will be more expensive, the market mechanisms will take over and eventually recycled products will be cheaper when it has become the norm.

The repair yard expects that recycled steel should be cheaper since the cost to produce is less and therefore the customers would expect a cheaper price. This is why they refuse to disclose the information about the recycled steel content.

There is enough scrap available but it follows the market rules. If iron ore goes up, so does scrap steel and vice versa. There is no price differentiation between different products. This could change when CO2 quota's become more important and expensive.

The break yard says it is a volatile market and it is difficult to predict the price for scrap when they buy a ship for scrapping.

4.15. Demand for recycled steel

The steel manufacturer currently does not see specific demand for recycled steel, but they do see demand for products with a low carbon footprint. To this demand they are responding with offering of energy mixes from renewable sources. Their point of view is not to focus too much on recycling but on the entire process including the energy mix and new innovations. It will be possible in the future to produce primary steel with almost no CO2 emissions, even without the use of recycled steel.

The breaking yard mentions the demand for scrap steel is following the demand for steel, so it is very high at the moment. Most of it comes from household scrap and regular scrapyards.

One financial institution has no knowledge of any customers demanding ships with a recycled steel content. If it would prove to reduce the CO2, this would be an important innovation. The demand for recycled steel would be part of our acceptance criteria. This handles the materials used. As financiers they would preferably not be the one obligated to push customers for using recycled steel. They do see the possibility of such a demand starting from the customers after which it would start moving upstream to the steel manufacturers. They don't see an immediate benefit for the financial sector. From a moral point of view they do feel the need to work in a sustainable manor and using recycled steel for new built projects could be an aspect of sustainable practices.

4.16. Green investments

One shipping company is aware of increased interest from financial institutions looking for green investment possibilities. If you can prove it is a sustainable and green investment the loans are better and the demand for these investments is high.

The other shipping company agree the financial sector should be providing better loans for green projects.

The OEM mentions the financial sector demanding more effort into SDG in return for financing of projects.

One financial institution says the European Central Bank is incorporating sustainability risks into credit risks. More capital becomes available for financing projects with a sustainable character. When evaluating a project for financing this institution first looks at the business and financial risks. Secondly the sustainability risks are evaluated. The other financial institution says this advantage is low and some companies are focused on providing loans specifically for green projects. Subsidies can probably be found and if its a

project that is green and also saving money then you already need less financing. They also mention the shift if the kind of assets that get financing. These assets are becoming increasingly younger, just like in the aircraft industry. The older models have the risk that they will not comply with rapidly changing sustainability standards.

4.17. Contamination of scrap steel

The ship repair yard mentioned that the steel from ships (due to repair or EOL) is regarded by the steel scrap collecting industry as high grade steel with low contamination. This is acknowledged by the breaking yard. Their steel scrap is mostly sold within Europe. Lesser quality scrap is exported to Egypt and Turkey for example.

The OEM sees downgrading in the recycling process so they feel they have too improve on their collection process.

Looking at the production of steel contaminants are worse for very thin products like sheet metal, used in the car industry. This highly accurate products need to be made in the BOF and this is also the reason why, at least until now, there will always be the need to make primary steel. For ship building it is possible to use scrap steel and the EAF route.

The shipyard believes that in order to be sure of the high quality of the steel products, it has to be primary steel.

The allowed scrap contamination percentages for the European market is 0% and for the export market 1%. The cost to achieve this difference is covered by the price.

4.18. Data and standardisation, collaboration between stakeholders

One shipping company acknowledges that there is no common standard in the industry. This creates an uneven level playing field. However this doesn't mean we need to refrain from raising the bar. Eventually it will pay off to be the front runner. Parallel with the safety standards, cost were high at first but later companies saw that the saved costs by less accidents were even higher.

The other shipping company agrees there are as of yet no common conventions and standards. This needs to change since there is only going to be more collaboration in this sector on a global scale.

The ship repair yard states that only a few companies or ships provide them with clear documentation (3D drawings, digital or hard copy). Since ships have no servers, the files often get lost. To be provided with clear documentation would definitely have a positive effect on the planning of the repairs and the downtime. we manage always but sometimes this creates unnecessary delays.

The shipyard doesn't want to know the CO2 emissions related to the production of steel, they are more interested into the recycled content for the circularity. This because of less natural resources then need to be depleted. When asked about the scope 3 emissions the shipyard mentions that they like to source their steel locally to reduce transport emissions. However, it is possible that local steel producers use less renewable energy than producers that are further away. It is a trade off that has to be made. Engaging suppliers worldwide is a difficult task due to lack of standardisation and cultural differences. They see the lack of transparency between stakeholders as the biggest barrier. The mindset is not yet changed with all suppliers. The shipyard tries to influence this mindset and also is implementing a platform to make this transparency easier between all stakeholders from their supply chain.

The break yard sees no benefit in a full materials inventory list. The IHM is important for safety.

The breaking yard does not see the benefit of design for reuse or remanufacture. It is too costly to break a ship down the way it has been build. Their way of working is to literally turn a ship into a pile of scrap in a safe but fast way and then sort this scrap. Due to quality issues and the fact that pats are getting outdated very fast they also do not see any demand for reusing of ship parts. Here also the mindset is clearly not there yet.

One financial institution warns that true impact will only be achieved if the current outdated fleet at any point in time also gets retrofitted to meet the new standards.

After reviewing all the answers from the different stakeholders it can be concluded that all stakeholders are aware of the need for increased efforts towards a more sustainable maritime industry in all phases of the value chain. Common census is that the way towards this common goal should be more standardised. No

stakeholder is able to carry the burden alone so collaboration is key. Mixed views exists mainly on the question to which stakeholder is the enabling player along the value chain. These mixed views are also found towards the rile of governments and corresponding regulations. The technological feasibility of the certification of recycled materials is not seen as an issue to most of the stakeholders. In the next chapter these views, together with the identified challenges, will blend towards a model for a new certification of recycled materials and a certification for CE concept.

5

Solution Certification Procedure

The aim of this chapter is to present a new class notation for the use of recycled steel in shipbuilding. Based on the barrier identification and the discussion resulting from the interviews, the requirements for a class notation that certifies the use of recycled steel have become clear. These requirements can be divided in variables that form three pillars. These three pillars present the barriers to a feasible certification concept. The variables are: 1) There must be a demand for sustainable innovations, 2) this innovation must be economically and logistically feasible and 3) the supply of (in this case recycled steel) has to be possible. Figure 5.1 shows these three pillars with respect to the feasibility course. This problem can best be reviewed

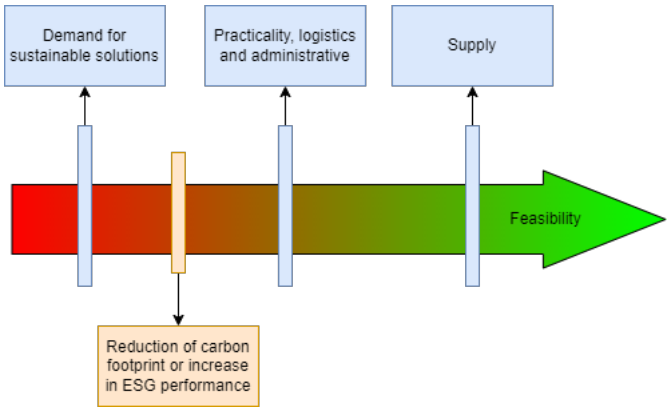

Figure 5.1: Feasibility diagram for a new Certification

starting from the demand side. The demand side consists of the shipping companies and shipowners. They are forced to comply with new climate change mitigation measures set by governments to reach climate goals by 2050. These goals are predominantly measured or looked at in terms of carbon footprint. Increased public opinion forces companies to review their business practices and be more transparent by reporting their ESG for example. As stated in chapter **??**, many companies have opted to relate their company policies to the SDG's. So the demand pillar focuses on whether a new certification procedure can benefit the company in this way. It has to be noted that there is no direct demand for this new class notation. This notation, however, does provide an opportunity for companies to increase their efforts in becoming more sustainable. This will increase their competitive place in the market and help meet their sustainability obligation in society. Currently the trend is to watch the entire life cycle of the products or services. This means that the entire value chain is looked at. It is therefore important to reduce the carbon footprint of a companies' own activities, but additionally, it is important to map the ESG performances of stakeholders both upstream and downstream. The more transparent this entire chain becomes, the more benefit a company will see in terms of public appreciation. The hurdle for companies to proactively search for innovations to increase their ESG performance is the lack of direct financial returns. This, however, is counteracted when for example government tenders take into account 'greening' measures. Companies that

are willing to invest now into reducing their scope 1, 2 and 3 emissions will benefit over the long term. Scope 1, 2 and 3 are explained in table 5.1 and figure 1.4.

Table 5.1: Scope 1, 2 and 3

Scope 1 emissions	Emissions related to use phase
Scope 2 emissions	Emissions originating from energy supplier
Scope 3 emissions	Emissions related to downstream and upstream stakeholders

Summarising, the demand side is mainly driven by government, financial institutions and public opinion. Once it is acknowledged that there is a demand and an advantage for innovations that reduce carbon footprint or increase the ESG performance in any way, it is key to prove how a new certification of recycled materials can reduce carbon footprint or increase ESG performance. The reduction in carbon footprint is investigated by a fast track LCA and the increase in ESG performance is checked with professionals representing the different stakeholders. This way, the purpose of the class notation is validated. Once this is done the next pillar comes into play. This pillar is about the logistical practicality of implementing a new certification method. Where in the process are there going to be changes to the process? Which information needs to be acquired by which stakeholders? How is the ship building process logistically influenced and is this practically feasible? Stakeholders involved in this pillar are the material manufacturers, both steel manufacturers and original product manufacturers, using steel. The shipyards, classification societies and shipowners, shipping companies are also involved. Next to the logistical process the administrative process needs to be looked at. An increase in paperwork creates an increase in resources spent. All aspects need to be taken into account and related to the benefits a new certification for recycled materials can create. If there is a demand, there is no doubt that the supply, if feasible, will follow. Some stakeholders will benefit more than others to fulfill this demand. It is key to pinpoint where the increased value can be found in the value chain. With an increased cooperation and an increased interest in the entire life cycle of products and services, stakeholders should be able to see and negotiate where the common interests lay in embracing a new innovation. If logistics and processes do not pose a showstopping barrier for the implementation of this new certification procedure, the last pillar that needs to be checked is the one representing the supply side. To be able to recycle materials, there needs to be an abundant supply of scrap materials that can be recycled. If this is not the case the economic viability will quickly evaporate as the price for scarce goods will rise. When all barriers (or pillars) are investigated and solutions are presented to counteract the barriers, the feasibility is proven. Steel is chosen for this investigation since it is dominantly present in shipbuilding these days. This can be seen as the beach head innovation, paving the way for similar implementations of certifications for other ferrous and non-ferrous materials, wood, plastics and composite materials. The final goal is to be able the provide an overall certificate showing the overall circularity of a ship. To increase the circularity in the maritime industry, transparency over the lifetime of the ship needs to be increased. Improved collaboration can benefit multiple stakeholders along the value chain. Improved collaboration also means finding new ways for data sharing in an efficient way.

The road to more circularity in shipbuilding requires a change in mindset by the different stakeholders that are part of the shipbuilding process. This road to a more circular maritime industry is a logical step in the current societal evolution where all industries are obliged to become more sustainable. As described in the first chapter, actions can be, and are already, taken in different phases of the building process. Certification for ships, that are built with recycled steel, is an innovation aimed at creating more opportunities for stakeholders in the entire value chain. The stakeholders are influenced differently or see different benefits or barriers from such a certification. Since the value chain consists of many stakeholders with intricate dependencies, first the entire process is mapped. From this top-view approach, it is possible to zoom in to the stakeholders level or the entities level. This overview can be seen in figure 5.2 and shows the current related certification documents. The relevant existing certification documents for steel products and processes related to this investigation are given in table 5.2. Stakeholders are depicted in green, entities in blue and certificates in red. Black arrows show the relations between the nodes.

Table 5.2: Relevant Certification documents

Document nr	Document title
NR266	Requirements for Survey of Materials and Equipment for the Classification of Ships and Offshore Units
NR320	Certification Scheme of Materials and Equipment for the Classification of Marine Units
NR480	Approval of the Manufacturing Process of Metallic Materials
NR216	Rules on Materials and Welding for the Classification of Marine Units
NR528	Green Passport

Certifications connected to the stakeholders are about the processes that relate to the use or production of recycled steel. This graph, however, does not show the different processes in a time frame. Figure 5.3 Shows the adjusted relations with the new certification documents. These new certifications will help prove the circularity of a maritime structure. They are the result of the challenges found in the literature together with the insights provided by the stakeholders during the interviews. How these certifications provide a solutions is described later in this chapter per stakholder by the STAR method.

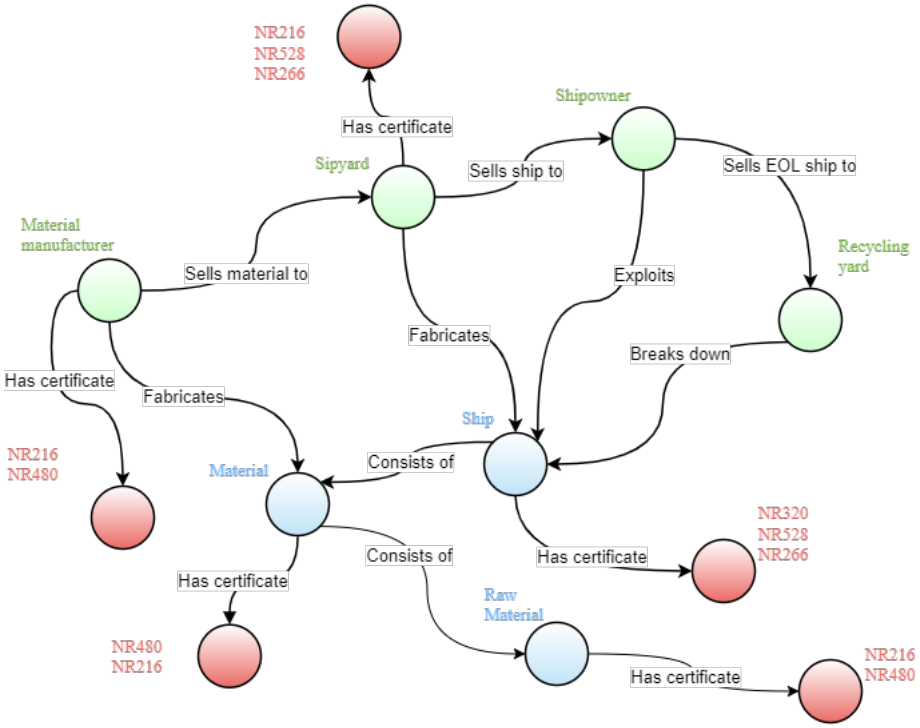

Figure 5.2: Process Diagram Current Certifications

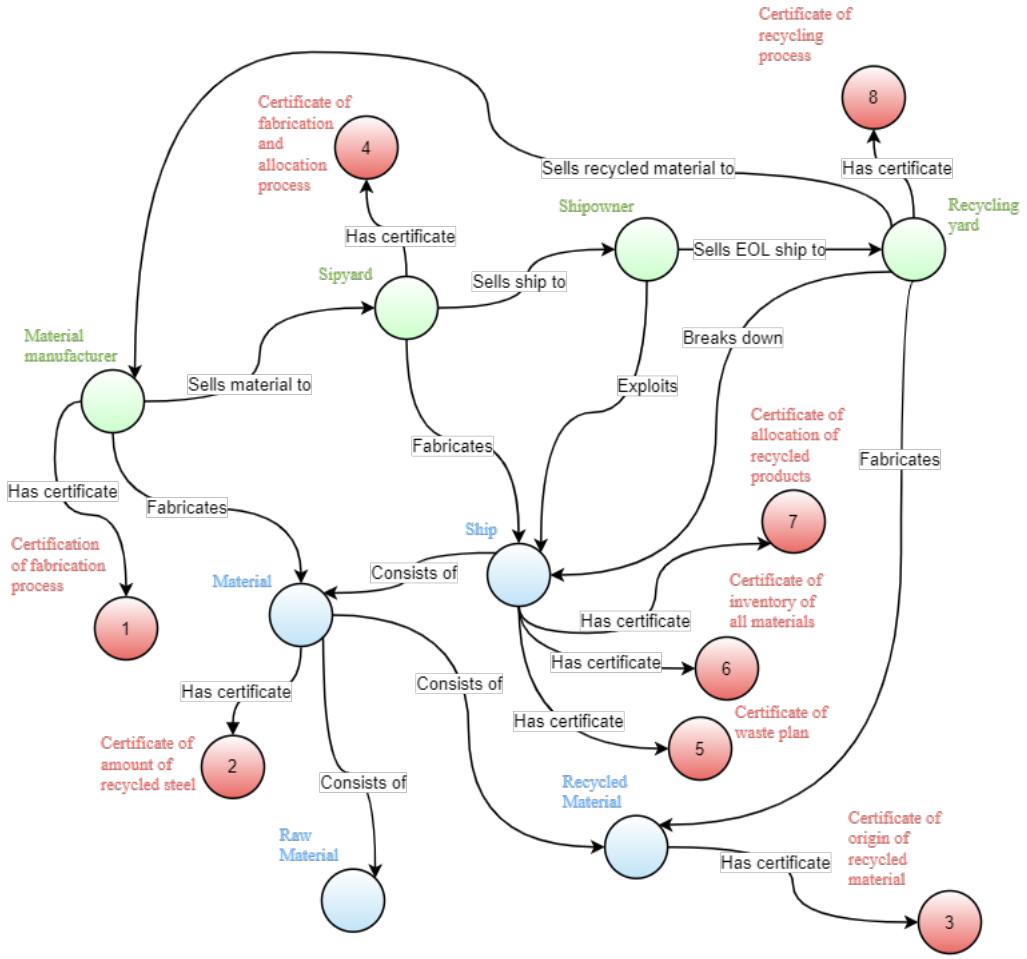

Figure 5.3: Process Diagram New Certifications

Figure 5.4 is a representation of the complete new procedure which corresponds with the life cycle of a ship. The red arrows represent the flow of entities (material, parts or ship). This figure also represents the exact solution for the scope of this new class notation. The flow of entities is what needs to be traced. Along this trace, the green hexagons depict the documents. These documents are the certifications, these represent the output of the class notation. These documents can be used separately at each step, creating value for the involved stakeholders at these steps. However, when combined, all these documents improve the circularity of the ship over its life cycle. This circularity is focused on the building materials, in this case steel. Increased transparency by the different stakeholders, depicted in the blue rectangles, about their processes, results in scope 1, 2 and 3 emission information. This adds more data about the ships carbon footprint. Finally, the information about the use phase of the ship can be added (not in the scope of this research). Now all the data is present to assess the sustainability of a ship or maritime structure. What is described here above is a hierarchical structure how to improve or which steps lead to more sustainability.

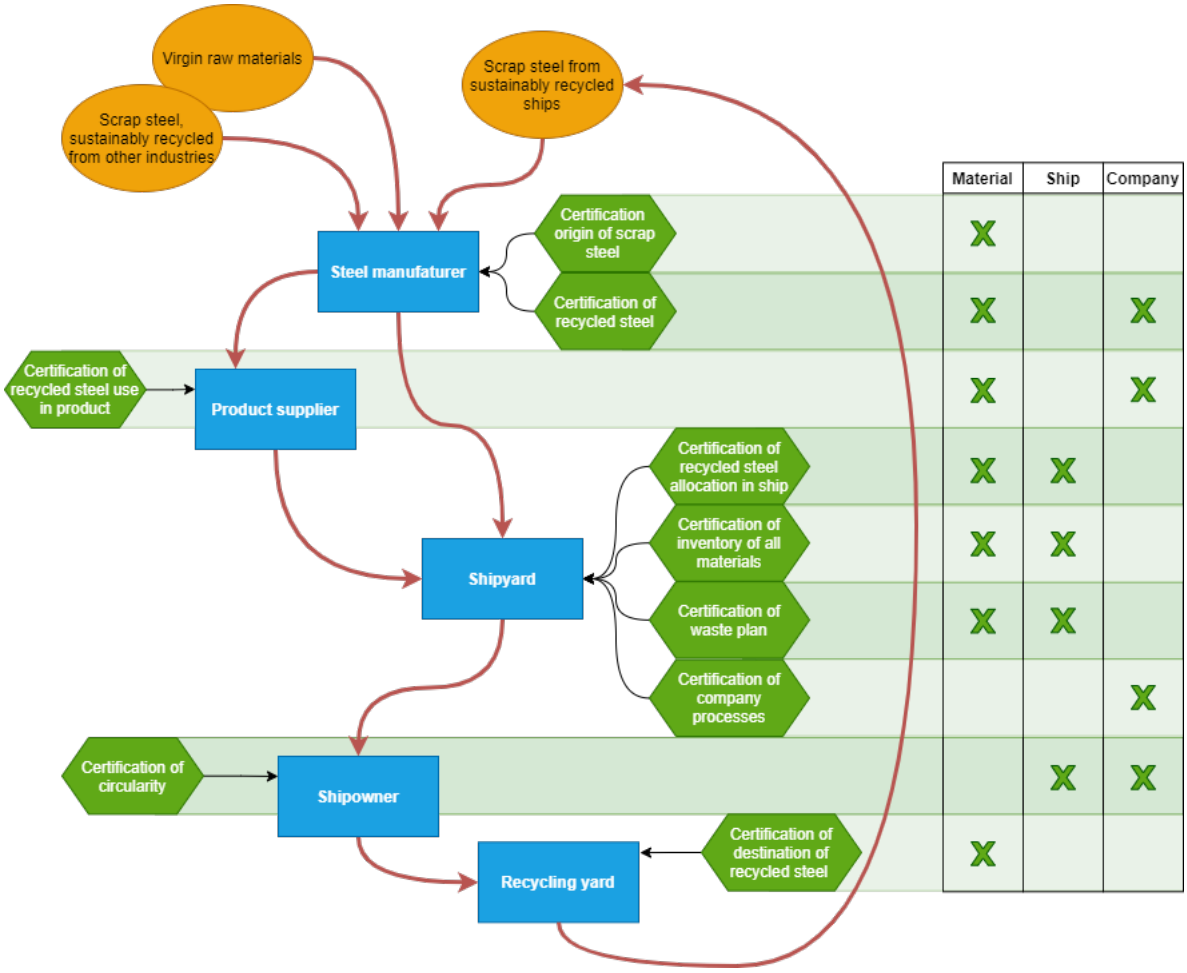

Figure 5.4: New certification possibilities related to the LCA of a ship

Figure 5.5 shows the relations between the new proposed certification documents. To which stakeholder in the process they are issued, and to what they refer, is shown as well. On the certification documentation, the process used by the steel manufacturer should be stated as well as the input amount and origin of scrap steel to the fabricated batch. The output should state the percentage of scrap steel used in fabrication, so this information can be used for carbon accounting in the upstream value chain. A certification for recycled steel (including percentage of scrap steel used) says nothing about the amount of CO_2 emission emitted during the fabrication process. This is also dependent on the input of supplied energy to the steel manufacturer. How the information, provided by certification, is used, depends on the user. Stakeholders upstream can use the information in their ESG reporting or in their decision making strategies for the choice of suppliers but they cannot take the saved CO_2 emissions for their own account. Only Scope 1 emissions related to the direct processes of a company, anywhere in the life cycle, have an effect on the CO_2 emission output of a company. Scope 2 (supplied energy) and Scope 3 emissions are important for the accountability of the company. This shows the discussion between the function of certification and its possible goal of improving carbon accounting for the relevant stakeholders. As there is no regulation enforcing the use of recycled steel, the following question arises. Why would customers, like ship owners, and consumers, as users of shipping services, opt for ships made from recycled steel? The circular economy concept for the maritime industry and the ESG performance of companies involved in the maritime industry both play a role here in combination with the function of the certification of recycled steel. The function of certification, to be clear, is to provide transparency and traceability, and by doing so, provide trustful information between different stakeholders. Looking at the life cycle of a ship, the same discussion holds. In this case, the certification of recycled steel is combined with the certification of the allocation of the recycled steel products. These products need to be traceable back to the manufacturer (and therefore to the supplier of scrap steel if used) and need to be traceable inside the ship. Although this is already important information

about the ship and about the sustainability of the ship and of its users, this information lacks any relation towards possible emission reductions. The amount of recycled steel used can only be compared with estimates of emission reductions.

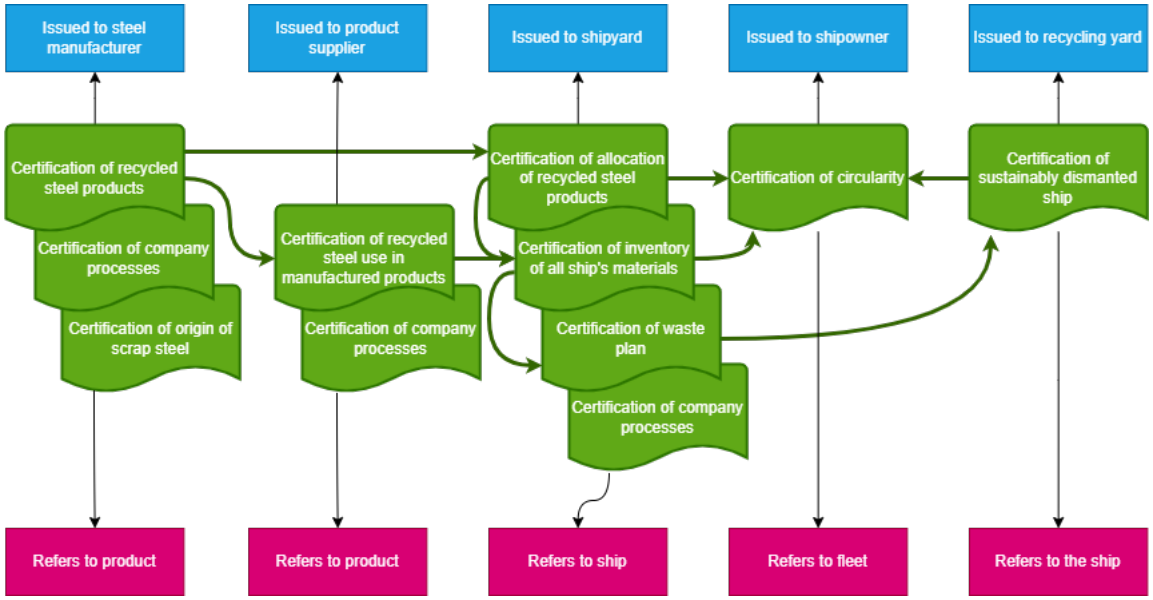

Figure 5.5: Correlation between new certification documents

Figures 5.4 and 5.5 show the concept for a new class notation. The different new certification documents are explained next. The explanations are connected with the numbers shown in figure 5.3. First the related documents from Bureau Veritas are mentioned and next more information is given regarding the new documentation itself.

Certification of fabrication process[1]:
Related to NR216 Rules on Materials and Welding for the Classification of Marine Units and NR480 Approval of the Manufacturing Process of Metallic Materials

Material manufacturers will have to provide information on how their fabrication process works in order to verify that recycled materials are used. Furthermore, their methodology for the determination of the amount of recycled material contained by the end products, needs to be known and verified as well.

Certification of recycled steel[2]:
Related to NR266 *Rules on Materials and Welding for the Classification of Marine Units* Requirements for Survey of Materials and Equipment for the Classification of Ships and Offshore Units and NR320 Certification Scheme of Materials and Equipment for the Classification of Marine Units

This certification has the objective to provide information about the amount of recycled steel, present in the manufactured products. It is issued to the steel manufacturer and can only be issued to the manufacturer (since it is impossible to verify if steel has been recycled without a survey at the manufacturers' location). The parameters that need to be included are:

- origin of scrap steel
- manufacturing process used
- percentage of recycled steel in finished product

This information can be added to existing certification documents, since this information can be seen as attributes of the steel products.
Document NR480 *Approval of the Manufacturing Process of Metallic Materials* needs to be adjusted in

paragraph **1.3 Preliminary information to be submitted** In this section extra information needs to be added about the process, storage and documentation of the recycled products. The origin of raw materials is already required, this will include the origin of scrap steel. All subsequent chapters in this document need to be adapted to include the documentation and storage of recycled products. This results in extra information, about the percentage of recycled content, coupled to the finished steel products. Henceforward, the products leaving the steel manufacturer will be called green steel products, as long as they have some recycled content.

This extra certification influences the certification procedure for I_{BV}. Where this happens in the process can be seen in the scheme of Figure 5.6. The scheme is available on the site of BV [19]. The extra steps are represented by the red rectangles.

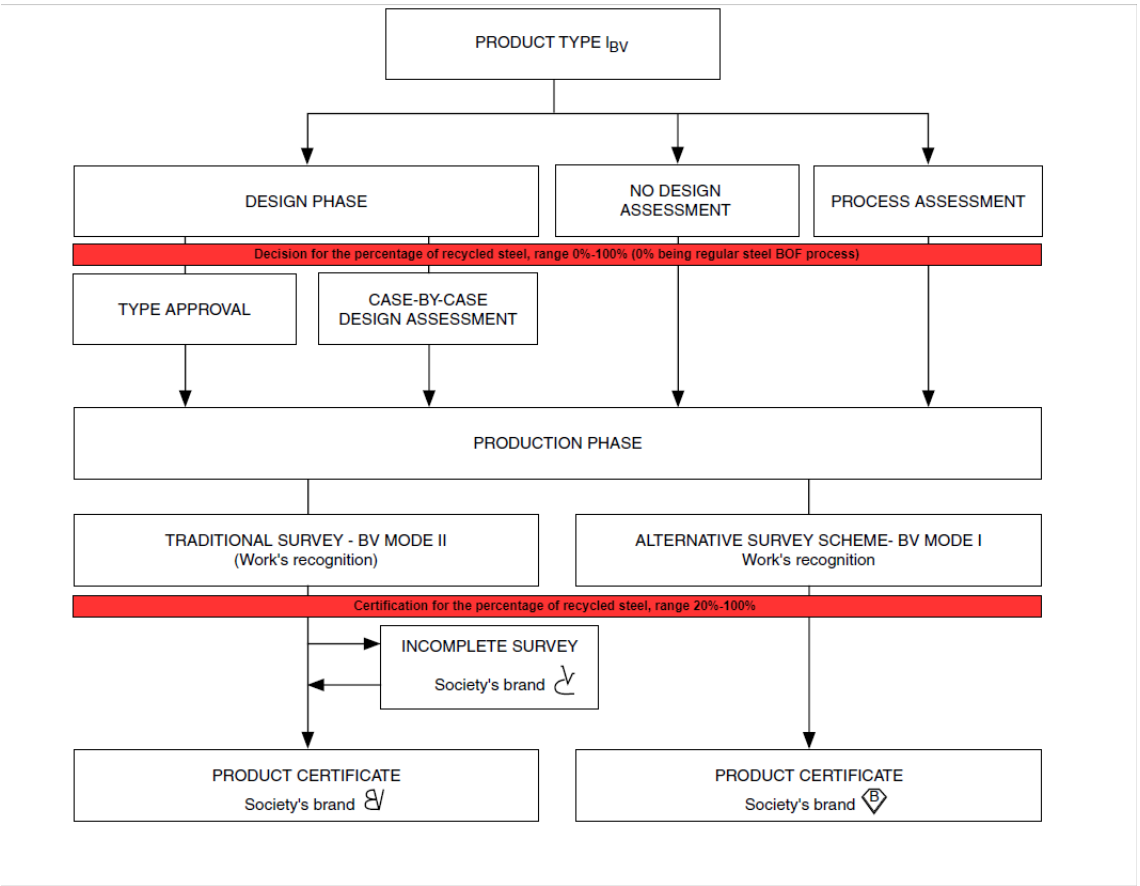

Figure 5.6: Adaptation of certification scheme for I_{BV} product [19]

Certification of recycled steel allocation[7]:
To determine the total amount of recycled steel used it is important to document which parts of the ship are made of recycled steel and where these parts are located. The parameters that need to be included are:

- steel product identification
- location of steel product in the ships' plan

The traceability of recycled steel is a crucial factor for the determination of the final amount of recycled steel in a ship. It is preferred to use an symbol or letter to indicate a range of of the amount of recycled steel since it is hard to predict the exact percentage of recycled steel used. The two major parts that contain steel are the hull end machinery. The use of recycled steel in machinery needs to be determined at OEM level. Equipment gets ordered and delivered with the exact weight and material composition specs from the supplier. The hull will subsequently be made of 'regular' steel and (partly) recycled steel. There needs to be a

procedure to accurately track the steel parts and what properties these parts posses. One way is to accurately keep records of all parts that are built in the ship. The challenge here is that steel parts, like for example steel plates, need to be reworked before they can be built into the ship. This means that the properties of the incoming steel products change. Every part therefore, needs to be weighed before entering the build. A second way to estimate the total amount of recycled steel, can be done using CAD/CAM programs. Every part of the ship is modelled into these software packages. The next step is to allocate the actual steel plates and products to the actual parts in the digital plan. It should be possible for the Program to calculate the total weight. The added weight caused by the welds can accurately be estimated. A final check to verify the total weight is the inclination test.

The shipbuilding industry is, as it is today, already a multi stakeholder industry. There are different locations in the process where certifications can add value that are currently missing. How this value can be added and to whom these certifications add value requires some deeper understanding of the processes. first of all, certificates can be issued to three entities being materials, a ship or a company. Certificates attached to materials are needed by the material manufacturer when he wants to sell the materials to the product manufacturer or the shipyard. Certificates attached to the ship are needed by the shipyard to accompany the sell of a ship to a shipowner or shipping company. Certificates issued to companies are mainly about the production processes. The missing locations in the shipbuilding process require all three types of certificates.

Certification of inventory of all ships' materials[6]:
Related to NR528 *Green Passport*

Although a full inventory of a ships' materials and equipment requires a lot of work and extra resources, such an inventory can improve processes further downstream in the life cycle of a ship. The determination of a resell value becomes easier and more exact. Recycling yards can dismantle ships more efficient and more possibilities will arise for the reuse of different parts of a vessel. The reason why certification by a trustworthy third party is needed, is because of the long lifespan of ships and the ownership can change multiple times. Furthermore, when recycled materials are (partly) used and documented, it make sense to document the entire materials' inventory as to make conclusions to the ship's overall sustainability score. This certification also provides clarity as to how much recycled steel is used. It does not certify the input for LCA methods. These methods need the exact data about emissions. This document provides the correct information about the materials used including the recyclability of the used materials. The Resulted LCA impact can differ depending in the suppliers of these materials. Since the LCA methods are not yet standardised it is up to the user to decide what kind of data they want to extrapolate from the fact there are recycled materials used. Similar projects are already being performed in ship building industry. Maersk has projects where they are looking into the full inventory of ships materials at the design stage and the yacht building industry is working on a model called YETI (Yacht Environment Transparency Index) for the assessment of the environmental impact of yachts.

Certification of waste plan[5]:
Related to NR528 *Green Passport*

When all the ships' materials are known and certified, a waste plan can be submitted by the shipyard as well. This plan contains guidance and recommendations for the dismantling, being recycling, re-using, re-manufacturing (or another process from the waste hierarchy ladder. see figure 1.3. This certification facilitates the resale or the sale at the EOL phase of the ship and can improve the efficiency of the dismantling process at the recycling yards.

Certification of origin of recycled material[3]:
Related to NR216 *Rules on Materials and Welding for the Classification of Marine Units*

Similar to products made from virgin steel the origin of scrap steel needs to be known so it can be traced back for quality and transparency reasons.

Certification of fabrication and allocation processes[4]:
Related to NR216 *Rules on Materials and Welding for the Classification of Marine Units*, NR528 *Green*

Passport and NR266 *Requirements for Survey of Materials and Equipment for the Classification of Ships and Offshore Units*

This is an important certificate. For the recycled content to be meaningful, there needs to be mentioning of the production process. The energy mix is crucial information that needs to be provided by the manufacturer.

Certification of sustainably dismantled ship[8]:
The dismantling processes are included in this certification and the resulting steel scrap volumes are identified and certified to ensure correct traceability,

Certification of circularity[CE]:
Similar to NR266 *Requirements for Survey of Materials and Equipment for the Classification of Ships and Offshore Units*

An overall certificate regarding the circularity of a ship can be issued to the ship owner. This certificate contains all the presented new certification documents, shown in 5.5 and gives an overview of the achieved circularity. Figure 5.7 shows the path for a shipping company to improve its ESG performance. It consists of 4 steps: 1) Component improvements, 2) Circularity improvement, 3) Circularity improvement by Scope control and 4) Sustainability improvement. This means that reaching a high level of sustainability through certification requires fulfilling all these steps. Separate component certifications are already valuable and can use in reporting. Combining these component certifications takes the circularity of the ship a step further by providing an overview of different components. For example the recycled content of both hull and machinery could be known. The next step as a company is to receive certifications for investigating and controlling scope 3 emissions, similar to the Dutch CO2 performance ladder. The difference is that it can become certified. Adding the documentation about the emissions reduction measures during operation (use phase) truly makes the whole circularity complete and this way creates a higher sustainability value.

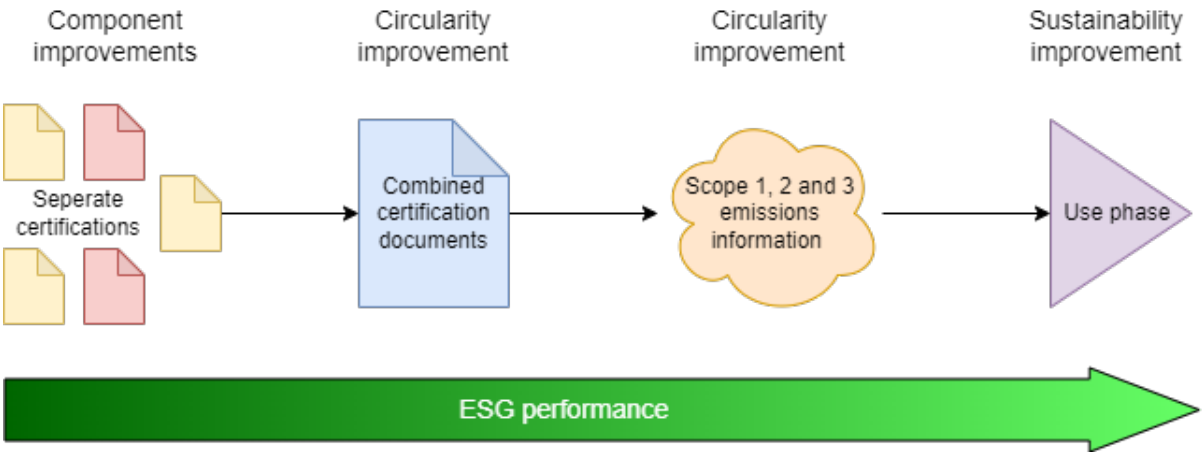

Figure 5.7: Path to sustainability

After reviewing what type of documents need to be added in this process, the logistical changes and challenges are evaluated. In terms of fabrication process, there is no change for the steel producers. Scrap steel is already being used by both BOF and EAF production processes. BOF uses up to 30% and EAF can use up to 100% of scrap steel as input. The only change for the steel manufacturers is that they need to provide more information about the composition of their end products. This seems a straight forward process but could have bigger consequences. Without differentiation, all steel products end up being sold at the same price (according to their type, size and grade). When there is a differentiation within the same product range, they risk having to sell the same products (recycled content and non recycled content) at different price levels. Depending on the market this can be a disadvantage and thus a challenge from a business perspective. They also have to take into account the batch size in which steel gets produced. More differentiation for the same type of products means more logistical challenges and possibly more resources

spent by the sales teams.
Equipment manufacturers can easily add products made from recycled materials to their catalogue. Most products will be made by order and as long as they can find the supply of recycled steel materials, they can produce and easily make fact sheets specifying the amount of recycled material in their end products.
The challenge for the shipyard is already explained when discussing the certification for recycled steel allocation. First the ships' steel has to be divided by hull and machinery. Hull steel parts are the shell plating, superstructure, hatches, doors, decks, structural elements, etc. All these parts enter the shipyard as steel plates and are cut, shaped and welded into blocks. These blocks are welded together to form the ship. The steel plates are already certified to ensure the quality of the steel plates. Machinery parts are supplied by specific suppliers. These parts include, engines, gearboxes, cranes, winches, shafts, etc. The specifications of these parts can be obtained from the supplier. The machinery part is easily determined as it consists of parts from suppliers, accompanied with clear fact sheets stating the exact amount of materials used. The hull part is the complicated part. This part can consist of many different steel grades. The different steel grades that are currently used in shipbuilding are shown in table 5.3

Table 5.3: Steel grades used in shipbuilding, Source Bureau Veritas NR467

Steel grades	Minimum yield stress	Ultimate minimum tensile strength
A-B-D-E	235	400-520
AH32-DH32	315	440-570
EH32-FH32		
AH36-DH36	355	490-630
EH36-FH36		
EH36CAS1-EH36CAS2		
FH36CAS1-FH36CAS2		
AH40-DH40	390	510-660
EH40-FH40		
EH40CAS1-EH40CAS2		
FH40CAS1-FH40CAS2		
EH47	460	570-720
EH47CAS1-FH47CAS2		

The perfect scenario would be if the steel supply for all the different steel grades could contain the same amount of recycled material. In that case The ship contains as much recycled steel as the supplied material. If this is not possible, the shipyard has two options. On the one hand they can opt to accurately weigh and trace every steel part that goes into the ship or another solution is to use the help of cad/cam software. In both these options, the location of each piece of steel is known and each piece of steel is accompanied by data about its grade, composition and weight. The welds, finally, can be accurately estimated. The location is important for when the ships enters drydock and needs repairs. The certificate must be remade after drydocking to take into account the changing of the composition of materials. Green steel can be replaced by grey steel and vice versa. Except from keeping track of the location of every piece of steel, the shipyard might have more logistical challenges depending on the size of the shipyard. Shipyards will need extra room to stockpile more different types of steel.

Next the point of view for the different stakeholders will be discussed. This new class notation has the acronym SURV and stands for the Sustainable Use of Recource Vessel. The approach towards each stakeholder is structured by using the STAR method. STAR stands for Situation, Task, Action and Result. By using this method, a clear focus is realised which in turn will help structuring the interviews.

Material Manufacturer
SITUATION:
Steel producers work with two main production methods, the BOF route and the EAF route. The input of the BOF route can take up to 30% of scrap steel. The input of the EAF route can take up to 100% of scrap steel.

Currently steel manufacturers already make use of this possibility but they do not differentiate for different end products. This means that, regardless of the amount of scrap steel that is used. the end product will be the same.
Certification of the manufacturing process and certification of the percentage of recycled steel in the end product are relevant here. These correspond to certification nodes 1 and 2 of figure 5.3.

TASK:
Extra activities arise here in checking the input side. The manufacturer will have to be transparent as to their manufacturing process. The traceability of the origin of scrap steel is already part of the current certification process, this will not create issues. Information about the energy mix they use for fabricationis important for their own business process. This information should also be part of the certification.

ACTION:
Implementation of traditional certification methods at the input side. the output side is already subject to surveys for certification. The existing certification of steel products will be augmented with information about the amount of recycled material present in the end products.
If the evolution is in such a way that demand for steel products with a specified and certified recycled steel content will grow, the steel manufacturer will be able to provide the percentage of recycled steel content very accurately. Customers, however, will not be able to choose the exact content unless they can order the batch size of about 150 tonnes. For new build projects this should not be an issue but for repairs the needed amount of steel could be below the batch that needs to be ordered for choosing the recycled content.
In terms of reducing the carbon footprint, steel manufacturers are able to provide customers with a choice for different energy mixes used to manufacture the steel products. This directly influences the scope 3 emissions for these customers.

RESULT:
The differentiation between products with different recycled steel content can be both a benefit and a draw-back for the steel manufacturer. By providing information about their recycled steel content they risk having to sell certain types of steel at a lower price depending on the demand. On the other hand, certifying this information, could cater to a new, niche market, which in turn would give the manufacturer a competitive advantage.

Product Manufacturer
SITUATION:
OEMs have two other reasons to opt for recycled material. Scarcity of raw materials and cost perspective can drive the product manufacturer towards using recycled materials. The increased ESG performance due to this evolution, is in this case an added bonus. So far the sustainability and ESG performance has not yet been a driving force for using recycled materials.
Since they are more B2B oriented, the economic perspective still has the upper hand. Demand for products made of recycled steel is still lagging. An early mover can, however, gain a competitive advantage.

TASK:
Certification for recycled steel is en easy addition for the product manufacturer. This is only a matter of verification and survey of the process and products. The fact sheets are already present and easy to adjust and share with their customers.

ACTION:
Most type of products or manufacturing processes are already being certified. Only small add-ons and minor extra surveys are needed to add steel products to this new class notation.

RESULT:
By using only a small amount of extra resources, product manufacturers can gain a big advantage when using recycled materials and using this information in their ESG performance. By recognising that they are part of a bigger value chain that reaches two, three or even more stakeholders downstream, they can achieve an advantage over there competitors.

Shipyard

SITUATION:
The shipyard is situated in the middle of the value chain. They try to get grip on the circularity of their product,
Shipyards are well equiped in handling a stock of materials on the yard for manufacturing vessels. Overall their process will not change much.

TASK:
Extra certification tasks will have to be performed during and after the building of the ship, They will have to prove by showing clear working procedures that their material inventory of the build matches with the recycled content that was set in the contract.

ACTION:
Shipyards will have to source for recycled materials, investigate the circularity and scope 1, 2 and 3 emissions of their supply chain more and facilitate information sharing with all their stakeholders. Managing the stock of materials on the yard and during the design phase will become harder and new digital solutions will have to be used.

RESULT:
When building and selling vessels with the new certification they will increase their competitive advantage and possibly get better financing for their projects. They gain experience in new digitisation solutions by doing so. Opportunities are possible by investigating new business models and tracking of the vessels they make over their life cycle will become more important.

Shipowner

SITUATION:
The shipowner receives more information about their ships. They have more choices to make in what direction the companies' strategy will evolve. They have to take into account the rapidly changing standards regarding climate change and make sure not to be left out.

TASK:
The shipowner eventually is the one tasked with buying and ordering ships that are sustainable. They will feel the effect of their choices more and more when it comes to sustainability.

ACTION:
The shipowner will gain advantage from increased digitisation of their fleet. This will also facilitate the tracking of their fleets materials and calculate the circularity.

RESULT:
Shipowners will see the benefit of using ships that are more sustainable. They will see positive effects from getting easier access to financing, improved chances to receive tenders, improved company image and in the long term will see economical benefits from these kind of decisions.

Ship repair yard

SITUATION:
Ship repair yards will only be confronted with the certification of recycled steel in a number of years when the first ships using this certification need maintenance or repairs.

TASK:
When repairing vessels with certification for recycled steel, it will be their task to keep track of what goes in and what goes out of the ship so the certificates can be updated accordingly.

ACTION:
Like the ship[yards they will need to increase their stock of steel and make sure to have a well organised system in place to keep track of the extra steel plates with different properties. Extra certifications will need to be performed with respect to the recycled steel content of ship repairs

RESULT:
They will thrive and be able to work quicker and more efficient if the digitisation and collaboration reaches higher levels. They will be able to respond eve quicker.

Ship recycling yard
SITUATION:
Currently they are focused on breaking ships as economically as possible which does not leave much room for circularity. They are focused on recycling instead of remanufacturing

TASK:
The only task they can do is work as efficient as possible to generate the least amount of waste possible. They can only follow how the market evolves.

ACTION:
The ship recycling yard should be ready for when the market evolves towards a mix of recycling and remanufacturing. This will create a novel way of working that will need some time to develop.

RESULT:
Certification for recycled materials could influence the scrap steel market in a positive way. If demand grows for scrap steel, ship recycling yards can sell their scrap at a higher price. This creates opportunities for EU clean recycling yards.

5.1. Future innovations and solutions

Classification societies, due to their nature of work, possess the credibility and experience in auditing companies and products to certify and monitor actors to the blockchain network. They can provide the blockchain service and platform to which actors are allowed to participate. By doing so all actors immediately gain access to the different parts of the supply chain. By providing this service, classification societies meet the demand for trust, trace-ability and transparency by all stakeholders over the entire supply chain.

In favor of this methodology is the improvement in data due to transparency and the continuous checks made possible due to the blockchain system which is accessible by its actors at any moment in time. This stands in contrast to the traditional certification methods where checks are made at a specific moment in time and until the next check or audit, it is unknown whether the highest standards are being maintained..

The concept of blockchain uses a network that is made by connecting many different computers/servers. BV can create their own application or work with a third part to develop this application. The ship and all the parts get digital id's. Once these are made and confirmed by two or more nodes in the system. These id's, in the form of blocks, can't be changed anymore. All transactions with these blocks are set and can't be altered. Transaction are always confirmed by two or more nodes making the system transparent and secure. Transactions can be buying or selling or building blocks together (creating a ship from many different parts) or demolishing ship into many different parts. The decentralisation of the system makes it secure and solves the transparency and traceability issue. All collaborators to the system can choose which information they provide to the system. Different stakeholders can be given different clearance levels. BV is the one party to control this application. BV can still perform its surveys on location like they are used to do. All the documents can easily be made digital and will be provide to the correct parties in a digital non transmutable form. The digital twin concept, already developed by BV can easily be incorporated in this system. The digital version of the ship will find new application for the life cycle analysis. Also this blockchain application makes it more interesting to develop new business models. Life time business models for shipping have benefit with a clear and traceable system of the entire ship. It makes it easier for the yard to plan repair works and arrange the scrapping or partly recycling activities. 3D cad and cam programs are used today only by the yard. This information may not be very important during the use phase but it is important during the other phases. Yards already have the information about the entire ship so they should find a way to incorporate it into ERP systems and systems for recycling and lifecycle analysis. Due to the long life cycle of a ship and the many stakeholders involved it is easy to loose track of what information is important at which stage and

which information is needed when. It can become burdensome for different stakeholders too manage data and information if they have no use for it. But it can be of importance to keep this information for future stakeholders. Therefore a fully integrated system needs too be built in a smart way that it tracks all the data but only provides the data the stakeholders need when they need it. The difficulty is that all this data is connected and influenced in a specific way. System engineering integration is therefore also key to the success of such a system. The digital twin concept was a very useful concept,

Blockchain is no longer only connected with crypto currency. Its advantages are also advantages for supply chains in different industries. It can be used for LNG supply chain [66], to overcome the problem of fraudulent wine making [23]. It puts in place a traceability system that tracks a bottle of wine up until the grape grower. It provides transparency, provenance, safety and security. Similar, a system can be set up for the certification of recycled steel. The method used for this decentralised ledger is by creating digital passports (blocks) for each green steel plate or product that enters the supply chain. information security and public visibility of information can be issues that need to be addressed but overall, blockchain technology provides advantages in supply chain.

Next the implementation of a new class notation in the 3 levels of figure 5.8 will be elaborated. For level 1, a new class notation does not require a new way of working. The required audits are performed by the classification society as described in the new documents. Product certification as well as type certification is performed as usual. The documents are issued at the relevant stakeholders or to the relevant products. Level 2 requires digitization of these documents and access through the cloud solution is predetermined. Stakeholders are granted viewing rights if they are entitled to these rights. Because level 3 allows for secure and transparent transactions, certification documents could be issued digitally only. For example for the certification of the use of recycled steel in ship building projects. The maritime industry also sees, like any other industry, an increase in data. New ways of data gathering, processing and evaluating are needed to keep the industry up to date. Other industries show the efficiency gains that can be achieved by investing in these upcoming technologies. Many initiatives can be found to facilitate better collaboration between stakeholders and to increase efficiency and data transmission. Figure 5.8 shows three levels of how the information streams can flow between the different stakeholders for the life cycle of a ship. Level 1 represents the current way of business. Stakeholders directly contact each other when in need of information or when ordering parts, etc. This is a slow process and requires a hands on approach with the need for manpower. Strong relationships can be build between stakeholders this way but when looking at the increased amount of information required by all stakeholders this way of working will be inefficient in the future. For example the need to gain insights in scope 3 emissions over the entire value chain requires a lot of information from stakeholders up and downstream. Some shipyards and shipping companies, like Damen and Jan De Nul are performing these investigations to get a clear picture about their circularity. The problem is that a shipyard of decent size can easily have hundreds or more suppliers. Gathering information and updating existing information becomes a time consuming task this way. The next possibility is presented in level 2, working with cloud based solutions. These cloud based solutions provide an online platform where data can be stored accessible to all stakeholders. Stakeholders can choose or are granted permissions as to which information is accessible to whom, similar to the BIM see figure 2.6.

In terms of circularity, level 2 facilitates many improvements. The field of system engineering can, together with level 2, make the ship building process more efficient as well. Level 3 is similar to level 2, with the difference that level 3 makes use of blockchain technology. This decentralizes the data, making it more secure. This paves the way to include smart contracts as well. Next to the availability of data for all stakeholders (according to the digital permissions they have been granted), secure transactions make it possible to trace the project as an immutable entity. In other words the traceability is significantly improved and more secure. A ship or product receives a digital id. Once transactions are validated by the different nodes on the blockchain network they are confirmed and added to the chain. This information or transaction is locked and due to the decentralization of the validation process, unable to be changed again.
Concept: Blockchain uses a network that is made by connecting many different computers/servers. BV can create their own application or work with a third part to develop this application. The ship and all the parts get digital id's. Once these are made and confirmed by two or more nodes in the system. These id's, in the form of blocks, can't be changed anymore. All transactions with these blocks are set and can't be altered. Transaction are always confirmed by two or more nodes making the system transparent and secure. Transactions can be buying or selling or building blocks together (creating a ship from many different parts) or demolishing a ship into many different parts. The decentralisation of the system makes it secure and solves the transparency and traceability issue. All collaborators to the system can choose which information

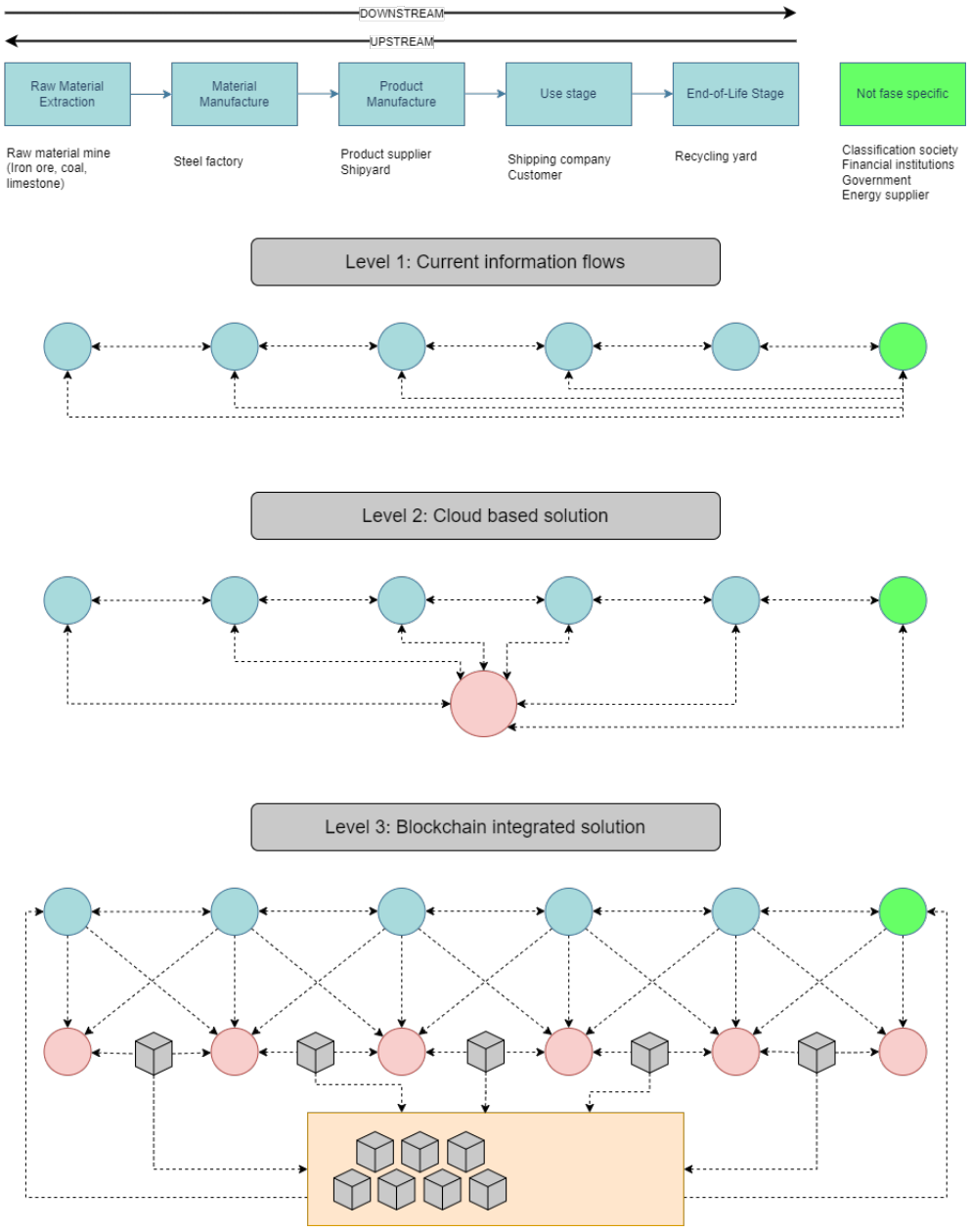

Figure 5.8: Information streams innovation

they provide to the system. Different stakeholders can be given different clearance levels. BV is the one party to control this application. BV can still perform its surveys on location like they are used to do. All the documents can easily be made digital and will be provide to the correct parties in a digital non transmutable form. The digital twin concept, already developed by BV can easily be incorporated in this system. The digital version of the ship will find new application for the life cycle analysis. Also this blockchain application makes it more interesting to develop new business models. Life time business models for shipping have benefit with a clear and traceable system of the entire ship. It makes it easier for the yard to plan repair works and arrange the scrapping or partly recycling activities. 3D cad and cam programs are used today only by the yard. This information may not be very important during the use phase but it is important during the other phases. Yards already have the information about the entire ship so they should find a way to incorporate it into ERP systems and systems for recycling and lifecycle analysis. Due to the long life cycle of a ship and the many stakeholders involved it is easy to loose track of what information is important at which stage and which information is needed when. It can become burdensome for different stakeholders to manage data and information if they have no use for it. But it can be of importance to keep

this information for future stakeholders. Therefore a fully integrated system needs to be built in a smart way that it tracks all the data but only provides the data the stakeholders need when they need it. The difficulty is that all this data is connected and influenced in a specific way. System engineering integration is therefore also key to the success of such a system. The digital twin concept is a very useful concept,

Using blockchain technology for improving the circular economy in shipbuilding and consequently its sustainability is explained in the following concept. The assumptions is made that stakeholders will benefit from data sharing over the entire value chain as opposed to data sharing just over single links. The idea is to connect all data to the entities. The most commonly used entity will be a ship which will be built out of many different components, equipment and materials. This data needs to be available throughout the ships' lifetime

In favor of this methodology is the improvement in data due to transparency and the continuous checks made possible due to the blockchain system which is accessible by its actors at any moment in time. This stands in contrast to the traditional certification methods where checks are made at a specific moment in time and until the next check or audit, it is unknown whether the highest standards are being maintained.

In level 2 and level 3 there is room for the digital twin, created by BV. Since this digital twin is already developed by BV, it can find a new application as an inventory tool for ships materials. Level 2 and 3 require the integration of CAD and CAM software. CAD and CAM documents provide the base for the digital twin and all together they provide the perfect documentation needed for tracking recycled steel products. When repairs need to be performed these documents can be updated.

6

Conclusions and Recommendations

As opposed to solving or providing a solution to solve the difficult task to reduce the carbon emissions in the ship building industry, the implementation of certification for recycled steel gives the industry an important tool with which the industry can further improve its approach on how to reach sustainability goals, of which emission reduction is just one such an example. This tool helps by means of creating trust, traceability and transparency over the entire value chain. The proposed new class notation consists of a number of new documents. These documents are stand alone documents and have their own purpose separately. They all contribute to the sustainability of a project. Together they contribute to a larger extent to the sustainability. Combined with the efforts that are already taking place to reduce emissions during the use phase, they contribute to the circularity of the project. They can be bundled and by doing so, prove significant effort regarding circularity. In contrast to emissions during the use phase that can be measured at the chimney, there are too many variables to perform the same task at the end of the building phase. Therefore, the proposed documents specify the data that can be proven and measured with accuracy. This data is the amount of recycled material in the end product. It is up to the user and consumer to translate this data into any data they see fit.

Demand for measures to improve sustainability is high. Interviews with consumers, shipping companies, have shown that because of the increased importance and the increasing cost of CO2 emissions many companies and organisations have started creating their own evaluating procedures. To increase transparency there should be a consensus as to what data is important for sustainability reporting.

It is seen that the certification of recycled materials will influence different stakeholders in different ways. Overall the maritime industry would benefit from an improved sustainability realised by less carbon intensive processes to build ships. Classification societies create new business opportunities and gain advantage of early movers. Other than business opportunities their green image as a sustainable company will give them a competitive advantage. The downside for classification societies is that they have to spent resources, banking on its success in the future. Steel manufacturers are not keen on adopting this certification due to the fact that they don't want to see a differentiation for a similar product based on its recycled content. On the other hand they can also benefit from this and ask a premium for recycled products. Technically they have already all the info they would need to provide for certification of recycled products. Product manufacturers have an incentive to provide the opportunity to their customers with a choice for products made from recycled steel. They would need the assurance from in the form of certification however. Customers requesting products with recycled steel content could make the procurement of materials more difficult. The traceability of recycled materials also needs to be well maintained to be able to receive a final certification of recycled content. Shipping companies have the advantage of improved ESG reporting about their companies and possible better position when receiving contracts. Public opinion is becoming an important factor in the maritime industry as well and green companies have a competitive advantage, Financial institutions are seen by many stakeholders as the enablers of greening the maritime industry. The market for green investments is rising as well, so financial institutions will be interested in funding projects made with recycled steel, however they do not want to be limited to only funding green projects. Certification of recycled materials creates the need for a better collaboration and transparency between stakeholders.

This research shows that there is a market for certification of recycled products and the use thereof. This

is only a first step to make this part of the ship building process more circular. Only steel has been looked at in this research. Other materials should be looked at too to make the circularity of a ship complete.

A

Interview questionnaires

A.1. Financial institution

CSR, CE and ESG

1. How do you define CSR, CE, sustainability and ESG in your sector? How is it, positively or negatively, important?
2. Is a companies' sustainability policy subject to your decision making process when it comes to financing projects? What factors need to be addressed by a companies sustainability policy? How important is the reduction of GHG emissions in this matter?
3. If a new build project is made with or partially made with certified recycled steel, would it have a higher chance of receiving financing?
4. When financing a project, do you take the ESG reporting of the upstream suppliers to this project into account?
5. Is the information about ESG accurate and trustworthy? Are ESG ratings for example accurately defined so that different rating agencies reach the same results when reporting on a company?
6. Do you think CE has a future in the maritime industry? What would be the barriers and potentials?
7. Looking at the 9R framework of waste hierarchy in a CE, do you feel there are opportunities for stakeholders that collaborate more and exchange data in order to improve the CE character of the maritime industry?

Opportunities and barriers to the use of recycled steel in ship building

8. Do recycled steel products have the potential to become competitive against virgin steel products? Why or why not?
9. Who could benefit from using recycled steel in the maritime industry?
10. Is the knowledge of using recycled steel a decision changing factor on itself or does this need to be correlated to the possible environmental impacts, such as GHG emission reductions?

Possible support mechanisms for certification of recycled steel

11. If recycled steel is certified, what information should be provided to add value to these steel products? For example the percentage of scrap steel used, origin of this scrap steel, information about GHG emission reduction, ...?

Extra

12. Is there anything else you would like to add?

A.2. Consumer

CSR, CE and ESG

1. How do you define CSR, CE, sustainability and ESG in your sector? How is it, positively or negatively, important?

2. Would you like to have ESG information of all upstream suppliers? Would you use this ESG data as a selling point?

3. Do you take sustainability into account when choosing your suppliers?

4. Do you take sustainability into account when choosing your shipment suppliers?

Opportunities and barriers to the use of recycled steel in ship building

5. Are you willing to pay more for more sustainable or greener products?

Possible support mechanisms for certification of recycled steel

6. Do you think the maritime industry should do more effort to reduce its carbon footprint? How do you think the industry can reach such a goal?

Extra

7. Is there anything else you would like to add?

A.3. Shipping company

CSR, CE and ESG

1. How do you define CSR, CE, sustainability and ESG in your sector? How is it, positively or negatively, important?

2. Would you like to have ESG information of all upstream suppliers? Would you use this ESG data as a selling point?

3. Do you take sustainability into account when making decisions in your upstream supply chain?

Opportunities and barriers to the use of recycled steel in ship building

4. Would it be a selling point to your customers or clients if a ship in your fleet is made out of or partially made out of recycled steel? how would you present that?

5. Would you pay a premium for a ship, made out of or partially made out of recycled steel? Why or why not?

Possible support mechanisms for certification of recycled steel

6. Do you think the maritime industry should do more effort to reduce its carbon footprint? How do you think the industry can reach such a goal?

7. Do you wish to see more collaboration between different stakeholders over the entire life-cycle of a ship in favor of a CE?

Extra

8. Is there anything else you would like to add?

A.4. Steel Manufacturer

CSR, CE and ESG

1. How do you define CSR, CE, sustainability and ESG in your sector? How is it, positively or negatively, important?
2. How important is the information about your energy supply in this context. Are your clients downstream interested in this information and can it be a competitive advantage if your energy supply is green?

Opportunities and barriers to the use of recycled steel in ship building

3. Do you use scrap steel in the EAF process? If so, why do you use scrap steel, if any, in these process?
4. Is it possible to guarantee traceability of steel products with respect to the input of scrap steel?
5. Is it possible to quantify the percentage of recycled steel in finished steel products with accuracy? Which accuracy and how can you measure it?
6. What are your sources of scrap steel?
7. Is there an abundance of scrap steel available?
8. Is the supply of scrap steel constant or does it fluctuate?
9. Are steel products made from scrap steel sold at a higher or lower price compared with those products made from virgin steel? What was the trend previously? What do you expect the trend to do? Do you expect this pricing to follow this trend or is it expected to change in the future?
10. Do you see a willingness to pay with consumers for greener products?
11. Is there a demand for recycled steel products? Are products made from recycled steel competitive with products made from virgin steel? How did this demand develop over the past years? How do you expect it to develop over the next decade?
12. Has there been a reduction in CO_2 emissions in the production process when using scrap steel?
13. Is the reduction in CO_2 emissions significant in the production process when using scrap steel?
14. What factor do you think is more important as a selling point in the downstream supply chain, the CO_2 reduction possibility or the CE emphasis?
15. What is the main barrier to reducing CO_2 emissions in your sector?

Possible support mechanisms for certification of recycled steel

16. If there is a differentiation between 'virgin' steel and 'green' steel products on the market, how can you prevent greenwashing?

Extra

17. Is there anything else you would like to add?

A.5. Shipyard

CSR, CE and ESG

1. How do you define CSR, CE, sustainability and ESG in your sector? How is it, positively or negatively, important?
2. How do you take sustainability into account when choosing your upstream suppliers?
3. Are you able to put pressure or incentivise your suppliers to engage more in sustainable practices?

4. Would you like to have ESG information of all upstream suppliers? If so, Would you use this ESG data as a selling point?

5. Looking at the 9R framework of waste hierarchy in a CE, do you feel there are opportunities for stakeholders that collaborate more and exchange data in order to improve the CE character of the maritime industry?

6. Do you feel more can be done to incorporate CE in the design phase?

Opportunities and barriers to the use of recycled steel in ship building

7. How does the supply of steel products work? Do you work with fixed suppliers?

8. Is steel bought according to stockpile levels of the yard or is steel bought in batches that specifically match a new build project?

9. Do you already use recycled steel at the moment? If yes, how are recycled steel products separated from 'virgin' steel products? Do they come at a different cost?

10. What are the barriers to working with recycled steel products, if they have to be certified? Do you need to spend extra resources (financial and logistics) working with both virgin steel and recycled steel on the shipyard?

11. Is there willingness to pay more for more sustainable or greener products amongst your customers?

12. Is there a demand for sustainable products at your clients side downstream? Is there a demand for recycled steel products?

13. Is it a goal of your company to promote the use of recycled steel products or is this totally dependent on the clients wishes?

14. Do you think regulation need to be made by authorities to achieve a market penetration of recycled steel (accounted recycled steel products) in the maritime industry?

Possible support mechanisms for certification of recycled steel

15. Do you provide full material inventories of new build projects as we speak? is this, or could this be an advantage with respect to the life cycle of the ship when it reaches its end of life phase?

16. If recycled steel is or would be used in a new build project, is it possible to map exactly where in the construction this recycled steel is used and consequently provide details as to how much of a percentage of recycled steel products are present in the construction?

17. How would you cope with the risk of greenwashing? What would you need or what would you do to minimise this risk?

18. What is the main barrier to reducing CO_2 emissions in your sector?

19. Would you be willing to share more data about your operations in order to improve the CE of the maritime industry?

20. is it possible to design for more reuse of parts of the ship. Would you have an advantage in this field since Damen already works with standardisation?

Extra

21. Is there anything else you would like to add?

A.6. Original Equipment Manufacturer

CSR, CE and ESG

1. How do you define CSR, CE, sustainability and ESG in your sector? How is it, positively or negatively, important?
2. How do you take sustainability into account when choosing your upstream suppliers?
3. Is there a call to be more sustainable from your downstream customers?
4. Looking at the 9R framework of waste hierarchy in a CE, do you feel there are opportunities for stakeholders that collaborate more and exchange data in order to improve the CE character of the maritime industry?
5. Do you think there is a role for regulation from the government in obligating the use of recycled steel in the maritime sector?

Opportunities and barriers to the use of recycled steel in ship building

6. Is there willingness to pay more for more sustainable or greener products amongst your customers?
7. Do you fabricate new engines from scrapped old ones? If so, how do does this process work?
8. What is or would be the incentive (financial, environmental, regulatory) to do so?
9. Does this process come at an extra cost in capital cash-flow and/or resources?
10. Does this practise deliver extra revenue? Does it increase your competitiveness in the market?

Possible support mechanisms for certification of recycled steel

11. Would you be willing to share more data about your operations in order to improve the CE of the maritime industry?
12. Do you think the maritime industry should do more effort to reduce its carbon footprint? How do you think the industry can reach such a goal?
13. Do you see a risk of greenwashing when using recycled steel?
14. Do you wish to see more collaboration between different stakeholders over the entire lifecycle of a ship in favor of a CE?

Extra

15. Is there anything else you would like to add?

A.7. Recycling yard

CSR, CE and ESG

1. How do you define CSR, CE, sustainability and ESG in your sector? How is it, positively or negatively, important?
2. Would you like to have ESG information of upstream companies related to the to be recycled vessel?
3. Looking at the 9R framework of waste hierarchy in a CE, do you feel there are opportunities for stakeholders that collaborate more and exchange data in order to improve the CE character of the maritime industry?
4. Do you feel more can be done to incorporate CE in the design phase?

Opportunities and barriers to the use of recycled steel in ship building

5. What factors determine the value of waste streams and more particular the value of scrap steel?

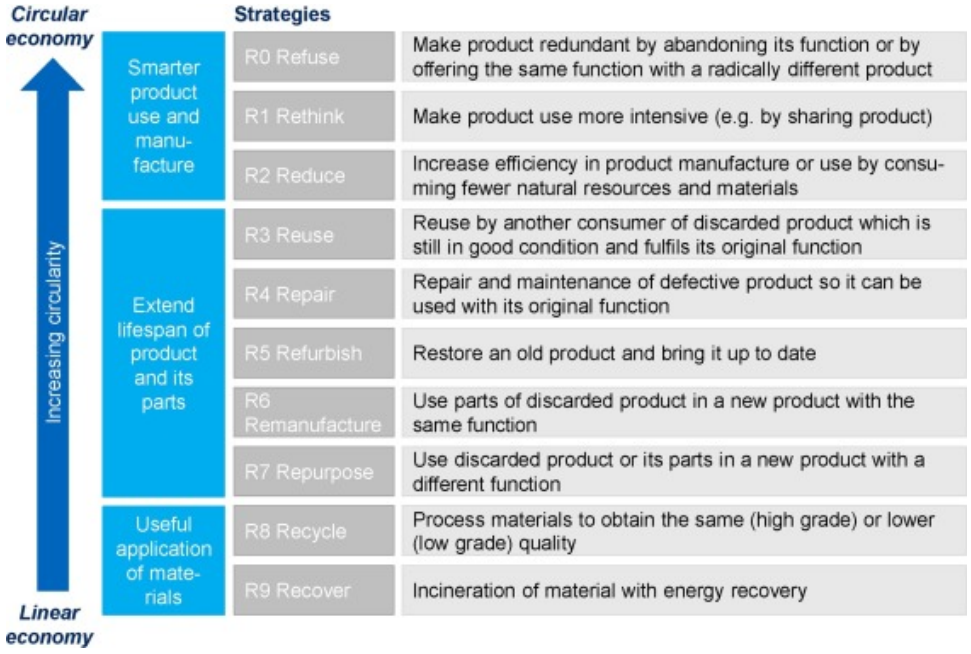

Figure A.1: Waste Hierarchy [63]

6. Do you think the current pricing for scrap steel is competitive enough?
7. Should the price of scrap steel be adjusted to the potential value it holds to reduce CO_2 emissions in the EAF manufacturing process?
8. Would a full inventory of ship materials, updated through its life cycle, facilitate easier and more efficient ship recycling?
9. Would an integrated recycling plan in the design phase of the ship help facilitate easier and more efficient ship recycling?
10. Is it logistically possible to trace where scrap steel comes from and where it ends up? Would it be possible to match these flows?
11. Would there be an advantage to tracing the destiny of scrap steel?
12. What is the main barrier to reducing CO_2 emissions in your sector?
13. Do you think regulation need to be made by authorities to achieve a market penetration of recycled steel (accounted recycled steel products) in the maritime industry?

    Possible support mechanisms for certification of recycled steel

14. Do you think there is added value in providing information about the circularity of ships or maritime construction?

    Extra

15. Is there anything else you would like to add?

A.8. NGO

CSR, CE and ESG

1. How do you define CSR, CE, sustainability and ESG in your sector? How is it, positively or negatively, important?

2. Which of the UN Sustainable development goals are most important for this sector? How are they relevant and why?
3. What are the advantages and barriers to a CE in the maritime industry?
4. Is there sufficient progress towards reaching these goals on EU scale and on global scale? how would you characterise progress, if any. How can it be increased?
5. Do you think ESG reporting should be obligatory for all companies in the maritime industry?
6. Looking at the 9R framework of waste hierarchy in a CE, do you feel there are opportunities for stakeholders that collaborate more and exchange data in order to improve the CE character of the maritime industry?

Opportunities and barriers to the use of recycled steel in ship building

7. How do you think the steel market will evolve with respect to the shipbuilding industry?
8. How do you think the scrap steel market will evolve with respect to the shipbuilding industry?
9. Do you think regulation need to be made by authorities to achieve a market penetration of recycled steel (accounted recycled steel products) in the maritime industry?
10. Could using recycled steel in shipbuilding helping the maritime industry becoming more sustainable?
11. What are the barriers of working with recycled steel?
12. Is the knowledge of using recycled steel a decision changing factor on itself or does this need to be correlated to the possible environmental impacts, such as GHG emission reductions?

Possible support mechanisms for certification of recycled steel

13. Will recycled steel become a competitive commodity compared to virgin steel? Can building with recycled steel become a selling point?

Extra

14. Is there anything else you would like to add?

A.9. Government

CSR, CE and ESG

1. Is, in your view, sustainability and corporate social responsibility important in your sector?
2. How is it, positive or negative, important?

Possible support mechanisms for certification of recycled steel

3. Is sustainability a determining factor when deciding which company gets a contract for a tender?
4. do you have any upcoming legislation
5. do you want to regulate this

Extra

6. Is there anything else you would like to add?

B

Interview transcripts

B.1. Anglo Belgian Cooperation

Researcher: What Does ABC do and What is your relation with recycled steel?
ABC: We fabricate engines, medium speed, 1MW to 10 MW, till 110 tons in weight. There is still a lot of cast iron used in these engines. 15-20% of these engines is steel and about 80% is cast iron. We operate 4 factories where our cast iron part are produced. We try to buy back our old engines and remelted the cast iron parts. Steel parts are being recycled by other companies.
Researcher: What does ABC understand under sustainability and where is your focus in this subject?
ABC: Our main focus is the future fuels. The trend is to not use heavy fuels anymore but we are also looking in the reduction of CO2 with our engines. We fabricate engines that run solely on hydrogen or dual fuels. Our customers are mainly interested at the moment in engines that eliminate the CO2 emissions by using alternative fuels. Recycling of materials is at the moment not demanded by our customers.
Researcher: What is ABC driving to recycling if customers do not demand for it?
ABC: Material availability is an important driver. Supply of cast iron and steel has been difficult. Recycling old engines partly covers this uncertainty. Recycling brings a cost reduction. We invested 7m € in new ovens that reduce the use of CO2 during fabrication and these are also able to handle a wider range of scrap metal. In terms of recycling we also think that we can be more selective in our recycling process. At this moment high tensile steel is being mixed with other scrap steels, there is an improvement possible in this step to make higher grade recycled steel if we separate better in an earlier stage. These high grade steels have longer delivery times so there should be more efficiency in the recycling process.
Researcher: Is there quality loss when recycling steel?
ABC: Due to impurities there will always by downgrading when recycling. These can be improved when making the scrap steel collection process more efficient.
Researcher: The recycling process is not within the interest of your customers?
ABC: We have long ago started with this philosophy but currently, our customers our only looking at the economical value. So far the recycled content has not yet been a determining factor with our clients.
Researcher: Do you see that changing anytime soon?
ABC: We hope this will change since it is already one of our strong points and could give us an competitive advantage.
Researcher: How do you look at the sustainability of your suppliers?
ABC: For this reason we work with mainly European suppliers to reduce transport distance and costs. Communication is easier as well. Recently we started with a survey at our suppliers investigating their position with respect to the SDG's.
Researcher: How is this SDG information important or how can it be important moving forward?
ABC: Financial sectors are demanding more of this kind of information or improvements on the SDG levels. Their impact is high and can create a mindset when requesting more sustainable measures in return for financing of projects.
Researcher: Is recycling of steel giving you an extra advantage in the sense of CO2 reduction?
ACB: probably yes, but we do not have the exact numbers. Those materials do not need to be mined, the recycling chain does require extra resources. In the end there will be a win in terms of CO2 reduction but we

do not know exactly how much.
Researcher: Do you think this information will create extra value or will be more important in the future?
ABC: If this reduction can be clearly quantified this will surely have an added value for different stakeholders. CO2 taxes are being introduced everywhere. The frontrunners in this area will have gain a benefit in the future. But this reduction needs to be easy presentable and transparent in its calculation.
Researcher: Do you feel that government needs to implemented regulations to prevent greenwashing?
ABC: On the one hand, we feel that governments are already creating to much regulations making processes too complicated. Government regulation are welcomed, as long as they have a positive impact, are easy to interpret and do not pose a competitive disadvantage on a global scale.
Researcher: Is there enough scrap steel available in Europe?
ABC: Due to the shift of the make industry to countries outside Europe, steel parts and products are being imported on a larger scale. 90% of our products are exported. From a European point of view we need to make sure we can meet our own need for finished steel products and export a part as well.
Researcher: Can you specify the amount of recycled material in your supplied products?
ABC: This information is available through our factories. We supply our factories with scrap materials and they sent new parts back to us. Our factories are able to provide us with this information.
Researcher: Does this require extra costs or resources?
ABC: Extra costs that occur with the recycling of old engines are, dismantling costs (2-3% of the new build price), transport costs, and sawing costs. Totalling towards 5-10% of the new build price. Sawing costs occur when parts need to be cut small enough to fit through the openings of the melting installations.
Researcher: At this point the factory can provide the exact amount of recycled material?
ABC: Yes.
Researcher: Will engines cost more when using recycled materials?
ABC: If an engine is build out of 100% recycled material, this will have a significant effect on the cost. Currently our customers are not willing to carry this cost. If this can be accompanied by a proven CO2 cost reduction, there would be an interest.
Researcher: A CO2 reduction during fabrication, however, only benefits you as the manufacturer directly. For your customer this falls under scope 3 emission reduction.
ABC: True, for our customers it is indeed a sustainability improvement but I think they will be able to use this information for an overall CO2 reduction for the ship. For example this will increase their bid to receive financing since the financial sector is also looking more into the sustainability of their projects.
Researcher: Is there anything you would like to add?
ABC: Interesting stakeholders, for this subject, are the breakyard Galloo and the financial sector. They play an important role in this matter as an enabler. They can implement conditions for financing.

B.2. ABN AMRO

Researcher: Are the poseidon principles only focused on the use Phase?
ABN AMRO: The footprint of the building phase is only about 2-3% compared to the use phase. The poseidon principles are focused on how much and which emissions a ship emits during sailing, during the use phase. There is an obligation currently due to the IMO to keep track of the fuel and ballast usage during the ships' voyages. Poseidon principles work with a trajectory for meeting certain goals over time. We try to manage our collateral fleet to meeting those goals. We don't look into the single ships but we do advise on managing the entire fleet we finance and look into the greenhouse gas rating the entire fleet has. The poseidon principles are an important initiative in the sense that it's based on actual measurements and it creates more awareness in the maritime sector. It's still in its early stages. Results are only available now for two years.
Researcher: Are there better terms for green financing?
ABN AMRO: Yes, it is clear that the European Central Bank is incorporating sustainability risks in credit risks. The sustainability footprint (ESG) is important to us as a bank. On the one hand we are improving our understanding of these issues more and more and engaging with our clients into a dialogue, trying to incentivise them and make them adopt a proactive approach towards sustainability. Sustainability linked loans is a perfect example of this. On the other hand we see that the sustainable finance regulations are pushing the financial institutions in Europe to achieve significant steps forward. If we finance too many projects without a sustainable character, we will need to carry more capital on our own, which is not preferable for our position as a bank. Therefore, we can push our customers towards sustainable practices. If they refuse, the consequences are that the loans provided for them are too expensive and that we might not want to finance these projects anymore. ABN AMRO has three strategic pillars, sustainability is one of these three pillars.
Researcher: Is there consensus in the terminology end definitions about sustainability?
ABN AMRO: We are a bank, and interest in sustainability risk has only become important over the last few years. Before we looked a little bit at the emissions, if the ship came from a reputable yard and if there was some awareness about the environment with our customers. There was a global sustainability rate index. In the we are a B2B industry. Shipping is still relatively far from the end consumer. But this is changing, for example the container industry sees a big shift in interest in the ESG story. We have started a few years ago with the sustainable recycling standards as we find the ship breaking practices in South-East Asia unacceptable. Our shipping portfolio is being evaluated with a climate stress test. At the moment this is a difficult task and it is hard to predict how our portfolio will change due to this climate stress analysis in the long term. This is also due to the fact that ships have a long lifetime. This evolution is an ongoing process and the results are hard to predict. On the short term the focus is about the energy transition and which fuel type will replace the fossil fuels.
Researcher: Do the classification societies have an important role in preventing greenwashing?
ABN AMRO: Yes, all the data related to the poseidon pinciples are verified by classification societies. Shipowners data passes through third party verification companies before being used.
Researcher: How does ABN AMRO evaluate projects seeking financing when they claim to use new innovative green technologies?
ABN AMRO: As a bank, we look at two different things. We take the credit risks and we want as least as depreciations as possible on our loans. To achieve this we have certain policies. Based on this policies we evaluate our customers on their solvency related to the market in which they operate. We assess the business and financial risks. We assess how companies can mitigate these risks and how they have dealt with these risks in the past. The next step is to look at the sustainability elements. If a customer wants financing for new projects using recycled steel, this aspect will definitely be an enhancing argument but this falls under the technical details in our view. Our number one and two priorities are the client and the market in which they operate. We check their expertise, experience, track record and market position. Another important aspect of our assessment is the collateral, the ships themselves. Here we perform standard checks, if the ships come from a reputable yard, the age, dockings, relevant class papers, etc.
Researcher: How does ABN AMRO's portfolio look like like?
ABN AMRO: The major part consists of refinancing or purchase of existing ships. Only 10-15% is estimated to be new build projects. About ten years ago there was still more need for pre-delivery financing (50% payment before delivery). Since 5 or 6 years ago, only 10% of pre-financing was asked by the yards. So then we dealt with post-delivery financing most of the time. In that case we have no influence on the type of project.

Researcher: What is the ratio between green and grey financing in the maritime sector?
ABN AMRO: Since 3 years we see the sustainably linked loans where incentives are incorporated, for example due to reduced emissions or improved safety for crews. These are validated externally and could result in reduced interest rates.
Researcher: What advantage does ABN AMRO get by providing sustainably linked loans?
ABN AMRO: These 'green loans' can give us advantages in attracting capital. Our public opinion matters, we are also monitored by NGO's. You don't want to be the last student of the class. Our strategy and slogan 'Better banking for generations to come' has to be backed by actions as well. It's part of our commercial DNA. That being said, it is difficult to change an existing fleet. We try to influence our clients by adding incentives for efforts into improving sustainability. But these are still relative small incentives.
Researcher: Will these incentives become more important in the future?
ABN AMRO: If sustainable financial regulation are being implemented more and more, over time GHG emissions will cost more, also to the financers. So yes, they will become more important.
Researcher: How is ESG reporting influencing or impacting the financial sector?
ABN AMRO: Our core business and way of operating stays the same. We need to mitigate the risks for the loans we provide. Loans that have a typical lifespan of 5 to 7 years. Slowly but surely we see ESG reporting claiming attention like an incoming big oiltanker. How quickly and in what extent this will change the sector, is hard to predict.
Researcher: Should there be more collaboration between different stakeholders, creating more opportunities for the CE in the Maritime sector?
ABN AMRO: The maritime sector is traditionally a conservative industry which moves reactively to new innovations. The IMO has proven over the years not to be very effective. Improvements will probably come from the demand side with big companies at the consumer side like for example Nike and Ikea, demanding more action on the sustainability front.

B.3. Arcelor Mittal

Researcher: Is scrap steel already used as an input in the two major steel fabrication processes, BOF and EAF?
AM (Arcelor Mittal): Yes absolutely, there are two major processes. The traditional blast furnace route can use up to 30% scrap steel depending on the product that needs to be manufactured. The second process is the Electric arc furnace route. This can be fed with 100% scrap but it can also be fed with DRI which is directly reduced iron. It can be a mix of DRI and scrap. Most EAF processes worldwide use 100% scrap.
Researcher: Do you share this information already with the buyers of the products?
AM: I would say that, historically, we have not yet differentiated between products that are made with the EAF route or products that are made by the blast furnace, direct iron ore route. We make the same product sometimes with the two different mills, with the two different processes. It was not really in our culture to specify the route but we are also sensing more and more, sustainability is an issue and carbon footprint is becoming very important to our customers. We are putting more emphasis on being able to supply steel that has a low carbon footprint, which is clearly the case if we use electric arc furnace with scrap. More and more we are using the advantages of the electric arc furnace route to produce more sustainable steel. Also for the blast furnace route we have put in place major ambitions to reduce our carbon footprint. We have aligned our CO2 emission ambitions with those that have been decided in Europe and AM as a company is planning to be CO2 neutral by 2050. That means, on the blast furnace route there will be some major investments to reduce the carbon emissions.
Researcher: How can you reduce the carbon footprint of the blast furnace route?
AM: At the moment the carbon emissions are coming from the use of coke in the blast furnace. We are working on a number of bio fuels or alternative fuels that are being produced in renewable ways, for example from waste products. Also by replacing the blast furnace completely by the DRI process. When making steel you have to separate the oxygen from the iron, so you have to reduce the iron ore. You can either do that by adding coke which will bind oxygen with carbon and cause CO2 emissions or you can do it with hydrogen. So if you use hydrogen as a fuel in a DRI installation, you can separate the oxygen from the iron and produce water and have a completely CO2 neutral production process. One of our plans is to change the blast furnace process to the DRI process based on the use of green hydrogen. We have projects in many different countries, Germany, Spain, Belgium, and the intention is to produce green hydrogen with renewable energy, for example with wind energy at our coastal plants and then use that hydrogen in the DRI plants to produce iron with zero carbon footprint.
Researcher: When using scrap steel, is there a degradation occurring when making steel products?
AM: It is not quite the same because there are some residual elements in the steel scrap. That is why, historically, the blast furnace route has been used a lot for flat products, especially for automotive products, which need to be very pure and scrap route has been used more for construction products, more for beams or re-bar for example. It depends on the grade of the plate. For the highly critical applications, like automotive, it is not possible to use scrap. There, currently we have to use the blast furnace and in future it will be the green DRI route, which produces a much more clean steel without the residuals. In construction products, the residuals that are in the steel are absolutely no problem. When you are rolling it out to very thin sheets to half a millimeter, you can not the do this with sufficient quality when there are residuals in the steel.
Researcher: But for plates used in shipbuilding, the residuals do not pose a problem?
AM: I am not that familiar with shipbuilding grades but I would say for plates it is not really an issue, because we have plate mills currently that are running with electric arc furnace.
Researcher: How accurately can you describe the amount of recycled material used?
AM: I would say, if we are running an EAF with scrap, it is 97-98% recycled. The remaining 2 or 3% will be alloying elements that are added in the process. We can say fairly accurately 97% recycled.
Researcher: Hoe is this measured? Is it quantified in volumes or in weights?
AM: On weight. We are weighing everything that goes into the process. The scrap is being weighed before it enters the electric arc furnace process. Based on that we can calculate the percentage.
Researcher: This is already monitored?
AM: Yes because it is part of the production process. It is therefore easy to calculate the percentage of recycled material because we know all the inputs per lot.
Researcher: One lot is how much steel?
AM: One lot is about 150 tons of steel.
Researcher: CO2 emissions are about 1.85 tons per ton steel produced in BOF and 0.65 tons per ton steel

produced in EAF. Are these numbers correct?
AM: Yes, that's roughly accurate. It depends whether they include the carbon emissions from the electricity or not.
Researcher: No, because they can vary?
AM: Also in the electric ar furnace you are not only using electricity. You are using a mix from electricity and natural gas. Typically you would have 0% of the energy coming from electricity and 30% coming from natural gas, but these can vary. So the 0.65 is a little bit on the high side. My estimation is 0.4 to 0.5, but it depends really on how you mange this energy mix.
Researcher: For a sustainability point of view this can be a significant difference.
AM: Yes, indeed.
Researcher: A selling point for your customers?
AM: Absolutely and what we are doing at AM, what we are offering to our customers is the specific sourcing of an energy mix that is certified. Then we can get a footprint as low as 0,3 to 0,5.
Researcher: This comes at a cost, I assume?
AM: Yes, at the moment there is a slightly higher cost to that but I think in the future as our share into renewables grows, I hope it will become more normalised.
Researcher: Ordering according to a specific energy mix is possible, would it be possible to order according to a specified amount of recycled material?
AM: That will be a little more tricky. The products we offer through our EAF rout, we already know that it is 100% scrap. I am not sure whether the producer will be able to meet a specified percentage of recycled material, there too many constraints on the production process. I can't speak for my colleagues that are in the plate business. I expect that that would be a little bit complicated.
Researcher: And what about a specified range?
AM: I am not sure if this is possible at the moment. I do think that if the market is expecting something, the producers will have to follow.
Researcher: Is there any interest at the moment?
AM: We are certainly seeing, that in some cases, customers are really looking for products with a low carbon footprint. It is not the majority but we expect it to increase. To be sustainable, it doesn't necessarily mean recycling. A sustainable carbon neutral solution is also possible with the current developments of the DRI route using green hydrogen. It cam be carbon neutral, even when there is no recycling. In the future steel can also be sustainably produced without the use of scrap.
Researcher: But then it is not sustainable in the sense that you are still depleting the earths resources?
AM: Yes you are still using iron ore. But there is only a certain amount of scrap steel available. You can see this curve that shows the availability of scrap. You have the worldwide steel production curve and following behind is the scrap availability curve. We assume that steel has an average lifespan of 30 yrs. So on average 30 yrs after the initial steel is produced, it becomes available as scrap. But the scrap is following behind the steel production. So you need some kind of primary steel production from iron to have the scrap available in the future.
Researcher: But it is safe to say that all the steel is being recycled these days?
AM: Yes, the vast majority is recycled. It is magnetic, it makes the separating easy.
Researcher: No quality issues?
AM: Only for the car industry there will always be those quality issues.
Researcher: Is there enough scrap steel available in Europe?
AM: Yes it is available but it the price follows market rules so if iron ore is expensive, the scrap dealers will try to get more money for their scrap. It is available but the price can fluctuate enormously.
Researcher: Products made from scrap steel will consequently also fluctuate then?
AM: Yes, like all products. They are basically following the market tendencies for iron ore.
David: At the moment there is no price differentiation between products made from primary steel and made from scrap steel?
AM: At the moment not, most producers still have sufficient CO2 quota's. But in the future, in Europe, if they have to spend more to purchase CO2 quota's, the blast furnace will become more expensive.
Researcher: A win for sustainability?
AM: For sustainability yes. This is what the regulators try to do. Force sustainability by making CO2 emissions expensive.
Researcher: Can you influence your customers downstream?
AM: We are offering all kind of different products, but in the end they decide what they want. We are seeing

that our customers are looking more and more for an element of sustainability in the products that they purchase.

Researcher: What barriers am I missing from you r point of view?

AM: The barriers for me are the availability of scrap, we have to be conscious there will always be a need for the production of primary steel. So as an industry we have to work also on making the primary steel production sustainable and not only focusing on the recycling of scrap steel.

Researcher: Which different energy mixes are you able to provide to your customers?

AM: We do not specify the energy mixes with our customers, except when they are requesting the use of renewable energy. Then we will certify that we have purchased renewable energy for their production. We also have our own ambition in our decarbonisation plan. There we are also looking to decarbonise our own energy source.

Researcher: A third party certifies the energy mix for those customers?

AM: Yes, we have a system of sourcing for renewable energy that is audited and certified so that we can prove this to our customers. On the test certificate that our customers will receive for their steel, it shows that it is produced with renewable energy. This is audited and certified.

Researcher: Given the fact that you are using scrap steel already for a long time, this is not a selling point for you?

AM: I would say that recycling for us is one element of our strategy to be sustainable but it is not the only one. Historically, it was not commercialised. If the same product is being produced from two different mills with two different routes, you do not necessarily want to draw attention to that fact, because you don't want customers say "we want to product from that specific mill or route". We as AM want to sell our product from our most convenient mill at the same price. The industry did not necessarily want to emphasize too much that recycling is going on because roughly only 30% of the steel worldwide is being produced by the EAF route. If everyone wants the recycled product, what will you do with the remaining 70% that is produced with by blast furnace. The last two years, however, the discussion has become much more public with all the decarbonisation that is going on. In the past there was no incentive to sell these products in different ways.

Researcher: What other strategies do you have for sustainability?

AM: What we have for certain products, are environmental product declarations. These give the carbon footprint for certain products. AM launched Xcarb as a brand last year. This is our low carbon brand. Certain product that we produce are produce with Xcarb brand which means that they are recycled and produced with renewable energy. This is not currently available for all products because some products at the moment are only available through the blast furnace route. This was a request from the market, more specifically from the building construction market. I don't know if this exists for plates that are used in shipbuilding.

B.4. Arcelor Mittal Spain (follow-up questions steel plates)

Researcher: Which route is mostly used for the producing steel plates? How much scrap steel is currently used in this route?

AM: There is only one steel plate mill in ArcelorMittal Europe, located in Gijon (Spain), it produces plates for different sectors depending on final chemistry or mechanical performances requirements (wind turbine, pressure vessels, structural applications, shipbuilding & others), all the plates follow same route (raw material goes to Blast furnace +steel shop continuous casting + Hot rolled quarto plate mill), around 20% of scrap is used on this process whatever the final use of the plate. Please find attached a diagram in order you can understand the flow. See figure B.1

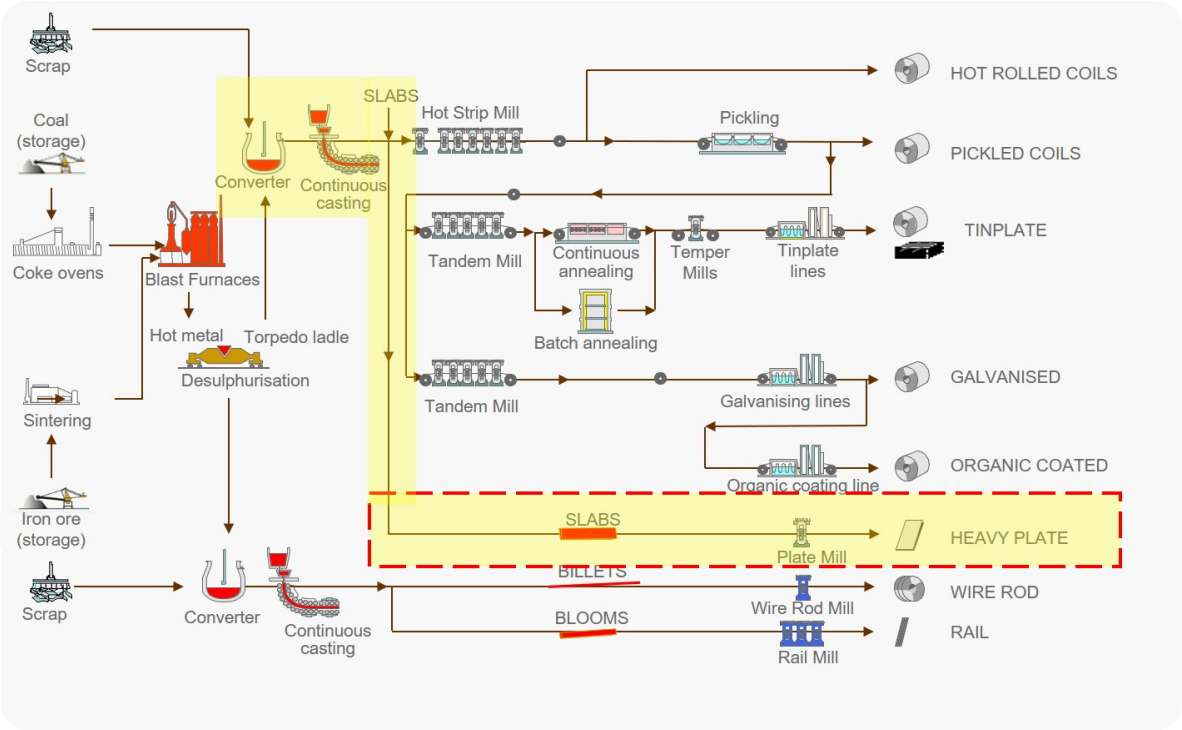

Figure B.1: steel production flow diagram

Researcher: Is it technically possible to operate a steel plate mill using the EAF route?

AM: Yes in fact the green future for the Gijon mill should be DRI +EAF Route (But nowadays we have no confirmation for that)

Researcher: Is your Xcarb brand also available for steel plates in the shipbuilding industry?

AM: Yes, Xcarb offer is available for all industry product types.

Researcher: Is the batch size of 150 tonnes a general number or does this vary with different plants?

AM: If speaking about production batch, batch size is different from plant to plant. Average is around 300t (270t for Avilés which is the steel shop which provides material to Gijon plate mill).

Researcher: How quickly do you expect green hydrogen plants will be able to deliver a significant amount of steel?

AM: We don't know exactly,Very difficult to have an answer here as Green Hydrogen infrastructures are on development (it will depend on the country in which the mill is located).

B.5. Damen Shipyards

Researcher: On the subject of the use of recycled steel in shipbuilding, I learned that there is already a lot of scrap steel used for the fabrication of steel products, but this information is not known and/or reported.
DAMEN: Exactly, this is something i see as well. I contacted the steel manufacturers and they don't have the exact numbers of how much steel is virgin and how much is non-virgin. They only have an assumption.
Researcher: How does the yard order the steel they need?
DAMEN: It depends a lot on the yards. They are responsible to contact the steel manufacturer. Most of the time they get it locally. Our yard in Poland will get it from a local manufacturer.
Researcher: Is it project based?
DAMEN: Yes, the steel is ordered after the vessel is ordered. We try to use the resources efficiently.
Researcher: Is there room on the yard for more separation between plates that have different recycled steel content?
DAMEN: I know that we are separating the different grades. Also in the documents.
Researcher: Is there enough room to facilitate more separation?
DAMEN: Since the yard is working project based. So it depends on the customer. In terms of capacity on the yard, I don't know.
Researcher: Did you already encounter this question from customers about using recycled steel?
DAMEN: I was responsible for finding the recycled steel content for the ferry, for assessing the circularity. I don't know if our clients already want to know this. I don't think it is one of the requirements on sustainability they are asking yet. For this purpose I wanted to know the composition of the steel, so how much is coming from virgin and non-virgin but I couldn't find the precise information. The yard manager told that it could be from 5 to 95% and it is assumed to be 20% coming from recycled steel. It's hard to get this information from the steel manufacturer since they have a secret recipe for manufacturing their products. But we are trying to create more transparency in the supply chain to get this kind of information, because we want to find out more about the circularity of our vessels.
Researcher: So the main struggle is the lack of information coming from the steel supplier?
DAMEN: Yes, I think it depends a lot from where you get you your steel if you want to know the composition. At Damen we want the high quality steel and it is harder to get this high quality steel with non-virgin feedstock.
Researcher: Do you think it would be a good selling point if you can build your ships with recycled steel?
DAMEN: Yes, clients are starting to care more and more about sustainability requirements. We also see that in tenders documents they are asking for sustainability and circularity requirements. So I think it would be a good selling point if we know the percentage of recycled steel used. Especially if you consider that the ship mostly consists out of steel. 80% of your vessel is then recycled, it's quite circular. It is a good selling point and we are doing research on this. That's why I am working as an intern now on the circularity of the current vessels. It is of great interest to Damen to know the circularity of their vessels.
Researcher: Why do you need to know more about the circularity? Is the information important for the CO2 data?
DAMEN: For the circularity, we don't take into consideration the CO2 emission from the steel manufacturing process. We are just assessing if the steel is virgin or non-virgin.
Researcher: Why is the use of recycled steel positive for circularity?
DAMEN: For the virgin material we would have to use finite resources that we are depleting more.
Researcher: What about the energy supply for the steel manufacturers (scope 3 emissions)?
DAMEN: This is an interesting discussion point for the CO2 emissions indeed. That's why we are getting the steel from local suppliers so that we don't have to transport it too far. Most of the time the steel manufacturers in Turkey or Poland use non-renewable energy. That is true. The best cast would be that we choose manufacturers that use non-virgin feedstock and renewable energy to produce their steel, but we don't have that yet. It is hard to have both.
Researcher: Do you think customers are willing to pay more for a ship made from recycled steel?
DAMEN: I don't know if they would pay more, but I think that because of the regulations in Europe are changing that in the future more steel we are using for the production in Europe comes from the recycled feedstock. We will be obliged to have a percentage form our steel coming from the recycled feedstock. Customers are already interested in sustainable requirements so they might be willing to pay a bit more for recycled steel as well.
Researcher: Do you expect there to be regulations regarding this subject in the future?

DAMEN: I think that governments can provide a framework to promote the recycling of steel. Recycled steel will then be part of the market. It can, however, not be achieved by Damen alone. We need guidelines for this. Asking recycled steel at our suppliers would work better if there would be guidelines and all companies would do this.

Researcher: But it can be a competitive advantage to be the only one providing ships made with recycled steel?

DAMEN: Indeed, that's why we are trying to assess our circularity and where we can improve. If you want to make your vessel circular, you start with the steel. But the recycling at the EOL of the ship is also very important for circularity. We need to make sure that this ship will b e recycled as well. The infrastructure is not there yet. Most of the vessels are scrapped now these days. We have little power here since this is a decision from the shipowner. We are trying to find ways how we can monitor the vessel over its whole lifecycle.

Researcher: Any evolution on the monitoring of the vessel over its lifetime yet?

DAMEN: This is very difficult. As far as I know, they install monitors and sensors to keep track of the vessel. Also new circular business models are being discussed to buy the ships back at the end of their life cycle.

Researcher: What other possibilities do you see in the 9R framework?

DAMEN: Circular business models, leasing models. If we keep ownership of our vessels, we can monitor that these vessels do not deteriorate very fast, Customers can lease the ship. The feasibility of these models is being investigated.

Researcher: What about reusing parts of a ship and designing for this purpose?

DAMEN: Yes we are trying to incorporate circular design principles in the design phase. Standardisation, easier assembly and disassembly, material choices, the use of non-virgin materials and EOL are all taken more and more into account during the design phase. For the interior design, Damen tries to work with circular companies. Companies have to take back and recycle their products at the EOL phase.

Researcher: It's a win-win for all stakeholders in the value chain.

DAMEN: Yes it's very important to engage the suppliers in this sustainable journey. We want to provide the most sustainable maritime solution but to achieve that we need the transparency from our suppliers. This is one of the steps we are taking now. We need the suppliers to provide us the information but also help them becoming more circular and sustainable themselves. This way we can reach a more sustainable supply chain.

Researcher: What is the barrier in this task?

DAMEN: It is a lot of work because we have thousands of suppliers. We have yards all over the world so the suppliers are located all over the world. They have different standards and cultures so we can't use a straightforward solution for all of them. For example we have to approach our suppliers in Europe and Asia differently. This way it is not an easy task to make our supply chain more sustainable.

Researcher: Are you able to use this as a leverage to choose different suppliers?

DAMEN: I am not sure, it depends on our purchasers in the future. If the regulations become stricter and it becomes a restriction for us, then yes. Now I don't think we can use it as a leverage.

Researcher: How about the companies' vision?

DAMEN: It becomes more important to know more about the materials being used. We want to sell high quality vessels to our clients and we want to provide the information about the circularity as well.

Researcher: Do you miss a general approach or consensus to assess sustainability?

DAMEN: Yes, there is no standard, common accepted way to assess sustainability. There are also so many different tools to assess circularity. It depends on the industry, the company. It is still very complicated for the companies and the clients. Different tools can have different results. Also which aspects that are taking into account differ very much for different tools.

Researcher: How about the ESG reporting?

DAMEN: We are busy on that. We have a material matrix in our CSR report. We know our material issues and we are assessing how they are affecting our business and how we can mitigate these risks and where are our opportunities. In terms of circular economy, we are part of the capital equipment coalition and working on circular economy together with other big companies.

Researcher: Which stakeholder can influence sustainability improvements the most?

DAMEN: It has to be a combination of multiple stakeholders. The government has to provide the framework. The client/shipowner can have the most impact. It is there responsibility what kind of vessel they order and how they use. Its about different actors that have different responsibilities. In the end the client chooses the vessel.

Researcher: What about financial institutions?
DAMEN: Yes they have more power and influence in how green shipping will become. Financial institutions are giving better loans to shipowners to make them buy greener ships.
Researcher: How can we prevent greenwashing?
DAMEN: At Damen we are trying to be very careful to prevent greenwashing. Our approach is realistic and the facts in our CSR reports are factual and correct. We are aware of the risks of greenwashing and we try to eliminate this risk.
Researcher: Looking at the practicality of the shipbuilding process, if many parts of the ship have different recycled steel content, how can we trace these parts and accurately define the final percentage of recycled steel used? Is it possible to do this by using CAD programming?
DAMEN: We are doing life cycle assessment for some of the materials, so they do have the information for the inventory. I assume that the documents for the full inventory are available. They are working on this because they want to know the percentage of recyclability.
Researcher: The yards knows this information however?
DAMEN: Yes the yard has the full material inventory in documents. The recyclability of each material is not there yet, but there is the intention to know this for all materials. It is assumed that 20% of all materials to come from non-virgin feed stock.
Researcher: Do you think customers have a benefit by knowing the total inventory of their ships' materials?
DAMEN: We provide the IHM, inventory of the Hazardous Materials. They have all the information about the other materials, so it is possible to provide this to the customers.
Researcher: Could it be advantageous for the recycling phase?
DAMEN: If we know what type of materials we use in the ship, we can predict the recycleability. For example for steel we know that it is fully recyclable.
Researcher: A full inventory can thus be provided?
DAMEN: We have the documents of what goes into the vessel, we know how it is built, we have the design, we have access to the ERP program, all components that actually go into the vessel are known, so I assume we can give a full inventory to our customers.
Researcher: It's already a big step.
DAMEN: Yes, it's already clearly possible to make a material breakdown of the ship and calculate the potential recyclability. But it is not yet possible to see what materials are virgin and non-virgin. It is very difficult to calculate how circular our outflow is going to be. We don't know what happens at the end of life. For now we try to change the circularity at the inflow. Other initiatives we have are repair follow up services, life time extension services. our vessels are built in a way that they are easily maintained or adapted during their lifetime.
Researcher: What is the main barrier in sustainability and circularity improvements?
DAMEN: The transparency between the different stakeholders is a big issue. The mindset is not changed yet. Most of our suppliers don't have a sustainability or circularity strategy. It is difficult to find a way to engage the suppliers in the sustainability journey. It's very important to have the suppliers on board. In order to improve our own sustainability we need their help, their input. Transparency is very important towards our clients as well. That is one of our struggles. We need a platform where our suppliers can engage and be more transparent.
Researcher: Can this process be automated by using some sort of platform?
DAMEN: We are working on that right now, to have a platform for our suppliers to engage. We are discussing this. The difficulty is that there are so many variables, clients, stakeholders, requirements, ship types, etc. We need to aspire our suppliers, we need to show them why it is important for us and for them and what benefits this will bring.
Researcher: How do you sell this story?
DAMEN: We could make sure we keep buying at these suppliers that follow us in these ambitions. With some suppliers of course we will have more or less leverage. But it is a story about collaborations between many different stakeholders to achieve the common goal of improving sustainability and circularity.
Researcher: You see opportunities in the use of recycled steel?
DAMEN: Yes. We don't have finite resources so we need to investigate how we can reuse and recycle our resources at this moment. There might occur problems in the future with the sourcing of different materials. We can see already problems in the supply of some materials now.

B.6. DEME

Researcher: How do you define ESG, sustainability, circular economy?
DEME: This has environmental and social aspects. We use the SDG framework. We created 7 programs based on surveys, performed with our stakeholders. Waste and resources management, climate and energy, diversity are examples of these programs. Circularity in the industry is on the rise. Emissions is at this moment the number one topic of interest. Circularity follows in a second place. Circularity, however, can be found in smaller more local initiatives. More focus is being made towards the re-use of tools and equipment where possible. Re-use of sea fastenings and cables for example. Practical and economical solutions can also be seen as circular as this creates less waste. Design of equipment that can be used for multiple projects. Communication about the circularity is not on the agenda at the moment.
Researcher: A ship, with a proven recycled content, has a CO2 reduction from the resources and building phase. This reduction is part of your scope 3 emissions. How will you be able to use this information in your advantage?
DEME: The goal is to become more sustainable. We want to be front runners in this area. It will be key in the future to prove our sustainability with numbers and scores. We are starting with projects to map and control the emissions related to our activities. Steel and concrete are our major focus points. together with the emissions of our ships and the cables which we buy. Our second focus is to look at our complete supply chains. We are evaluating the way to score our stakeholders, agencies that can provide us with scores. Which tools can we use? We are looking to address this subject with a standard that can be used for all stakeholders all over the world. Parallels can be seen with the sift towards safety and the standards that have evolved to tackle the safety issues worldwide in the industry.
For future ships, if we are presented we the choice to opt for green steel, we would pick that option. We are prepared to pay more for ships, made from recycled steel, if our customers are prepared to do so. As long as the profit is guaranteed. We want to be able to present the option to our customers and be front runners in that perspective. We will see a change in mindset by doings so.
CO2 ladder in The Netherlands is a very good system but complex and too much paperwork. It is a transactional system. We need a system that is transparent and evaluates vendors or stakeholders in a way that they are comparable.
Researcher: Our mission is to provide the information about the recycled content of the products (like engines from ABC or ships,...). Is DEME interested in this kind of information and why?
DEME: We need to be prepared for future evolutions. We need to look forward to future demands in tenders. Therefore this information is important. We need to be front runners. Car wrecks are already being used as resources for steel making. However, so far we did not use this argument for being sustainable. Corrosion prevention, resource management in windmills are examples of arguments. We are busy and interested in different ways to be sustainable.
We buy a lot of steel, cranes, foundations, cables, etc, We need to know if quality can be maintained.
Researcher: Quality is being checked separately in certificates. There is no issue in that sense. Standards need to be maintained at all costs. NR 216 from BV states all requirements.
DEME: No steel suppliers have as of yet offered steel with recycled steel contents. This is why I wonder if this is qualitatively important. If this process is possible, in my view the recycling has huge potential from a sustainability perspective. Think about entire windmill parks that can be recycled to make new ones, etc.
Researcher: There are two processes in steel making, BOF an EAF. EAF is capable of using 100% scrap steel in the input. So far the information is just not being provided.
DEME: In case this is possible, then we want to have this discussion in our supply chain. If quantification and valorisation can be proven, this can give us a quantifiable advantage. Tenders these days in different countries are demanding more and more sustainability efforts. At the moment most of these efforts don't have to be quantified but this is changing and in the future will surely be the case. The CO2-ladder is an example that does require quantification. We want to be able to provide our customers with the choice and this choice needs to be quantified and transparent, therefore we are surely interested in the possibility to have certificates that prove the recycled content of steel of our ships.
Researcher: Are you prepared to choose for these certificates, without knowing for sure whether your customers will pay for it.?
DEME: We need to be prepared for this case. As long as we have a clear case that we can prove and we are convinced about the sustainability. We want to present a case systematically to all our customers that proves the sustainability with clear, transparent facts and figures.
Researcher: Is the financial sector looking for or demanding for evolutions like this?

DEME: Yes, absolutely. The European Investments Bank in Luxembourg and other funds are focusing a lot more on green investments. Investments are on a high and green investments are on a high. With proven facts and figures investments will be lining up. For green evolution, we want to be front runners but also be transparent so that it is a successful global improvement. Financial institutions are providing better loans for greener projects.

Researcher: Is it your expectation that the use of recycled steel, as a project, will be more expensive?

DEME: The project and investment will be more expensive, financing will be cheaper, and in future it will be the 'correct' investment. I expect governments national and international will pick up similar demands and require for example a minimum use of recycled materials. Logically ships will cost more but all customers will pay equally more for sustainable projects.

Researcher: What barriers do you still see for the use of recycled steel in shipbuilding?

DEME: The most important barrier is that there is no level playing field yet, but we need to keep raising the bar and be prepared to raise the bar. Green will be the norm the next generation so we have no choice to evolve towards these projects. Then it only makes sense to start now and be front runners so we can reap the benefits before the competition follows.

Researcher: With offering contracts to your customers, which factors play a role in this case.? Is the reduced CO2 use the biggest selling point?

DEME: Our customers are definitely looking for tangible information like reduced CO2 content. Maybe this case will become cheaper or more efficient. Parallel with the safety issues a few decades ago, safety was considered only as a cost for companies. The evolution, however, showed a reduced cost due to less accidents and the aftermath of those accidents. This will possibly be the same evolution in the sustainability issue. First it will cost more and governments will have to bridge the gap with subsidies but on the long term these investments will pay off. Subsidies in Europe for offshore and wind farms created experience as an export product for European companies.

Researcher: Is there anything you would like to add?

DEME: There is a lot of interest in sustainability but it is still a conservative industry. It is still hard to convince everyone of the importance of improving the sustainability. Therefore it is important to create more awareness and the best way to go forard and get results is by using facts.

Researcher: What other sectors can be examples for the maritime sector?

DEME: We look more at first movers like Ikea, Maersk, Urstead, ... Companies that make statements and dare to move ahead before everyone else.

B.7. EDR Antwerp Shipyard

Researcher: EDR is a ship repair yard. What are your main activities?
EDR: EDR has a spare part department for ships worldwide. Next we do maintenance work during the operation of ships. Due to corona, this work has gone down considerably. We perform maintenance in ports in Antwerp, Rotterdam, Germany, France, Italy and even in other continents. All this activities cover, on average, 50% of our revenue. The remaining part consists of work at our shipyard, being maintenance and repair work at our quay and in our dry dock. Repair work consists of cleaning and painting of the hull, replacement of steel sections, repair to electrical and mechanical components. Everything until for example the adjustment of radars.
Researcher: How much new steel is typically needed for a single ship repair?
EDR: At the moment we have an exceptional case in our dry dock that requires the replacement of 240 tonnes of steel. This is exceptional, on average this number will be about 30-40 tonnes. Repairs in port will amount to 1 ton on average.
Researcher: What do you mean with repairs in port?
EDR: Repairs in port are usually small repairs for which the ship spends 1 to 3 days alongside the quay. These are small steel repairs adding up to 3-4 tonnes on average. These damages can be the result of collision or stormy weather for example.
Researcher: Do you have a stockpile of steel or does it needs to be ordered per project?
EDR: Before COVID we had 400-500 tonnes of steel on stock. since the start of COVID we increased our stock due to high prices and market scarcity to 1300-1400 tonnes. Compared to other yards, this is a lot and other yards regularly try to buy from us. In the ship repair business, our aim is to be competitive and offer a quick service to our customers. Not having steel on stock can drastically delay the time needed to repair a ship, especially when it concerns an emergency.
Researcher: What happens with the steel cut from the ship?
EDR: A ships' hull gets inspected for the required thickness. The areas that are not thick enough anymore due to rust are cut out, including some adjacent areas for the attachment (welding) of the new steel parts. This happens in accordance with the class surveyors. The old parts are sold to collectors who resell these to steel factories worldwide. These steel parts are still valued as high grade steels in many cases. Those scrap piles are often exported to Turkey, Egypt, India and China.
Researcher: Do you work with different steel suppliers?
EDR: Yes, For logistical and financial reasons. Our supply of steel comes form different companies in different countries. For example Spain, Turkey, Austria.
Researcher: Are there companies that mention the recycled content on the certificates?
EDR: No, and they will not provide this information because it's not in their interest. They want to sell all products without price differentiation.
Researcher: What if there is a specific demand from their clients?
EDR: If the industry demands it, yes then it could be possible. If everybody asks for this information.
Researcher: Is it possible to increase your steel stock on the yard with extra steel plates with a recycled content certification?
EDR: This would not be easy.
Researcher: Why not?
EDR: We already use 73 different steel grades of which we probably have 50 in stock. Assuming we would have a grey and a green plate for each grade, this would increase our workload and need for storage space. What would be our benefit? Probably there will be no difference in cost.
Researcher: Do you think there is a benefit for a ship owner to order a ship made with recycled steel?
EDR: At the moment, I don't think so. If EU or another organisation or country wants to help or support the industry for the use of reusables.
Researcher: What do you mean with helping?
EDR: Subsidies, just like the EU did with the wind industry.
EDR: This is also the business model for most of the Chinese yards. They take the old steel back and the yards are being subsidised. The costs of recycling are quite low because they are all subsidised. They attract a lot of business from all over the world to have scrap steel back in their foundries. They are importing huge quantities of scrap steel from all over the world.
Researcher: Because it is more advantageous to use scrap steel in foundries?
EDR: Less energy and the CO2 reduction because the raw materials need to be processed first to take out all of the pollution's before they can be melted into steel. I believe the use of scrap steel is already happening.

Researcher: Research and earlier interviews agree that it happens already but the information about the recycled steel content is not yet disclosed.
EDR: I believe the steel manufacturers do not want to sell recycled steel cheaper than virgin steel.
Researcher: Why would they have to sell it for less?
EDR: Because their cost is less, the customer expects a cheaper product then.
Researcher: The price could be higher because of the green label?
EDR: We will end up in the economic discussion once the demand from the market for green steel arrives. The profit for the steel manufacturers will be different for virgin and recycled steel products, but at the moment they are sold at the same price.
Researcher: Do you expect the environmental or sustainable incentive will increase over in the future?
EDR: I think this will be inevitable. 2030, CO2 free shipping? This is already very challenging.
Researcher: In ship repair, are you provided with clear documentation by the ship owner, for example cad files that make it easy to plan these repairs?
EDR: No, not at all.
Researcher: Do you document the amount and location of the steel repairs?
EDR: Yes, we have to make a detailed report including it has to be registered by the classification. and the reports have to be added to the ships files. Sometimes they get lost afterwards.
Researcher: They are kept hardcopy?
EDR: Yes, we keep it electronically but a ship usually has no server to store these files sop they keep them hardcopy and sometimes these files get lost.
Research: Is it easy to plan the repairs without having the proper documentation?
EDR: No it's not easy but you find out while you go along. We always get a general plan but the exact details are never clear. So we have to inspect and define together with the class surveyors the exact details.
Researcher: Clear documentations could save a lot of time for your work?
EDR: Indeed. Sometimes it poses specific challenges. For example when a repair asks for a specific type of steel and the client didn't ask for it in time, so we didn't order it in time. It creates extra delays. SO if green steel demand is added to this problem, it could create extra difficulties to get the right part of steel in the right place. This process will need more complicated planning for the ship building and ship repair.

B.8. Galloo

Researcher: How is the ship breaking sector doing?
GALLOO: In Turkey and Asia very good, but not in Europe.
Researcher: No positive effects from the SRR (Ship Recycling Regulation) in the EU?
GALLOO: No. We hoped for improvements when we obtained our EU license in 2015. We expected to increase our market share due to the changing regulations. What we see is that out of the 1.000.000 tons of ships that are scrapped, about 75.000 tons finds its way to European yards, 150.000 to 200.000 goes to EU approved yards in Turkey and the remaining tonnage ends up at non-EU regulated yards in Turkey or South-East Asia. About 80% of this European tonnage was illegally scrapped last year. According to EU law, shipowners performing this illegal practice can be prosecuted in court. The truth is however, that ship owners know how to bypass these regulations. They know to find the loopholes.
Researcher: Who can solve this problem?
GALLOO: The solution has to come from Europe, The European Commission says they have created the legal framework. In case of illegal activities it's the responsibility of the member states to act. A Shipowner who illegally scraps a Greek flagged ship, must be trialled in Greece for example. Then we see a division between the North-West European countries and the South European countries in the willingness to act on these shipowners. Northern countries are willing to pursue and trial these illegal activities, but countries like Cyprus, Malta and Greece have no incentive to do so. Last year, Greece accounted for the scrapping of 2.500.000 tons of illegal scrapping. (to compare, Galloo scraps about 25.000 to 30.000 tons in a year). There is enough tonnage to scrap in Europe but lacks enforcement of its own rules.
Researcher: Shipowners do this because the European market is not competitive?
GALLOO: Yes, for a vessel we offer about 25% compared to prices of yards in Asia. Only shipowners with a very sustainable mindset will opt for a European approved yard.
Researcher: Is the demand for scrap steel high in Europe?
GALLOO: Demand is very high. Europe needs about 170 million tons of steel. Only 1 million could potentially come from EOL ships. Demand is abundant.
Researcher: Where is the supply coming from?
GALLOO: Household material or regular scrapyards.
Researcher: What is your business model?
GALLOO: Mostly we buy the ship from the owners, break it down and sell the scrap. We are owners of the ship during scrapping.
Researcher: You have to receive an IHM according to current regulations. Would it be helpful for your activities if you have a full inventory of the ships' materials?
GALLOO: No, what matters are the hazardous materials. From experience we also know where to find the standard hazardous wastes. What is most important is to know the where and how much asbestos can be found on board. This is the most dangerous material for our workers and also costs the most the remove.
Researcher: Is the market for scrap steel volatile?
GALLOO: Yes, Over the last two years the price for scrap steel has doubled. It takes 6 months to a year to scrap a ship. Therefore, it is hard to predict the value of the scrap material when we buy ships for scrapping. In this market with rising prices we know we can make more profit but this can change instantly.
Researcher: Do you think this trend will keep rising, since demand is so high?
GALLOO: The market is too volatile to predict this.
Researcher: Who buys your scrapped materials?
GALLOO: Scrap material from ships is of high quality and finds its way to clients inside Europe. Lesser quality is for export like Egypt and Turkey. Europe had plans to ban these export from January 2022 but the powerful export lobby prevented this and have delayed this ruling by 3 years. With this regulation, Europe wants all waste materials to stay and be processed inside Europe. This however, could disrupt this industry. We need the export market. Turkey is not part of Europe and therefore part of the export market.
Researcher: This regulation would also have a negative impact on the scrap processing industry?
GALLOO: Yes, this regulation is part of the green deal and part of the efforts to increase the circular economy. This would significantly reduce our market. At the moment the European market can still compete with the export market. A ban on exports is not the way forward.
Researcher: Will scrap steel degrade when it is recycled?
GALLOO: We sort 260 different grades.
Researcher: that's very accurate sorting!
GALLOO: This is our strength. The better you sort, the more materials you can sell and then we end up with

less waste. In the car industry they used to only take out the steel for recycling, Nowadays 92-93% of the entire car gets recycled including plastics etc.
Researcher: This gives you a competitive advantage over other scrap yards?
GALLOO: Yes, GALLOO is state of the art in terms of recycling with an elaborate structure reducing our final waste to a bare minimum. Other scrap yards basically have to streams of which the remaining waste stream tends to be much larger than ours.
Researcher: Does this reflect in better prices for you?
GALLOO: The recycling process is also more expensive at our end. Recycling of the extra waste stream only generates a small extra revenue.
Researcher: Creating a competitive advantage?
GALLOO: This is more the result of our company philosophy. We want to pursue this green character in our business.
Researcher: An aspect that is gaining popularity and maybe valued more and more down and upstream?
GALLOO: No, the economical aspect is still the dominant and deciding factor in the scrap market.
Researcher: More precise sorting also doesn't help your business?
GALLOO: Quality norms are pre-determined. For the European market, scrap steel has a contamination condition of 0%. For the export market this is 1%.
Researcher: Both markets give a different price for scrap then?
GALLOO: The price difference is in relation to the extra effort needed to reduce the contamination levels.
Researcher: Different stakeholders in the ship building process are starting to see the value of sustainability. The ship recycling phase seems to lag behind in this discussion?
GALLOO: The biggest difference here can again be found between Northern and Southern Europe. Scandinavian countries are far ahead. South-European countries are not yet switching to this mindset. and are not forced to do so by European governments. Their lobby is too big and important.
Researcher: Worldwide this problem is even more visible i presume?
GALLOO: Last year 15 million tonnes of ships were scrapped worldwide of which the European flagged counted only for 1 million tonnes.
Researcher: Can we as an industry improve or make the recycling phase more efficient by collaborating more between different stakeholders? For example by designing a vessel in such a way that it's easier to dismantle?
GALLOO: Not too much. Ship builders have a different mindset. They often think that scrapping a ship is the reverse procedure of building a ship. But we basically turn ships into a large pile of scrap and sort it afterwards. This is for us the most efficient way of working, reducing the amount of manual labour to a minimum.
Researcher: Re-using is also no option?
GALLOO: In the past, re-using parts was common practice. These days re-using of materials and equipment is not possible anymore due to quality standards and due to the fact that equipment is quickly outdated. And our economy and society runs on consumption. The same goes for the maritime industry.
Researcher: Now we see changes in the environmental cost of products?
GALLOO: The discussion should be focused on retrofitting our old equipment instead of replacing our equipment. In many cases the impact on the environment will be smaller.
Researcher: Any ideas to increase the life span of ships and by doing so, reducing this impact?
GALLOO: No idea. Reasoning for scrapping depends on other criteria also like the market cycles and some companies include clauses that their technology must be destroyed when selling of vessels to prevent that their competition is able to acquire these ships. This way all ships have their own stories. Warships have longer lifespans because governments keep investing in them, these ships are not prone to an economic evaluation. The purpose is completely different.

B.9. Jan De Nul

Researcher: How do you define ESG, sustainability, circular economy?
JDN: Corporate social strategy within JDN has been developed by an internal review and survey. Based on this survey, focus points within the company have been determined. A second step is to continue the survey outside the company and look at the different stakeholders within the supply chain. The internal survey resulted in 10 focus points like for example biodiversity, climate, emissions, safety, health, etc. All these focus groups are part of our strategy code zero with 4 pillars. Those four pillars represent our goals and are zero emissions, zero waste, zero breaches and zero accidents. Furthermore, our CSR view influences the way we operate and how our projects are planned and executed. Innovation is an important factor as well and we are looking continuously into new practical solutions but also try to innovate in terms of sustainability. ULEV vessels and vessels for the installation of cables in environmental vulnerable areas are examples of our innovation and implementation of sustainable technologies. Our customers are showing interest in these new solutions and innovations for sustainability. This is an important factor to keep pushing for an increase in operations with a low environmental footprint. Another example is the Dutch CO2 ladder, which we started incorporating into our business strategy in 2013. In return for our efforts into lowering our CO2 emissions, and thus receiving a higher level on the ladder, we are more favourable in the race to receive tenders. These kind of systems generate a level playing field and incentivise companies to increase their efforts in reducing their carbon footprint.
Researcher: JDN reached Level 5 on the ladder in 2019. This means insight in scope 3 emissions of the stakeholders in your value chain?
JDN: The ladder is being implemented in Belgium more and more. We, however, use the ladder as an information system for all our projects in the Netherlands, Belgium and Luxembourg. Within the Benelux our goal is to reduce the CO2 emissions for 50% of our design, built, maintenance and financial projects. Together with our suppliers we look into ways of achieving these goals by using new technologies and designs or by using less CO2 intensive resources. The barrier for scope 3 is that we do not have design responsibilities. Therefore we can't always influence these projects.
Researcher: How about the purchase of new ships?
JDN: Yes, the current evolution is purchasing more steel from Europe due to corona. This evolution was caused by price developments and uncertainties in transport. This, however, had a positive effect on our scope 3 emissions since the European market for recycled steel is more advanced. 40% of all scope 3 emissions of JDN are purchased goods and services. About 70% of purchased goods and services are steel products. Therefore, it is important for us to know when we are buying recycled steel or not. This has a major influence on our scope 3 emissions. For example when buying engines, our suppliers are thus far unable to specify the amount of recycled steel they use.
Researcher: ABC engines does recycle old engines for making new ones. They do not use this information and it is not certified by a third party.
JDN: There is indeed more and more interest by different stakeholders into this untapped potential of the use of recycled steel. For us this can benefit our scope 3 emissions. Our next step into this subject is to get more data. Now we use conservative data since transparency is still an issue. Barriers are the origin of scrap steel, how do you prove it is recycled steel, how to prevent greenwashing, etc. We use more recycled than we report at the moment.
Researcher: What are the most important reasons to opt for a ship made from recycled steel. Is this solely about CO2 reduction or are there more advantages?
JDN: Mainly CO2 reduction, but sustainable collaborations with different stakeholders to achieve more innovations in the maritime sector are equally important.
David: How will the recycled steel market evolve?
JDN: Probably recycled steel will be more expensive but this value has to compared with the value of CO2 emission reductions. We expect this difference in price between recycled and virgin steel to decrease over time when recycling becomes the norm. Design for recycling (circular design) will become more important. To sum up, initially more expensive, adjustments due to market mechanisms and eventually cheaper.
Researcher: You do expect governments to step in as well by obligating recycled contents in products?
JDN: Yes. Not specifically carbon pricing, but some sort of restrictions or obligations for the use of recycled contents. We do expect fast evolving regulations.
Researcher: Which are the most important stakeholders that can drive an innovation like the use of recycled steel in shipbuilding?
JDN: Probably a combination of different stakeholders. JDN, as a company must come with its own vision in

this matter. This vision is also influenced by the other stakeholders. The financial sector is very important by providing better loans for green projects. Our clients are important and also need to reduce their footprint on the environment and look into the life cycles of the products or services they use or purchase. Governments are usually later than the innovations but once they are implemented, innovations can move quickly and stakeholders have no choice but to comply with them. So a combination of different stakeholders, without underestimating our own importance.
Researcher: JDN wants to be a frontrunner in this matter?
JDN: Yes. we want to distinguish ourselves and also create a competitive advantage. Its a logical step towards a sustainable future for this company.
Researcher: Is it difficult to find collaboration between the different stakeholders?
JDN: As of yet there is still no common language. Standards in this field are missing and this can still create difficulties when talking to different stakeholders in different parts of the world. More can still be done to increase transparency and standards so clear and correct comparisons can be made. Clear conventions are the biggest barriers.
Researcher: Do you want to know where the steel of a scrapped ship ends up?
JDN: It is important to know where the ship ends up and that the ship and the materials are recycled according to the regulations.
Researcher: For example recycled steel from ship to a new build ship?
JDN: Economically this would not lead to an advantage. Looking at circularity, this can of course be a nice story.
Researcher: Do you have anything else to add?
JDN: Circularity is finding its way in more and more parts of our organisation. At product level, procurement looks into purchasing products with a better reuseability or recycleablity. Our biofuels are certified as sustainable. Our biofuels are coming only from waste streams. We are looking how we can implement more sustainability in our projects. For example sustainable coastal projects that maintain themselves. We work with a lot of sustainable internal projects, for example reducing our own use of plastics.

B.10. Nesec

Researcher: What is Nesec? What does Nesec do?
NESEC: Nesec is a creditor, we provide credit loans.
Researcher: By using funds from?
NESEC: We use funds of life insurance provider. Together with the Dutch National Bank we manage a fund which we use to provide loans to shippers and shipowner for their new built and second hand vessels.
Researcher: What is the ratio between new built and second hand?
NESEC: At the moment 25% new built. This will change. A lot of shipping companies are planning ahead but contracts are not signed as of yet. It is my opinion this will change over the next years. Also due to new regulations.
Researcher: What kind of regulations?
NESEC: Regulations about emissions. New ships have to comply with stricter EEXI regulations and standards, and in general complying with the Paris Agreement.
Researcher: These regulations deal with the use phase of the vessels. Do you already see signs for attention about the building and/or recycling phase of vessels?
NESEC: I don't see this happening yet. New built projects are mainly focused on improving their performances and reducing the emissions during the life of the ship. Mainly CO2 and NOx. We see initiatives like the Poseidon principles, of which we are not a partner. This is another initiative asking for membership fees and Nesec prefers a uniform general rule set coming from the EU on this matter. We don't feel it is our job as financers to force shipping companies to improve on their sustainability. As far as I know ships get designed for their purpose and maybe to facilitate an efficient building process. I have not seen anyone design a ship yet keeping the EOL phase in mind. There is some attention focus on the recycling part but mainly about the handling of hazardous waste.
Researcher: What about looking at the origin of the materials?
NESEC: Same story, I have not seen anything like this. Does recycled steel have the same properties?
Researcher: Yes the properties are maintained and every steel product coming from a plant is approved by class or type approved by class. Steel makers are already using scrap steel in their processes. We believe that this information can be commercialised downstream, either by ESG reporting or by reduced CO2 emission taxes.
NESEC: Yes I agree. Any measure that can prove the reduction of CO2 emission at the building phase is of importance.
Researcher: With this kind of innovations in mind. how does Nesec evaluate projects that ask for financing?
NESEC: Good question. We work with three acceptance criteria. Client acceptance, credit acceptance and asset acceptance. In the asset acceptance we look at the ships, where they are built, etc. For this criterion we also could look at the materials used. From the EU, there is the EU taxonomy. Financial companies have to evaluate the impact on the environment of all their assets. I would prefer that financial stakeholders would not be pushed to bear this responsibility. It is my view that these rules should be made for and apply to the shipping companies. Specifically relating to the use of recycled steel, this is not yet part of our acceptance criteria but this is definitely food for thought and an interesting discussion. It is perhaps possible that regulators could pick this up and demand the use of a certain amount of recycled steel to be used in new built projects. I am sure, when shipyards are asked this question, they will not yet know but this way the ball starts rolling and the discussion will move upstream afterwards.
Researcher: Do you see an advantage for NESEC or similar stakeholders?
NESEC: There would be no direct advantage. It is common sense to look for solutions to preserve the planet in any way. In the end we want to pass on this planet to future generations in a good state.
Researcher: This is exactly why we are looking at the entire process and try to find ways to improve this process. Given the fact that it is a process depending on many different stakeholders, it is a question of who can influence who in what way? As a financial stakeholder you seem reluctant to take on this role?
NESEC: Yes I don't think it is my place to force a shipping company to change its ways to become more sustainable. This responsibility lays with the shipping company or should be collectively achieved with regulations that directly influence the stakeholder, in this case the one that orders the ship. This should be an open discussion. and in my experience, North-Western shipping companies will take action if you start up this discussion. They will take matter into their own hands. For South-European shipping companies, it"s a slightly different story. They are more reluctant and conservative when it comes to these kind of changes. This is clearly visible in the discussion about CO2. The correct way to approach this is starting with

the shipping companies, who will in turn talk to the shipyards, who will in their turn talk to the steel manufacturers.

Researcher: Are there subsidies to be found at the moment, incentivising 'green' projects?

NESEC: I think funding can be found with the EIB (European Investment Bank) and EIF (European Investment Fund). The risk is low, financing could be found for sure. This project is, in my opinion, ahead of its time. This idea of building with and tracing recycled materials could potentially become very important between now and five years.

Researcher: Do 'green' projects get better conditions when looking for financing?

NESEC: Some stakeholders are focused mainly on projects with a 'green' character. Invest-nl is such an example. These projects do not necessarily get better conditions, except maybe from some subsidies. If the project is saving fuel for example, they are needing less financing so they are indirectly creating better conditions.

Researcher: Are there certain conditions being set by the funds (life insurers) you are using?

NESEC: In future, the trend will be that they only want to finance young assets. This is because the regulations are changing and ships and fleets will have more strict requirements regarding sustainability. Newer ships will have the required CO2 reductions. We see the same happening in the aircraft industry. Older models of aircraft are also less in demand because of less interest by the financers due to the use of older technology that does not meet current and future sustainability standards.

Researcher: This makes room for innovation?

NESEC: Yes but since these assets have a long life span, they risk of being outdated faster and faster in the current climate. Green technology today could turn grey in a few years. To achieve real impact on climate the current fleet has to be retrofitted as well.

Researcher: Food for thought!

NESEC: On the use of recycled steel, stakeholders are not aware at the moment of this CO2 component at the building stage. this touches the field of sourcing. people and companies are becoming more aware of sourcing and the true impact sourcing has on the product by transportation between phases and the production phase.

Researcher: Do you believe there is a risk of greenwashing?

NESEC: Yes, but I think we are past this phase. Public opinion is on top of things to expose the ones who do it and companies themselves are changing their mindset and know why they need to be part of this transition. Most actions are performed with the purpose of actually achieving an impact. That being said, an independent declaration or certification from class societies would be necessary for the financing of projects claiming to use recycled steel. It needs to be traceable and proven.

Researcher: What is the driver to choose a project with recycled material? Emissions, resource depletion, ESG?

NESEC: The re-use of finite resources and the reduction of emissions, yes.

Researcher: Do you have anything else to add?

NESEC: Sourcing will play a major role in the future, also in the maritime sector. The CO2 component is becoming very important so any measure taking this into account are expected to attract more financing and animo, Especially if the price difference is not too large.

Researcher: What if the price is higher?

NESEC: I think there is a willingness to pay. People are also prepared to pay more for biological products. I don't know the price elasticity for bio products.

Researcher: Your expertise is the maritime sector, what about the price elasticity in that market?

NESEC: I think the price elasticity is low. As long as you can sell it with the right arguments, there will be some willingness to pay extra, but not too much.

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