# The Environmental Trade-offs of Ship Recycling

*The Case of India: Ship Recycling & Steel Industry*


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**Utrecht, July 2013**

Universiteit Utrecht

## Acknowledgments

This thesis project has been the final part of the Master in Sustainable Development at the University of Utrecht. It represents the completion of an exciting journey. For that reason, I would like to thank the people who with their input, knowledge, inspiration, support and guidance helped me along the way.

First of all, I would like to thank my supervisor, Prof. Ernst Worrell. Without his guidance, feedback, scientific (and psychological!) support, this whole project would have not been possible. He was always there to clear out any confusion and help me find the questions and answers I was looking for. I left from each meeting with a new and great inspiration.

Furthermore, I am grateful to Mr. Deepak Prabhakaran, Head of the Ships Unit in Greenpeace International, who was the one that initially introduced me to the topic of ship recycling. His suggestion to carry out research on that field was more than precious. It opened up many new possibilities and helped me find a research topic for which I became really passionate. During the whole research process I also met many people involved in the field of ship recycling, or other related fields, with who I had the most interesting and helpful discussions, which inspired me and motivated me even more. Delphine Reuter from the NGO Shipbreaking Platform, Marietta Harjono from Greenpeace International and Manfred Beck, publisher and editor of the Recycling International magazine, are some of them and I would like to thank them as well.

Last but definitely not least, I owe a big thank you to all the people that even without any knowledge on ships or recycling, offered me the greatest help and support of all. My family for always being there for me and even from far away sending me all their positive energy and support. My friends Stefanos, Irini, Myrto, Electra, Panayiota, Harris, Vangelis, Filippos, Younes, Ilias and Lene, Mitzi and Mariem, all my flat-mates during this time, Dr. Seltsam for his music and his crew for their love and all the rest of the people around me that made this journey even better than the destination.

## Abstract

Ship recycling is an issue currently causing a lot of concern and debates in the globalized world. Around 70% of all end-of-life ships and more than 90% of the EU fleet, are recycled on the beaches of India, Bangladesh and Pakistan, causing serious environmental and health hazards. At the same time, ship recycling is a source of valuable recyclable materials, mainly steel scrap used for steel making. India is the 4$^{th}$ largest steel producing country in the world, having a high demand for steel scrap and at the same time accounts for the largest share of the ship recycling activity worldwide. The objective of the study is to provide insight to the relationship between ship recycling and the steel industry in India, with a focus on European ships. Although this relationship is very crucial for the ship recycling issue as a whole, it is one of the least researched angels. A hypothetical scenario is developed assuming that all EU ships recycled in India during 2012 were actually not recycled in India and consequently, the corresponding steel scrap was not available for steel production. The issues that are investigated include the alternative materials that could substitute ships' scrap for steel making, as well as the related $CO_2$ emissions and overall environmental impacts for the production of the substitute materials. The analysis reveals that in order to substitute steel scrap from ship recycling in India, production of direct reduced iron (DRI) as well as steel from induction furnaces (IFs) would have to increase. Furthermore, the production of these materials would result in additional $CO_2$ emissions as well as extensive soil and air pollution, especially for the case of DRI, due to significant waste generation combined with improper handling and disposal. Therefore, the main conclusion is that ship recycling has a particular importance for the case of India because of the special nature of the Indian steel industry, relying mostly on energy intensive and polluting processes for iron and steel production. In that way, ship recycling can have positive environmental impacts by contributing to $CO_2$ savings related to steel production. However, the results represent only one side of the issue and for that reason they are presented in the form of trade-offs. Ship recycling can contribute in a positive way to steel production in India, if at the same time the negative impacts of the ship recycling activity are dealt with in a proper way.

## Abbreviations

| | |
|---|---|
| APP | Asia Pacific Partnership for Clean Development and Climate |
| APPCB | Andhra Pradesh Pollution Control Board |
| BA | Ban Amendment |
| BAN | Basel Action Network |
| BAT | Best Available Technology |
| BC | Basel Convention |
| BF | Blast Furnace |
| BIOIS | Bio Intelligence Service |
| BIR | Bureau of International Recycling |
| BOF | Basic Oxygen Furnace |
| CIEL | Center of International Environmental Law |
| CPCB | Central Pollution Control Board |
| CSE | Center of Science and Environment |
| DRI | Direct Reduced Iron |
| EAF | Electric Arc Furnace |
| EC | European Commission |
| EF | Electric Furnace |
| ESM | Environmentally Sound Management |
| EU | European Union |
| FMP | Facility Management Plan |
| GHG | Greenhouse Gas |
| GIZ | Gesellschaft für Internationale Zusammenarbeit |
| GPI | Greenpeace International |
| HKC | Hong Kong Convention |
| IBM | Indian Bureau of Mines |
| IETD | Industrial Efficiency Technology Database |
| IF | Induction Furnace |
| IHM | Inventory of Hazardous Materials |
| IMO | International Maritime Organization |

| | |
|---|---|
| INCCA | Indian Network for Climate Change Assessment |
| ISP | Integrated Steel Plants |
| KT | Kilotons - Thousand tons |
| LDT | Light Displacement Ton |
| MSP | Mini Steel Plants |
| MT | Million tons |
| OECD | Organization for Economic Co-operation and Development |
| OHF | Open Hearth Furnace |
| PBB | Polybrominated biphenyl |
| PCB | Polychlorinated biphenyl |
| PI | Pig Iron |
| PVC | Polyvinyl chloride |
| SEC | Specific Energy Consumption |
| SI | Sponge Iron |
| SM | Star Matrix |
| SRF | Ship Recycling Facilities |
| SRI | Ship Recycling Industry |
| SRIA | Ship Recycling Industries Association |
| SRP | Ship Recycling Plan |
| SRR | Ship Recycling Regulation |
| SRRM | Steel Re Rolling Mill |
| SRY | Ship Recycling Yard |
| TPD | Tons Per Day |
| UNCTAD | United Nations Conference on Trade and Development |
| UNDP | United Nations Development Program |
| WFD | Waste Framework Directive |
| WSA | World Steel Association |
| WSR | Waste Shipment Regulation |

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# **Chapter 1:** Introduction to Ship Recycling

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# 1. Introduction to Ship Recycling

## 1.1 Background

Currently, 80% of international trade in goods is carried by sea and the percentage is even higher for most developing countries (UNCTAD, 2012). Therefore, when looking at the environmental impacts from different industries, the shipping industry is one of the key players. From the perspective of climate change, ships in general contribute in a positive way due to their high energy-efficiency when transporting goods. However, the shipping industry as a whole faces major challenges in order to reduce the environmental impacts of its own but also of all the associated activities (OECD, 2010). Through the whole life-cycle of a ship, there are environmental burdens related to each stage; the shipbuilding process, the operational life of a ship and finally the dismantling and recycling of the ship, also usually referred to as ship recycling or ship breaking. Some of the main environmental concerns related to the shipping industry are greenhouse gas emissions as well as the discharge of hazardous contaminants and toxic waste leading to water, soil and air pollution. From the different stages of a ship's life, there has been a lot of attention driven recently to the final stage of ship dismantling and recycling. This is due to the fact that these activities take place mainly in developing countries of South Asia usually by violation of International Conventions and Regulations and result in environmental and occupational health hazards.

Ship recycling is the process of dismantling an obsolete vessel's structure for scrapping or disposal whether conducted at a beach, pier, dry-dock or dismantling slip (Demaria, 2010). It includes a wide range of activities, from removing all gear and equipment to cutting down and recycling the ship's infrastructure (SRIA, 2006). It needs to be noted that different names such as breaking, recycling, dismantling or scrapping are used by different stakeholders depending on their interests (Stuer-Lauridsen et al., 2004). The purpose of the present study is to stay as objective as possible towards the issue. For that reason the term 'ship recycling' will be used throughout the whole analysis, without that implying that any side is supported more than others. Ship recycling is an inseparable part of a ship's life but also a crucial part of the shipping business as a whole (IL&FS, 2009). Ships have always been valuable and therefore have always been recycled (Lloyd's, 2011). Given their great value in terms of recyclable materials it is inevitable that ships are recycled when they are no longer operational and not simply abandoned. In the early years, the main recyclable material coming from ships was wood, high quality timber and copper, that gave their place to iron and steel as shipbuilding advanced.

The Ship Recycling Industry (SRI) converts end-of-life ships into steel and other recyclable items (World Bank, 2010). For that reason, it can be considered as a sustainable and 'green' industry, as when a ship arrives at the end of its life, almost everything can be recycled or reused. Therefore, ship recycling, when looked at from a life-cycle assessment point of view, is the most environmentally friendly and sustainable way to handle ships that are no longer operational (World Bank, 2010). Currently, the main material that is recovered when ships are recycled is steel. In addition to that, the recycling process recovers non-ferrous metals, machinery, equipment, fittings, and even furniture (Mikelis, 2013). Steel scrap coming from end-of-life ships can be recycled through different processes. Machinery is usually reconditioned and sold for further use and furniture or other equipment, are sold for direct use depending on their condition.

However, there is a reason behind the fact that ship recycling is an activity causing a lot of concern in the globalized world. If factors such as the high costs for human health and the environment resulting from the recycling process itself are taken into account, the sustainability of the SRI can be questionable (EC, 2007a). For that reason a holistic view is essential in order to be able to understand all the related impacts and trade-offs taking place during the process.

## 1.2 Current Situation

Currently, the largest percentage of ship recycling activities takes place in developing countries of South Asia and is mostly concentrated in three countries: India, Bangladesh and Pakistan with the key locations being Alang in India, Chittagong in Bangladesh and Gadani in Pakistan (see Figure 1.1). According to figures provided by a World Bank study published in 2010, these three countries account for the 70% to 80% of the total ship dismantling market, with China and Turkey holding most of the rest (World Bank, 2010). However, the last years China has shown a spectacular rise in ship recycling activity. More recent sources mention that India, Bangladesh and Pakistan account for a percentage of 67% of the global ship recycling market, China for 21% and Turkey together with other countries for 12% (See Figure 1.2, ICRA, 2012).


**Figure 1.1: Key locations for Ship Recycling (Alang in India, Chittagong in Bangladesh and Gadani in Pakistan)**

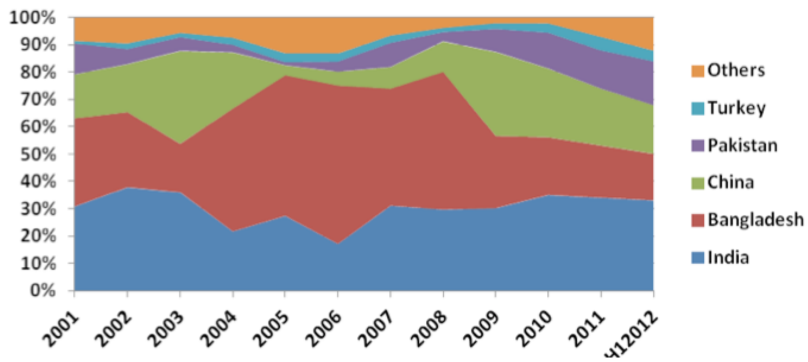


**Figure 1.2: Ship Recycling Market Share in LDT[1]. (Source: HIS (Former Lloyd's Register), ICRA, 2012)**

For the case of the European shipping industry, most of the European ships are dismantled in South Asia, mainly India and Bangladesh. Figure 1.3 presents a picture of the ship recycling activity based on the key locations, also distinguishing ships based on the flag State. Approximately 25% of the merchant ships around the world are EU-flagged. However, European countries own about 40% of the world tonnage (BIOIS, 2010). It needs to be mentioned that it is possible for a ship to 'fly' a flag of a State that is different from the State

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[1] Lightweight (LDT) is the mass of the ship's structure, propulsion machinery, other machinery, outfit and constants. It represetnts the weight of a ship without anything on board, used to determinethe value of a ship which is to be scrapped.

of ownership (the issue of re-flagging is more extensively explained in Appendix IV). The issue of ship recycling has gained particular importance within the EU but also at the international level. The EU bares an important responsibility for the current unsustainable situation related to ship recycling, as a large part of the global fleet is in the hands of shipping companies based in EU Member States. Furthermore, according to future projections an upward trend in scrapping volumes of EU-flagged ships is expected, which will intensify the problem the future years (see Figure 1.4). The expected capacity that will be needed for EU-flagged ships is approximately 1.6 million LDT annually, with peaks of 2 million LDT (COWI, 2009). What is important to point out though, is that what differentiates the ship recycling activity between South Asia and China or Turkey, is the recycling method used which will be explained further on. A small percentage of EU ships are also recycled in China and Turkey, where the dismantling conditions are of higher standards. However, India has been dominating the SRI for the past 10 years and still holds the largest share, also for EU ships.

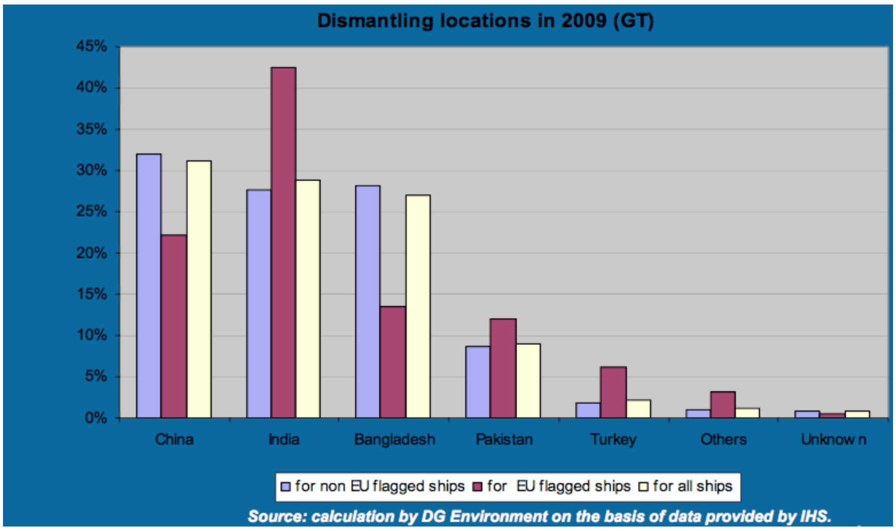



**Figure 1.3: Ship recycling locations in 2009. (Source: Blanco, 2012)**

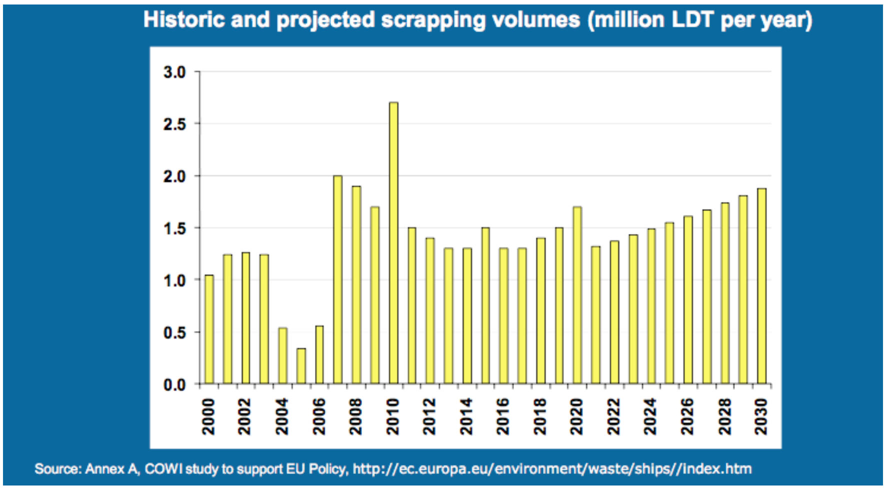



**Figure 1.4: Historic and projected scrapping volumes for EU ships (million LDT per year). (Source: Blanco, 2012)**

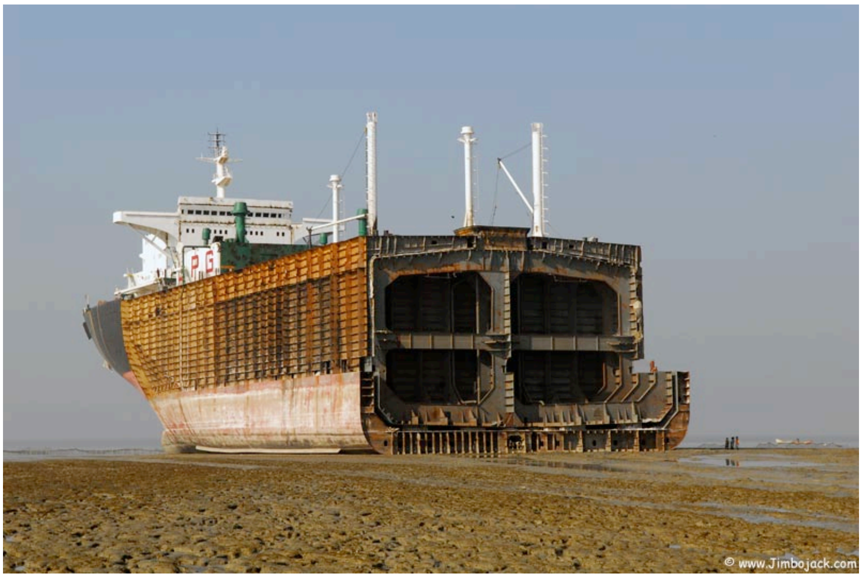
In general, the total volume of ships sent for recycling worldwide is witnessing a rise. This volume depends on various factors such as current market conditions, particularly on the freight market, and for that reason it is sometimes difficult to project (COWI, 2009). However, because of the global shipping downturn, the current low freight rates as well as the phasing out of all single-hull oil tankers (as specified under the International Convention for the Prevention of Pollution from Ships or MARPOL Convention), the ship recycling industry is expected to perceive a steady if not rising supply of vessels for demolition (ICRA, 2012). An impact assessment study carried out for the European Commission, provided projections on future volumes of ships sent for recycling categorized by ownership and flag State. Table 1.1, presents the related data concerning the volumes of ships sent for recycling up to 2030, where it is obvious that there will be a significant rise over the years.

| Mill. LDT per year | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|---|
| In total | 4,90 | 1,60 | 17,90 | 6,40 | 6,50 | 7,25 | 8,82 |
| hereof | | | | | | | |
| EU flagged and owned | 0,90 | 0,29 | 2,40 | 1,20 | 1,50 | 1,33 | 1,62 |
| EU owned, not EU flagged | 0,96 | 0,31 | 3,10 | 1,30 | 1,20 | 1,42 | 1,72 |
| EU flagged, not EU owned | 0,14 | 0,05 | 0,30 | 0,30 | 0,20 | 0,21 | 0,26 |
| Not EU flagged, not EU own. | 2,90 | 0,95 | 12,00 | 3,70 | 3,60 | 4,30 | 5,23 |

**Table 1.1: Historical and future volumes of demolition by owner, flag State and year of scrap (Million LDT). (Source: COWI, 2009)**

### *1.2.1 The 'beaching' method*

There are different methods that can be followed in order to dismantle and recycle end-of-life vessels. Ships can be dismantled in water, on land (dry-dock method) and at water and land interface (beaching method) (IL&FS, 2009). The 'beaching' method is used in the Ship Recycling Yards (SRYs) of South Asia and represents almost 95% of the ship recycling activity today (Lloyd's, 2011). During this procedure, the ship that is going to be dismantled is beached by the power of its own propulsion at high tide and during low tide is stably laid down on its flat bottom (Demaria, 2010). Consequently, all the activities and operations that follow in order to completely dismantle the ship take place directly on the beach (see Picture 1.1).




**Picture 1.1: Ship recycling on the beach of Chittagong, Bangladesh. (Source: http://www.jimbojack.com/)**

The fact that the beaching method is so widely used in these areas is a result of various factors. A very important reason is the lack of appropriate infrastructure, for example dry-dock facilities, as well as available technology. Moreover, especially for the countries of

South Asia there are additional advantages because of their favorable natural characteristics and hydrographical conditions, which allow the vessels to be more easily beached (EC, 2012b). Finally, a highly mechanized and fixed-capital demanding industry like that of ship recycling, that would currently be impossible to take place in developing countries, is through this procedure turned into a labor intensive one that can at the same time provide profit to the ship owner. In contrary to the SRYs of South Asia, in China as well as other ship recycling locations more mechanized methods are used. Table 1.2 shows the percentage of ships recycled in different locations based on the method used, for 2009.

| Recycling location | Method | Recycling fraction of total, % |
|---|---|---|
| India, Bangladesh and Pakistan | Beaching | 71,79 |
| China | Afloat | 22,22 |
| OECD non-EU | Landing, afloat and unspe-cific: Landing in analyses | 5,05 |
| EU (of this UK) | Slipway (docking) | 0,95 (0,06) |
| Total | | 100 |

**Table 1.2: Recycling locations in terms of percentage of total recycling (GT based) in 2009. (Source: COWI, 2009)**

After a ship is on the beach, inspections are carried out and gases are removed. Afterwards, the most important parts are being cut by fitters in order to remove the first valuable items which include furniture, beds, bunks, cabin materials, removable electrical items, electronic appliances, sanitary wires, engines, boilers etc. Usually, no sound technical system is used to recover valuable stores, spares, metals or other items of the ship. In order to make the vessel ready for scrapping, it is then filled with water up to the level of the deck. This water is then discharged into the sea. In that way, all the hazardous chemicals and contaminants carried by the water end up directly into the sea. In the second stage, the ship is being cut into parts so that the steel and other metals can be recovered. The cutting of big metal parts as well as the work of carrying them to trucks where they are loaded is done mostly by unskilled workers sometimes with a help of a motorized pulley (see Picture 1.2).

**Picture 1.2: Workers on the Ship Recycling Yard of Alang, India. (Source: http://www.marineinsight.com/)**

### *1.2.2 Reasons of concern - Environmental & health hazards*

Almost all the environmental and health concerns related to ship recycling are initiated from the beaching method. There should not be much doubt that the scrapping of a large ship on the beach qualifies as an unsafe and dangerous work especially when it involves unskilled workers and limited or no safety measures while working (Bailey, 2000). Moreover, most vessels contain large amounts of hazardous substances, such as asbestos, oils and oil sludge, polychlorinated biphenyls (PCBs), hydraulic fluids, contaminated holding tanks and heavy metals in paints and equipment (EC, 2007a). These substances are considered hazardous waste and are highly pollutant and very dangerous to human health (BAN, 2000). A complete list of the toxic materials that can be found on a ship is presented in Appendix I.

In general, the beaching method does not offer a safe manner in which the hazardous substances contained in ships can be disposed of. At the same time, there is ignorance or lack of information on sound management of the hazardous waste contained in the ships, which results in waste polluting the water, beach sediments, seashore soil and coastal habitats. Additionally, in countries like India, Bangladesh and Pakistan, environmental protection and regulation is very limited and there are no formal waste disposal sites in the areas as well as no environmentally sound downstream waste management. Therefore, hazardous materials can have significantly harmful effects on the marine environment by poisoning the surrounding waters of the yard (EC, 2012b). Marine flora and fauna get severely hampered which can lead to extensive pollution or destruction of the whole marine ecosystem.

Furthermore, working conditions at the SRYs of the developing countries that hold the lead in the ship recycling market are very poor because of lack of safety measures, limited use of personal protective equipment and frequent exposure of the workers to hazardous materials (World Bank, 2010). Besides of the fact that workers often work barefoot, with no protective helmets or equipment, there is also very limited knowledge on the ship's particulars and materials contained. This can even result in loss of lives because of potential explosions or fire. Accidents causing serious injuries or fatalities because of improper working conditions in ill–equipped SRYs are regularly reported. Additionally, demolition workers often suffer from diseases like asbestosis because of their direct contact with hazardous substances, as they are handling and inhaling toxic substances without protection (EC, 2007a). A list of harmful factors for workers related to ship recycling can be found in Appendix II.

### *1.2.3 Location shift*

Ship recycling has always been an essential part of the shipping business. For as long as ships have existed, recycling has been the final stage of their 'lives' if they were not lost at sea (IL&FS, 2009). However, the state of the ship recycling industry has not always been like the current one. Ship recycling activities were initially developed in the United States, the UK and Japan during the 2nd World War (Demaria, 2010). After the war, a vast amount of steel was left 'locked up' in warships and cargo ships that were scrapped and resulted in approximately 500 ktons of high-quality steel (Lloyd's, 2011). Consequently, the scrapping industry began to develop, as there was also an urgent demand for steel at that time. The location shift took place gradually; from Spain, Italy and Turkey in the 1960's, to Taiwan and South Korea in the 1970's to end up in the current re-location, that started in the 1980's, mostly in China, Bangladesh, India and Pakistan.

The location shift was initiated when the economies of South Korea and Taiwan began to grow. Consequently, labor costs increased, making ship recycling more expensive and therefore less attractive (EC, 2012b). As a result, less costly alternatives needed to be found. Ship recycling activities seek for areas providing:

- Sea Beach;
- Demand for steel scrap for reprocessing;
- Demand for second-hand equipment;
- Supply of low-cost labor to carry out the labor-intensive extraction process, (IL&FS, 2009).

The developing countries of South Asia such as India and Bangladesh were the perfect candidates for a re-location of the ship recycling industry. These countries could offer high labor supply, low labor costs, almost non-existent environmental and health regulations and at the same time a high demand for steel scrap coming from the dismantling of the ships (World Bank, 2010). Ship consist mainly of steel and at the end of their lives become a source of raw materials that can be used for producing simple steel products. Consequently, it can be argued that the geographical migration of ship recycling mirrors the global industrial economic development.

This change of location had of course a large local impact. It provided hundreds of jobs and worked towards a significant economic development of the local and regional communities. Moreover, it aided the generation of associated industries and the large scale of trading in used equipment and machineries coming from end-of-life ships (Mikelis, 2013). This can also be considered as one of the main reasons why these countries still manage and are willing to hold the largest share of the SRI. Taking into account the negative impacts on these areas, which were mentioned before, the difference in the languages of valuation and somehow the conflict of interests becomes truly visible. The contribution of the SRI to the local economies as well as the rise in direct and indirect employment clashes with the environmental and social damages (Demaria, 2010). In the same manner, the development of the steel market, which at the moment is largely related to ships' steel scrap, may leave the environmental injustice that occurs in the second place.

### 1.3 Ship Recycling in India

Ship recycling has been taking place in India since 1912 mainly in Kolkata and Mumbai (IL&FS, 2009). Officially, the first ship scrapped in India was the MV Kota Tenjung beached in Alang on February 13, 1983 according to the records of the Gujarat Maritime Board. Since then, the Ship Recycling Yard (SRY) of Alang witnessed a significant growth and became a leading SRY worldwide and the largest in Asia. There is an indication from reports that the number of employees in Alang since the ship recycling activity started had reached a number of 40,000 by 1989 (Lloyd's, 2011). Although there are SRY also in the areas of Maharashtra and West Bengal, the majority of ship recycling activity is still concentrated in Gujarat, with the SRY of Alang currently accounting for more than 90% of ships dismantled in India (ICRA, 2012). The SRY of Alang is located near Bhavnagar in Gujarat State on the western coast of Gulf of Cambay (Figure 1.5). It is estimated that it includes close to 160 plots for use as ship recycling facilities (ICRA, 2012). The unique geographical features of the area including a high tidal range, wide continental shelf, 15-degree slope, and a mud free coast, are ideal for ships of any size to be beached easily during high tide (SRIA, 2006). Figure 1.6 presents a fraction of a satellite image of the SRY of Alang, where the ships beached are actually visible.


Figure 1.5: Alang geographical location.
(Source: SRIA, http://www.sriaindia.com/)

Figure 16: Satellite image of the SRY of Alang (Source: Google earth)

Ship recycling in India was part of the industrial relocation that started around the mid 1980's when industries that were in need of low-skilled workers and low-wage jobs, shifted to developing countries, especially in South Asia. However, these were not the only reasons for the big boom of the industry in India. Ship recycling is a major source of steel scrap and local demand for the material was at rise at the same time in the country. The mid 1980's witnessed a rise in the use of the Electric Arc Furnace (EAF), which uses steel scrap as a raw material in order to produce crude steel. Furthermore, steel re-rolling mills (SRRM) were already experiencing a fast development since the 1970's and were growing very fast since then, especially in North and West India (SRIA, 2006). The main reason behind the expansion of the SRRM was the construction sector but steel scrap coming from ship recycling was also a valuable material for their function. In general, steel scrap from ship recycling either melted in an EAF or directly re-rolled in the re-rolling mills is considered a valuable and competitive material in terms of price compared to other raw materials that can be used for the final production of steel.

In 2012, India held the first place in ship recycling activity worldwide followed by Bangladesh, Pakistan and China and broke a record of maximum number of ships beached in a year. India accounted for a total number of 527 ships beached in 2012, resulting in average 1.4 ships beached per day. The total volume of recovered steel from ship recycling was 5.2 Mt (SM, 2012). Overall, there is an increasing trend in volumes and numbers of ships being recycled in India and future projections show that the figures will continue to rise.

In general, the importance of ship recycling in India is related to many factors such as recovery of steel scrap as raw material for steel making, recovery of other valuable materials, machinery and equipment as well as employment and business opportunities. The ship recycling activity in India is very labor intensive. In Alang alone, 40,000 workers are employed each year. Lastly, the SRY of Alang provides a balance to the steel sector of the country. As it is the only steel generation source in Western India, the ship recycling industry (SRI) results in savings in transportation costs for the steel sector industries (SRIA, 2006).

## 1.4 Steel Scrap Market, Recycling & Economics

Steel scrap is the main and most valuable outcome from end-of-life ships sent for dismantling and at the same time is being widely used worldwide as a raw material for steel making. Ships' scrap is of very high quality compared to steel scrap from other sources (SRIA, 2006).

This is because ships are manufactured with acute specifications and the chemical composition of the steel used for shipbuilding is controlled by rules and surveys of classification societies, which results in its good yield strength, ductility and impact strength. According to the literature, approximately 75% of a ship's total volume is recyclable steel (Mikelis, 2013). For that reason, it is no wonder that steel market is indeed one of the main factors determining ship-recycling activity. In an area with SRI, there is a direct correlation between the fluctuations in steel scrap prices, which reflect the demand, and the number of ships sent for recycling. Ship owners are paid when selling a ship to a SRY, as the steel that comes from ship recycling is very much needed (EC, 2012b). The SRYs in their turn, offer a price to the ship owner and the higher the price, the more competitive the yard. As a result, the decision on the location where the ship is going to be dismantled is based on the current price the facility can offer to the owner. This price is determined by various factors such as labor costs, infrastructure costs for workers' safety and environmental protection, domestic market demand for steel scrap, materials or equipment found onboard and finally tariffs and duties (EC, 2012b). On the supply side, ship owners decide to end the economic life of their vessel when the maintenance costs of the vessel start to exceed possible revenue, or when the vessel has become unattractive for the second-hand market, i.e. it is unlikely that it can be sold on (EC, 2007a). Therefore, the decision to send a ship for recycling is also influenced by various factors such as the costs of operation of the ship and the freight rates. Figure 1.7 presents the global, regional and national economic contexts that determine both the ships supply in the SRY and the steel scrap demand of the industry.

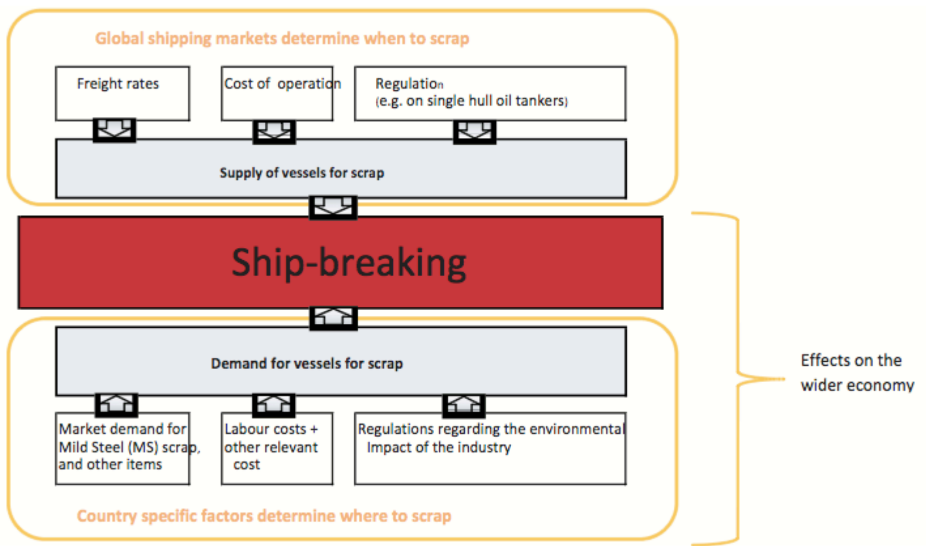



**Figure 1.7: Ship Recycling: Supply and demand. (Source: World Bank, 2010)**

It is obvious that the SRI is not different from any other industry and for that reason it is also driven by profit consideration. Thus, there is again a clash of interests and objectives. Ship owners seek for the highest price for their ship, which the SRY tries to provide in order to be competitive compared to other facilities. However, in order to be able to provide the best offer to ship owners, the working and environmental standards in a SRY need to be as low as possible in order to avoid extra costs. Therefore, it can be said that there is a financial gap between conventional and 'green' ship recycling methods.

Nevertheless, as it has already been pointed out, ship recycling can also be considered a 'green' industry from an en environmental and life-cycle point of view. The ship recycling companies as well as the industries that are involved in the broader activities that follow ship recycling, such as the re-rolling industry, mainly focus on the fact that the industry can be considered environmentally friendly because it saves non-renewable resources by recycling materials. Using steel scrap for the production of steel makes absolute sense, both from an economic and an environmental point of view (Mikelis, 2013). Apart from not using iron ore, which is needed in order to produce primary steel, recycling results in energy savings and at the same time produces less solid waste than primary steel manufacturing (Demaria, 2010). Moreover, other non-renewable resources such as coal, limestone and other minerals are used when producing primary steel and can be saved when using steel scrap as a raw material instead. The general environmental benefits that can be acquired when recycling steel compared to primary production are presented in Appendix III. Apart from steel, the ships that are dismantled in a SRY can provide many other materials or equipment found on board for local use, such as cables, electronic equipment, furniture etc. This can be considered as a positive input for the local communities and at the same time beneficial for the environment.

## 1.5 The Legislative Arena

Currently, ship recycling in the majority of cases cannot be considered a sustainable activity and it can also be seen as the cause of many environmental and social problems occurring mostly in developing countries. However, one would wonder if this issue has not been addressed so far. As in most cases of similar nature, there are already legal measures in place that could address the problem. The EU bears a crucial responsibility for the current unsustainable situation regarding ship recycling. This is due to the fact that a significant percentage of the world's fleet is EU-owned and at the same time the majority of ships sent for dismantling in the developing countries of South Asia (mainly India) are also in the hands of European shipping companies. From a legal point of view, there is a broad range of EU legislation in place that can be applied to the case of end-of-life ships sent for recycling (EC, 2007b). This section will focus on the main related legal instruments. More information on the legal side of the ship recycling issue can be found in Appendix IV.

### *1.5.1 The Basel Convention*

The United Nations' 'Basel Convention for the Transboundary Movements of Hazardous Wastes and their Disposal', known as the Basel Convention (BC) came into force in 1992 and is a very important piece of International Law. For the case of ship recycling, the BC could be a driver to improve conditions in SRY as well as to work towards better preparation of ships for recycling. It is actually the only legal instrument currently in force that can be applied for the case of ship recycling. The main goal of the Convention is to *"protect, by strict control, human health and the environment against the adverse effects which may result from the generation and management of hazardous wastes and other wastes".* Ships that are destined for recycling are considered as 'waste' under the BC and in most cases as 'hazardous waste', as they contain many hazardous substances (GPI, BAN, 1999). The Waste Shipment Regulation (WSR) implements in the European Union the requirements of the Basel Convention as well as the provision of an Amendment to the Convention, which is called 'Ban Amendment' (BA) (Lloyd's, 2011). The BA was a further effort to strengthen the protection of developing countries as it states that it is illegal to export hazardous waste outside the OECD (Mikelis, 2012a). In that sense, according to the BA, end-of-life ships from the EU are not allowed to be recycled in SRYs of South Asia as this is considered export of hazardous waste outside the OECD. The BA has not yet entered into force at international level, as not enough countries have ratified it (EC, 2012a). Nevertheless, in the EU level, it can be considered a law as all Member States have ratified it (Lloyd's, 2011).

Because of the special nature of the shipping industry as well as the fact that the BC was not designed for the case of ship recycling but for movements of waste, it is difficult to enforce it for the case of ship recycling. Legal loopholes are created by the structure of the Convention, and consequently ship owners can easily circumvent the law. As a result, EU ships are extensively sent for recycling in developing countries of South Asia, which can actually be considered as a transboundary movement of hazardous waste and is prohibited by the BC. The main legal loophole is related to the issue of re-flagging, for which more information can be found in Appendix IV.

### *1.5.2 The IMO Hong Kong Convention*

Because of extensive circumvention of the BC, there were reactions and pressure mostly from environmental organizations on the International Maritime Organization (IMO) to create and adopt a Convention that would specifically address all issues related to ship recycling. The result was the 'Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships', known as the Hong Kong Convention (HKC) that was adopted by the IMO Assembly in 2009, at the International Conference on the Safe and Environmentally Sound Recycling of Ships (Mikelis, 2012a). The aim of the HKC is *"to prevent, reduce, minimize and, to the extent practicable, eliminate accidents, injuries and other adverse effects on human health and the environment caused by Ship Recycling, and enhance ship safety, protection of human health and the environment throughout a ship's operating life"* (CIEL, 2011). Although the HKC was adopted in 2009, it has not yet entered into force, as it needs to be ratified by a sufficient number of both large flag and recycling states. This is not expected to happen before 2020 at the earliest (EC, 2012a). The main reason behind this delay is that, as mentioned before, the States that hold the largest share of ship recycling activities are developing countries that face big difficulties in meeting the requirements of the Convention.

Some of the key elements addressed by the HKC include environmental ship design and prohibition in the use of Hazardous Materials for new-buildings, an Inventory of Hazardous Materials (IHM) to be carried by ships destined for dismantling, authorization of Ship Recycling Facilities (SRFs), detection of violations as well as surveys and certifications (Mikelis, 2010). A SRF is considered authorized if it is located in a Party State, which means a state that has ratified the HKC. Additionally, SRFs are required to provide a Ship Recycling Plan (SRP) with which they can specify the manner in which each ship will be dismantled as well as a Facility Management Plan (FMP) (Lloyd's, 2011). Lastly, the SRFs should carry out a survey on the ship that is going to be dismantled and afterwards provide a certificate stating that the ship is ready for recycling. The main alteration that the HKC posed compared to the BC is that EU ships can be recycled anywhere in the world as long as the SRF is authorized and consequently meets specific environmental and safety requirements set by the Convention.

### *1.5.3 Proposal for a Ship Recycling Regulation (SRR)*

The period following the adoption of the HKC until it enters into force is known as the 'interim period' (Mikelis, 2013). For that period, the European Commission took the initiative to propose new rules in order to ensure that EU ships are recycled only in authorized SRFs, which do not cause environmental or health hazards to the areas where they are located. The result was the 'Proposal for a Ship Recycling Regulation' (SRR), which was adopted by the European Parliament in June 2013. The objective of the SRR is to *"reduce significantly the negative impacts linked to the recycling of EU-flagged ships, especially in South Asia without creating unnecessary economic burdens"* (EC, 2012a). This proposed Regulation aims at an early implementation of the requirements of the HKC, while also including some additional ones. The scope is restricted to EU-flagged ships. Similarly to the HKC, according to the SRR, EU-flagged ships can only be dismantled in SRFs of a European List, which will include certain facilities worldwide. The SRFs of the list should fulfill certain environmental and safety requirements, which have been developed on the basis of the technical requirements of the HKC but in some cases, are stricter than those foreseen by it. By allowing EU-flagged ships to be dismantled in SRFs that are included in the European list but can be located anywhere in the world, ships that are subject to the SRR are automatically excluded from the application of the WSR and consequently the BC and the BA. In simple words, the SRR pushes for global recycling of EU-flagged ships and in that way withdraws the EU from the BC. Apart from its adoption, the SRR has not been ratified by any country yet, so like the HKC is not considered as a law that can be enforced.

Figure 1.8, presents a simple timeline of the relevant legal instruments including their main points related to ship recycling:

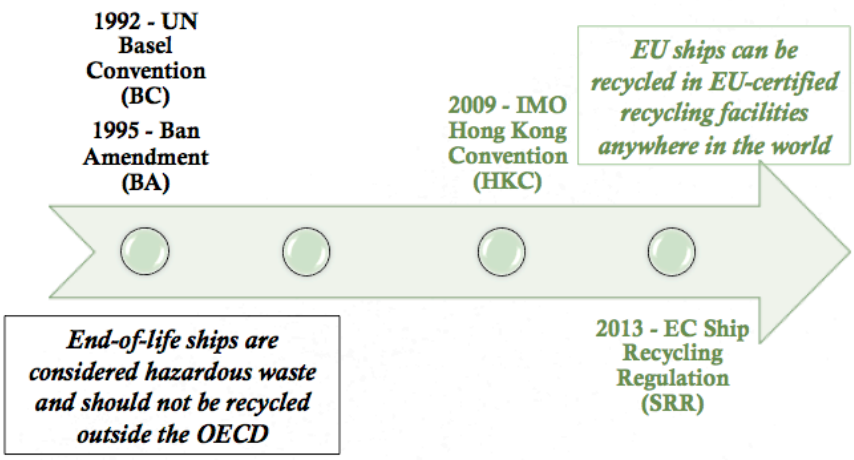



**Figure 1.8: Timeline of legal Conventions & Regulations related to ship recycling.**

The main difference between the legal instruments is related to the geographical restriction to ship recycling. In other words, the issue that is raised concerns the location where end-of-life EU ships should be recycled and the prohibition or not, of exporting them outside the OECD.

## 1.6 Scope of Research

Ship recycling is a highly complex issue involving environmental, social and economic aspects that need to be balanced in order to arrive at a more sustainable state. Most of the research already done in the field is based on the social and environmental hazards resulting from the actual ship recycling process, which burden the developing countries of South Asia. Based on that research, one could support the view that ship recycling should be relocated from these countries. On the other hand, there has also been a strong opposition to this opinion based on the fact that ship recycling is a vital industry for these countries and any relocation would cause additional economic and social burdens. One of the main arguments supporting this view is the fact that ship recycling provides valuable materials and particularly aids in meeting the high local demand for steel scrap in the main ship recycling countries. Additionally, ships' steel scrap used for steel making results in environmental benefits compared to primary production of steel. However, although this argument is widely used, there has not been sufficient research on this topic so far.

The aim of the present study is to provide insight to the relationship between ship recycling and the steel industry by investigating the way steel scrap coming from end-of-life ships contributes to steel production. India holds the largest share of the SRI and for that reason the study will focus on the case of India. Furthermore, there will also be a restriction to the origin of ships and the focus will be on European ships. The main objective is to examine the environmental trade-offs related to ship recycling and steel production in India. More specifically, the focus will be on the environmental impacts and consequently trade-offs taking place in the absence of steel scrap coming from ship recycling (with a focus on EU ships) for the country of India.

The main objective was to provide insights to a field not extensively researched so far, which is the one of the relationship between ship recycling and the steel industry. However, that restriction does not mean that the rest of the issues are ignored or neglected. For that reason, the reader should bare in mind that the goal was not to provide a solution to the problem, as the answer of where EU ships should actually be recycled cannot be answered so easily. This analysis aims at filling in some gaps when looking at the issue of ship recycling from an environmental point of view.

### *1.6.1 Research questions*

The scope of the research is narrowed down to the case of European ships recycled in India and even more to the relationship between the resulting steel scrap form EU ships and the Indian steel industry. The main goal of the study as explained beforehand, resulted in the following research question:

***"What are the environmental trade-offs related to the recycling of EU ships and steel production in India?"***

In order to answer the main question, it was essential to divide it in the following sub-questions:

*"What is the contribution of ship recycling to the Indian steel-making industry?"*

*"What would be the alternative materials for steel-making in the absence of EU ships' steel scrap?"*

*"What would be the related environmental impacts in the absence of EU ships' steel scrap?"*

### *1.6.2 Methodological steps*

In order to achieve the main objective of the study and answer the research questions, initially an extensive research and analysis on the Indian steel industry was carried out. In that way, the trends and dynamics of the sector could be revealed. By identifying the main processes followed for steel production in India, the contribution and importance of steel scrap for steel making could be identified. Consequently, an insight to the contribution of ship recycling as a source of steel scrap to the steel making industry could be acquired. Afterwards, available data were used in order to acquire figures on the scrap coming from EU ships dismantled in India. After this step, and based on the analysis of the steel sector, a scenario was developed where it was assumed that the steel scrap coming from ship recycling for a specific year was not available. Based on this assumption, an investigation on the different possible alternative routes for steel making depending on the raw materials used for steel production was carried out. Further on, the environmental impacts and trade-offs related to the production of the alternative materials that would substitute steel scrap from EU ships were identified.

## 1.7 Reading Guide

The present Chapter provided an introduction to the ship recycling issue from different angles, described the current situation and presented the related impacts of different nature.

Chapter 2 provides an analysis of the Indian steel sector, including statistical data on the different steel making processes. Furthermore, it presents the way ship recycling contributes to steel production in India.

Based on this analysis, Chapter 3 includes the hypothetical scenario on the absence of steel scrap from EU ships in India and the assumptions made on the materials that would substitute this scrap. Additionally, the specific methodology that was followed for the data analysis is presented.

Chapter 4 presents the results from the data analysis concerning the environmental impacts resulting from the substitution of ships' scrap and the overall trade-offs taking place for the case of ship recycling in India.

Finally, Chapter 5 concerns the main conclusions of the present study and also provides some recommendations that were built upon the findings of the research.

# Chapter 2: Steel Industry & Ship Recycling

*The case of India*

**CONTENTS**

## 2. Steel Industry & Ship Recycling – *The case of India*

### 2.1 Steel Production

When talking about sustainability and 'green economy', especially in the context of materials and resources, steel can be considered as a very important factor. This is due to the fact that it is 100% recyclable and for that reason it can be environmentally friendly. Once it is produced it becomes a permanent resource, as it has an infinite life cycle and recycling does not affect its properties (WSA, 2013). However, the quality of recycled steel may vary of course depending on the recycling process. Apart from the 'green' side of steel as an important recyclable material, it is a fact that it is anyway a key driver for global economy as it is essential for almost every aspect of everyday modern life. According to the 2012 report on Global Trends of $CO_2$ Emissions by the PBL Netherlands Environmental Assessment Agency, steel production is one of the main indicators of national construction activity because it is widely used in the construction of railways, other infrastructure, ships and machinery. Moreover, it is considered as the core of modernization and the per capita steel consumption is often used as one of the main indicators of a country's socio-economic development (IBM, 2012). Steel is generally used in transport, housing, energy, agriculture and infrastructure, while at the same time the steel industry provides direct employment to more than two million people globally and four million in supporting industries. The combination of its strength, formability and versatility, makes steel a unique material and justifies its wide usage (WSA, 2013). However, even if steel recycling has positive environmental effects, steel production is also one of the largest industrial sources of GHGs. The iron and steel industry account for an average 15% of the total industrial emissions globally (Tata Steel, 2007).

Steel can be produced through two main routes: primary production using iron ore as the main raw material and secondary production from steel scrap. Iron ore is one of the most abundant and important elements on the Earth and is the basic raw material for the production of metallic iron, which is then used as a raw material for the final production of steel (IBM, 2011). Iron making involves the separation of iron ores and apart from being the initial step for the production of steel it is the most capital and energy intensive process in the whole production chain (Chukwuleke et. al, 2009). Steel scrap can substitute iron ore as a raw material for the production of steel resulting in important energy and resource savings (see Appendix III). Before any further analysis on the steel sector and the different steel making processes, some relevant definitions will be provided in Box 2.1:

**Box 2.1: Glossary of Terms / Terminology used in Iron & Steel Industry (Source: Ministry of Steel, Government of India)**

**Iron Ore:** A naturally occurring mineral from which iron (Fe) metal is extracted in various forms.

**Iron:** A base metal extracted from iron ore.

**Hot Metal / Liquid Iron:** The hot, liquid, metallic iron product obtained upon reduction of iron ore. Hot metal is the primary input for production of steel in the Integrated Steel Plants (ISP).

**Pig Iron (PI):** A product in solid form obtained upon solidification of Hot Metal in a Pig Casting Machine.

**Liquid Steel:** The immediate hot molten steel product from a Steel Melting Shop.

**Ingot Steel:** The primary solid product obtained upon solidification of liquid steel. **Pencil Ingots** are of small size and are usually produced in mini steel plants (MSP).

**Semi finished steel products (semis):** Intermediate solid steel products obtained by hot rolling of ingots (in conventional process) or by continuous casting of liquid steel. Semis are intended for further rolling to produce finished steel products. (Types of semis: Blooms, billets, slabs, thin slabs/sheets etc.)

**Crude Steel:** The definition includes solid steel products resulting upon solidification of liquid steel. However, *according to the International Iron & Steel Institute (IISI), for statistical purposes, crude steel also includes liquid steel, which goes into production of steel castings.*

### *2.1.1 Steel production around the world*

According to the 2013 report of the World Steel Association (WSA), figures of global crude steel production broke a new record in 2012 with a production of 1.5 billion tons showing an increase of 1.2% compared to 2011 (WSA, 2013). The comparison between the two previous years (2010 and 2011) results in a much higher increase of 6.9%. The reason behind this is mainly the decrease in steel production for the cases of the EU and South America in 2012. On the other hand, Asia (mainly China) and North America accounted for the largest share of the overall increase in 2012 (BIR, 2013). In general, historical data on global crude steel production from 2009 onwards, show an overall increase. The decrease in production noticed the year before can probably be explained by the economic downturn, which started in 2008. Figure 2.1 presents the overall trend of global crude steel production for the years 2007-2012.

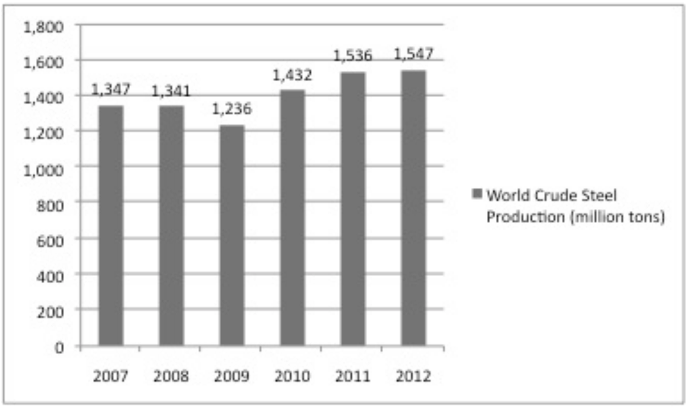



**Figure 2.1: World Crude Steel Production, in million tons (Data from WSA, 2013)**

India was the 4$^{th}$ largest crude steel producing country in the world in 2012, with a production of 77.6 million tons crude steel (WSA, 2013). Table 2.1 presents the 10 largest steel producing countries in the world for the years 2011 and 2012. It is worth mentioning that three of the five countries that dominate the global ship recycling industry (China, India and Turkey) are in the top 10 steel producing countries worldwide.

| Year / Country | 2012 | | 2011 | | 2012 / 2011 |
|---|---|---|---|---|---|
| | Rank | Tonnage | Rank | Tonnage | Increase/ Decrease |
| China | 1 | 716.5 | 1 | 702.0 | + |
| Japan | 2 | 107.2 | 2 | 107.6 | - |
| United States | 3 | 88.7 | 3 | 86.4 | + |
| India | 4 | 77.6 | 4 | 73.5 | + |
| Russia | 5 | 70.4 | 5 | 68.9 | + |
| South Korea | 6 | 69.1 | 6 | 68.5 | + |
| Germany | 7 | 42.7 | 7 | 44.3 | - |
| Turkey | 8 | 35.9 | 10 | 34.1 | + |
| Brazil | 9 | 34.5 | 9 | 35.2 | - |
| Ukraine | 10 | 33.0 | 8 | 35.3 | - |

**Table 2.1: The ten largest steel producing countries in the world. Tonnage in million tons (Data from WSA, 2013)**

### *2.1.2 Different processes of steel production*

The final production of crude steel can be divided based on the different processes or routes that were followed as well as on the raw material that was used for the production. Steel can be produced either from iron or steel scrap. The main energy and feedstock sources for steel production are coal and electricity (Gielen & Taylor, 2009). Currently, the main routes for steel production around the world are the following:

- **Primary production → Oxygen route: mainly the Blast Furnace (BF) / Basic Oxygen Furnace (BOF) route**, which uses iron ore as a primary raw material to produce Pig Iron (PI) through the BF and then refine it into steel in the BOF;
- **Secondary production → Electric route: mainly the Electric Arc Furnace (EAF) route**, which uses steel scrap as raw material that is melted in the EAF in order to produce crude steel.

It needs to be mentioned that primary production of steel also includes the open-hearth furnace (OHF) route. India is one of the last few countries that still use the OHF to some extent, together with Russia and Ukraine. However, according to WSA statistics, the contribution of this method to the overall world steel production as well as steel production in India is very low (1.1% and 1.3% respectively, in 2012). This route was gradually abandoned almost everywhere in the world mainly because of its low productivity as well as its high energy intensity and harmful environmental impacts.

Statistics show that globally the oxygen route (BF/BOF) is the dominating one representing approximately 70% of the total crude steel production worldwide, whereas the electric route (EAF) accounts for almost 30%. More specifically, for 2012 global crude steel production through the oxygen route accounted for 69.6%, whereas the equivalent share of the electric route was 29.3% and the OHF only 1.1% (see Figure 2.2).

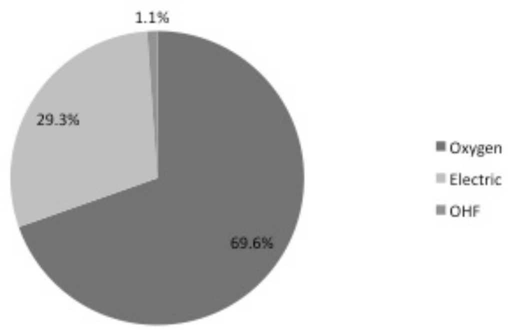



**Figure 2.2: World crude steel production by process (Data from WSA, 2013)**

### *2.1.3 Steel scrap for steel making*

According to the 2013 report of the Bureau of International Recycling (BIR), Ferrous Division, covering the period 2008-2012, global scrap usage for steel making remained stable in 570 million tons for the years 2011 and 2012 representing 37.3% and 36.8% of the total crude steel produced, respectively. The report highlights the growing importance of steel scrap as a global raw material for steel production, as the figures reached a record level in 2011 and the overall scrap consumption for steel making shows an overall increase since 2009 (BIR, 2013). It should be noted that statistical data on steel scrap consumption are not always available for many parts of the world, so these figures are based on estimates and calculations made by the Bureau of International Recycling in collaboration with the German Steel Federation (WV stahl).

However, it is also important to point out that the percentage of steel scrap in the overall steel production may vary significantly from country to country depending on the structure of the steel sector. For example, countries like China that have invested largely in Integrated Steel Plants (ISP), where steel is produced through the BF/BOF route using iron ore, show a relatively low usage of steel scrap for steel making. On the other hand, in countries like Turkey where the EAF route outweighs the BF/BOF route, steel scrap usage for steel making is significantly higher.

In general, sources of steel scrap used for steel making can be divided in the following categories:

- “Own arisings”, which comprise of steel scrap arising internally in steel mills as rejects from melting, casting, rolling, etc;
- “New steel scrap”, which is generated from fabrication of steel into finished products; and
- “Old steel scrap”, which is steel scrap from obsolete products that is afterwards collected, traded and sold to steel plants for re-melting.

  (Source: Mikelis, 2013).

Steel scrap coming from obsolete vessels clearly falls in the third category. From the above categories, old steel scrap has the highest contribution to steel making worldwide and at the same time its significance is rising over the years (See Figure 2.3).

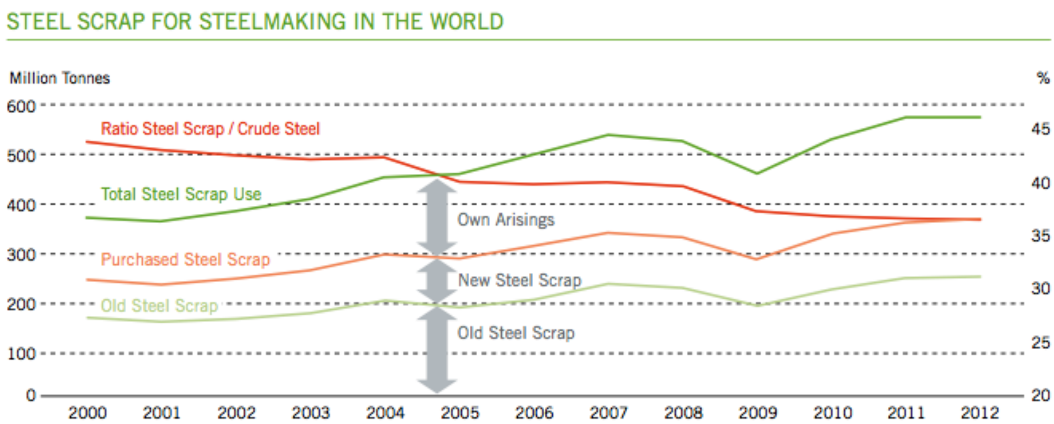



**Figure 2.3: Global use of steel scrap for steel making. (Source: BIR, 2013)**

Moreover, because of the growing importance of steel scrap in steel production, global trade of ferrous scrap as a commodity has been steadily increasing over the years as well, which proves the great value of steel in the global market. This can also justify the fact that steel scrap coming from ship recycling is a valuable resource and for that reason the countries where ship recycling mostly takes place want to maintain this activity in their area. In that way they can be more independent from the scrap market. To sum up, crude steel production witnessed a rise worldwide the last three years after some fluctuations possibly caused by the economic recession, and will probably continue to increase. Furthermore, steel scrap is becoming more and more significant as a raw material for steel making when looking at the global picture. Lastly, the global market for steel scrap is also developing. Figure 2.4 retrieved from the 2013 BIR report, summarizes the above.

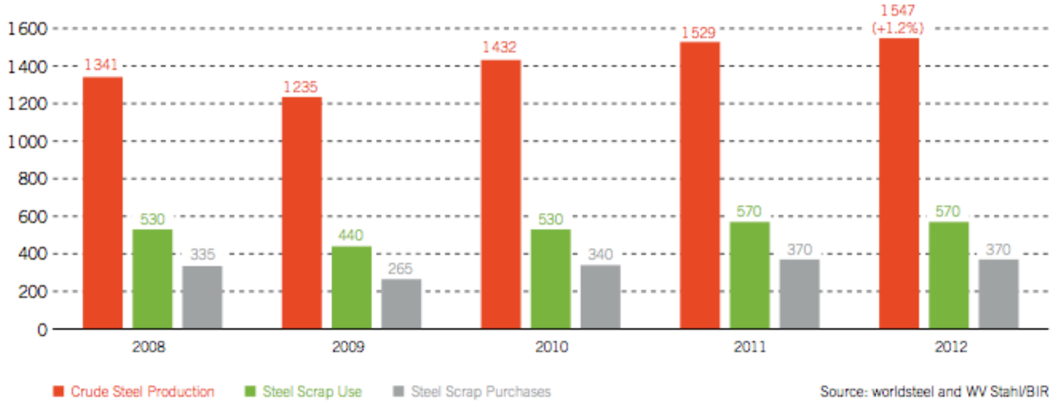



**Figure 2.4: Steel scrap use and purchases for steel making around the world, in million tons. (Source: BIR, 2013)**

## 2.2 Indian Steel Industry

India is one of the five largest steel producing countries in the world therefore it is obvious that the steel industry plays a key role in the country's economic development. Growing steel production in India can be explained by the growing demand for crude steel from the automotive, construction and white goods industry. Moreover, according to the Ministry of Steel of the Indian Government, factors such as large infrastructure investments, growth of manufacturing, increase in urban population and development of the rural market for steel, carry the potential of raising the per capita steel consumption in the country. However, the steel industry is also responsible for a high share of energy consumption and emissions in the country, mostly because of the use of inefficient and highly polluting technologies. Therefore, if the current technologies remain, in combination with the increasing demand there will be a continuous rise in emissions (GIZ, 2011).

The two main routes for crude steel production, which are followed in India, are the BF/BOF route, which is usually followed in Integrated Steel Plants (ISP) of large capacity and the electric route, which is adopted in Mini Steel Plants (MSP) also called 'mini-mills' or 'mini plants'. In the MSPs, which are usually of small capacity and produce relatively simple products, low-priced steel scrap is melted and refined through a strong electric current in electric furnaces (IBM, 2011). There are several different process variations, which utilize either AC or DC currents. The two main types of electric furnace though, are the electric arc furnace (EAF) and the induction furnace (IF). A special characteristic of the Indian steel sector is the high production of Sponge Iron (SI), which is iron produced through the direct reduction method and for that reason is called Direct Reduced Iron (DRI), which is the term that will be used further on. DRI is used as a raw material for the production of steel through the electric route and can be considered as a high quality substitute for steel scrap. DRI and steel scrap can also be combined in different percentages depending on the availability. The methods of producing steel from scrap instead of primary raw materials, such as iron ore, constitute the secondary sector of steel production. However, although DRI can be used as a substitute for scrap in order to produce steel through the same processes, it should not be included in secondary production as DRI is actually produced from iron ore.

## 2.3 Steel-making Processes in India

### *2.3.1 Primary production*

The oxygen (BF/BOF) route is the dominant method used for steel production worldwide. Nevertheless, this is not the case for India. During this process, initially, pig iron (PI), which is a carbon-rich molten iron, is produced from iron ore through a blast furnace (BF) and is afterwards refined into steel by removal of its impurities in a basic oxygen furnace (BOF).

The main feedstock in the BF process is coke from coal. The main process that takes place in the BOF is the injection of oxygen, which oxidizes the carbon in the heated metal. This process is autogenous in energy, as the required oxygen is generated by the process itself. For the whole oxygen route, the primary raw material is iron ore but apart form that, a maximum percentage of 30% steel scrap can also be added together with PI as input in these furnaces. The capacity of a modern BOF ranges from 100 to 400 tons (IBM, 2011). In India, the oxygen route is followed mainly in integrated steel plants (ISP) of large capacity, which require high initial investment. This is one of the reasons why steel production is gradually switching over to small-scale units for secondary steel making. Furthermore, there is low availability of coking coal, which is essential for the iron-making process in a BF.

#### Environmental Impacts

In terms of energy consumption and related GHG emissions, primary production of steel is less environmental friendly than secondary production. At the same time, it accounts for the consumption of substantial amounts of non-renewable resources such as iron ore, coal and oil. The high energy intensity of this process results mainly from the required chemical energy in order to reduce iron ore to iron using reduction agents (WSA, 2008). Especially in India, SEC is significantly high and in most cases presents a large deviation from the best available technologies (BAT). A study by the Center of Science and Environment (CSE) on the Indian steel industry based on a survey of eleven ISPs, mentions that SEC and $CO_2$ emissions in Indian ISP are above global average. The energy saving potential when comparing SEC in ISPs utilizing the BF/BOF process, to primary energy consumption associated with BAT in steel production through this route, is around 74% (CSE, 2010). It however requires high capital investment to be achieved. Some of reasons behind these high figures are poor coal quality as there is no availability of low ash coking coal[2], lower utilization of scrap and lack of energy-saving and energy recovery technologies. At present, there are 13 ISP operating in India with capacities ranging from 0.5 to 6.8 million tons crude steel. The specific energy consumption (SEC) in these plants ranges from an average 22 GJ/ton-crude-steel (tcs) to 34 GJ/tcs and the corresponding $CO_2$ emissions from 2.5 Mtons $CO_2$/tcs to 5.5 Mtons $CO_2$/tcs (CSE, 2010).

### *2.3.2 Electric Arc Furnace (EAF)*

Even though the oxygen route accounts for the highest percentage of steel production at a global scale, in India secondary production is currently the dominating one. The EAF route is generally the most common method used for secondary steel production worldwide. The EAF is a furnace that is used for heating up and melting a charged material, usually steel scrap, to produce high quality steel, by the use of high power electric arcs formed between a cathode and one (for DC) or three (for AC) anodes (Worrell *et al.*, 2010). In that sense, the required heat to melt the input material is provided by electricity. The major advantage of steel production through EAF is that it is not required for the input iron fed into the furnace to be molten. Steel scrap is widely used as the most important resource and EAF units are able to operate with even 100% scrap as input. However, a mixture of steel scrap, DRI and PI (up to 30%) is usually fed into the furnaces in various proportions. This is because the required external energy can always be provided by the supply of electrical power (IBM, 2011). EAF units can range from really small with approximate capacity of 1 ton, to large-scale units of 400 tons. This process is widely followed in the Indian steel industry, as the EAF technology has facilitated the proliferation of mini-mills, which can operate economically at a smaller scale than larger integrated steelmaking (APP, 2007).

[2] Coal containing high percentages of ash, results in higher energy consumption.

### Environmental Impacts

The electric steel making process is more environmental friendly than primary steel production, as re-melting of scrap requires much less energy than production of iron or steel from iron ore and at the same time it saves non-renewable resources and avoids the use of 'dirty' raw materials such as coal. Therefore, it increases the availability of semi-finished material, which otherwise would have to be produced using iron ore. Moreover, by the use of steel scrap, it reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment (IBM, 2012). Nevertheless, the EAF industry in India is facing economic challenges. This is because of high power tariffs as well as not sufficient and costly essential input such as steel scrap (CPCB, 2007).

Energy consumption during this process can vary significantly based on the product mix, local material, operating practices and energy costs and is therefore unique for each specific furnace operation (IETD). The IEA reported an average electricity use of 425 kWh/ton in 2005. However, this figure will be higher in small-scale plants in India because of the reasons mentioned above. $CO_2$ emissions from this process are the lowest compared to other routes, with an average of 0.5 ton $CO_2$/ton product if 100% scrap is used as input. Nevertheless, because of shortage of local steel scrap resources in India, DRI is widely used as a substitute, which increases the overall energy consumption and emissions significantly. Additionally, emissions from electricity generation, which is mostly coal-based, should be also taken into account.

### *2.3.3 Induction Furnace (IF)*

The IF is another type of electric furnace and presents an alternative way of secondary steel production where electromagnetic induction is used to heat the metal. It comprises of a vertical refractory-lined cylinder surrounded by coils that are energized with alternating current. The resulting fluctuating magnetic field heats up the charged metal. This type of furnace was primarily engaged in the production of high quality steel, particularly stainless steel from stainless steel scrap (IBM, 2011). However, with imported technology, a huge development of that sector took place in India. Additionally, the wide use of DRI revolutionized steel making in induction furnaces (IL&FS, 2010). IF units use as input a mixture of steel scrap, DRI and PI. An average proportion of these items is 40% DRI, 10% PI and the remaining 50% is steel scrap. However, an IF has the capability to operate on a charge up to 85% - 90% DRI or scrap and as in EAF, proportions vary depending on availability of materials (IBM, 2012). The main output products of IF are pencil ingots and billets. The capacities of an induction furnace range from about 1 kg to a 100 tons but the popular capacity range is 1-20 tons (CSE, 2012).

Induction furnaces play a dominant role in steel production in India, which is a unique feature. India is probably the only country using IF technology for steel making on a larger scale and reports the highest percentage of steel produced through that route. In fact, at the moment, the IF route for the production of steel has made a notable niche in the domestic steel industry. Because of the challenges that the EAF industry is facing, such as the availability of steel scrap, the industry is switching more and more to the IF route. Additionally, initial investment on the plant and the equipment is lower than in the case of EAF units. The reorientation towards the use of induction furnace facilities for steel making started in the late 1970s or early 1980s. Presently, its substantial contribution to the steel sector is widely recognized by the market and the Indian government. However, there are still quality issues related to this process, which need to be addressed.

### Environmental Impacts

As part of the secondary steel making processes, IF can also be considered to have less harmful environmental impacts than primary production. The IF process saves non-renewable resources such as iron ore and coking coal and at the same time, the required heat to melt the input material is provided from the electromagnetic effect of electricity. However, in India electricity generation is mostly coal-based and in that way there are significant environmental impacts from electricity production. $CO_2$ emissions from electricity generation in 2007, accounted for 65% of the total $CO_2$ emitted from the energy sector in India (INCCA, 2010). Furthermore, IF plants in India are generally small shops founded and operated all over the country by local entrepreneurs, as the initial capital investment for the set up is very low. Therefore, environmental awareness and pollution abatement measures are in most cases limited if non-existent. Surveys and field studies carried out in some of the small scale factories producing steel through the IF process, revealed high levels of air pollution in the areas, improper solid waste disposal as well as high energy and water consumption.

Average specific energy consumption in IF is 700 kWh/ton liquid metal (Gandhewar et. al, 2007). Practically achievable optimum value of SEC is 625–650 kWh/ ton, so higher than in the case of the EAF process (CSE, 2012). However, in small scale plants figures of SEC range around 1,000–1,200 kWh/ton and sometimes even reach energy consumption of 1,500 kWh/ton, leaving a big margin for improvement in that field. Apart from high energy intensity, many IF units in India have no air pollution control devices, which leads to high levels of dust and smoke. Furthermore, in many cases there are no arrangements for proper disposal of slag[3], which can lead to soil and water pollution of the area. In general, although the IF route can be considered as more environmental friendly than steel production from iron ore, the way it is being utilized in India for the majority of cases has opposite effects. Poor housekeeping of MSP, uncontrolled emissions and low energy efficiency are the main characteristics of this process. Furthermore, installation and operation of pollution control equipment is not economic in small-scale plants with a capacity of less than 100 tpd and is consequently neglected. Taking into account the fact that India relies to a large extent on the many MSP utilizing IF for its steel production, the steel industry will continue to have significant environmental impacts.

### *2.3.4 Direct Reduced Iron (DRI)*

Apart from the leadership in the induction furnace route, India is also a world leader in direct reduced iron production. These two facts can also be related when taking into account that DRI is also used in high percentages as a raw material in the IF process for steel production. Additionally, both processes are based on small-scale technology, which is suitable for a country with undeveloped infrastructure like India. In many cases, DRI plants include IF units that are capable of directly using DRI for the production of steel (Chatterjee, 2009).

DRI is iron produced in a solid form by the reduction of iron oxide. Direct reduction actually includes a group of processes through which iron ore is reduced to a solid iron product using a reducing agent (IBM, 2011). There are two types of technologies available for producing DRI: coal based and gas based iron reduction. In the coal-based process, the reducing agent is non-coking coal[4] whereas in the gas-based route the reductant that is used is natural gas. The technology used to produce DRI using coal is based on a rotary kiln[5]. From an environmental perspective, the gas-based route is preferable. However, DRI production in India is mostly coal based because of restricted natural gas resources that are also locally concentrated, in contrast to high reserves of iron ore and large availability of non-coking coal. Therefore, as most local coal is not suited for coke making, but can be used for DRI production, it can be concluded that the choice for the less efficient DRI route is a direct consequence of the low resource quality (Gielen & Taylor, 2009). According to future projections and scenarios, coal-

[3] Steel slag is a by-product of steel making, produced during the separation of the molten steel from impurities.

[4] Coal that is not suitable for coke production because of its coking property and cannot be used in primary production of steel.

[5] A rotary kiln is a device used to raise materials to a high temperature in a continuous process.

based DRI will continue to be the preferred method in India for the same reasons (GIZ, 2011). The advantage of the direct reduction method in comparison to the blast furnace for production of iron, is that it is a much simpler method to reduce iron ore and mainly that the reduction requires relatively low temperature compared to BF, as it takes place at a temperature below the melting point of the iron produced (CPCB, 2007).

In general, direct reduced iron can be used as a primary metallic input for steel production in EAF or IF units through the conventional melting and treatment processes. Currently the major portion of DRI is melted together with pig iron and scrap in electric furnaces for the production of steel castings (rounds, slabs, billets or blooms) (CPCB, 2007). Furthermore, the largest part of DRI produced worldwide, is actually used as a high quality substitute for steel scrap in these processes. Especially in India, this became the main function of DRI mainly because of shortage of steel scrap in the country as well as no steady prices in the global scrap market (IBM, 2012). Therefore, during the early 1990's, the DRI industry was particularly promoted in order to provide an alternative to steel scrap for re-melting, which was increasingly becoming scarce (IBM, 2011). Additionally, as imported scrap in India attracts high custom duty, its price becomes uncompetitive compared to locally produced DRI. Moreover, cheap labor provided by the abundance of unskilled local workforce also contributes to the growth of DRI plants. With the increasing demand for crude steel and the reduction in availability of scrap, dependence on DRI will increase further in India (CPCB, 2007). It was estimated by the CSE of India that by 2030, approximately 60% of the total steel production in India will be from DRI. Consequently, as the tremendous potential of DRI as an alternative route to iron and steel making has also been recognized by the Indian government, it is a vital sector for growth of Indian steel industry (Prasad et. al, 2011).

### Environmental impacts

The fact that in India, DRI is produced using mainly coal as a reducing agent, makes clear that there are significant environmental impacts. Additionally, low quality of local coal found in India, containing high levels of ash[6], results in high fugitive dust emissions and extensive waste generation and at the same time shows low potential in energy and emission savings (CSE, 2010). It is important to note that low coal quality also results in product quality issues. DRI plants release various hazardous pollutants like cadmium, nickel, hexavalent chromium (most dangerous through air and water), arsenic, manganese, and copper (Chatterjee, 2009). Moreover, they are prone to air pollution because of emissions of sulphur dioxide and nitrogen oxide. What is even more important to take into account, is that similarly to the case of IFs, the majority of DRI plants in India are small-scale facilities, a fact that consequently means reduced energy efficiency and higher carbon emissions (GIZ, 2011). DRI plants are easy to set up and initial capital investment is low and can be recovered in a short period. Additionally, there is liberalized financial support, which in combination with low-cost technologies resulted in the 'mush-rooming' of a significantly large number of mini DRI plants. In DRI plants of small capacity there is usually very limited or no pollution control equipment, no proper waste treatment and high water consumption, which is usually not monitored. The energy intensity of the DRI process in India is higher than that of the oxygen route and as a consequence, resulting $CO_2$ emissions are also very high. In average, energy intensity for coal-based DRI in India can be considered to be around 20GJ/ton DRI, which results in $CO_2$ emission intensity of 2.5 ton $CO_2$/ton DRI (GIZ, 2011). As a consequence, taking into account the aforementioned, the use of DRI in the EAF and IF routes introduces a counter effect to the environmental benefits that these processes have, as it is mostly based on non-renewable resources like iron ore and coal and is highly energy intensive and polluting in most cases.

[6] According to the CSE of India, 40% ash is contained in non-coking coal on average (CSE, 2010).

Figure 2.5 presents an overview of the different routes for steel production and the energy consumption levels for each. It needs to be mentioned that the IF is not included in the representation, but it can substitute the EAF in either primary production from DRI or secondary production from scrap. Figure 2.5 is used for illustrative purposes as energy intensity for each process may vary from plant to plant.

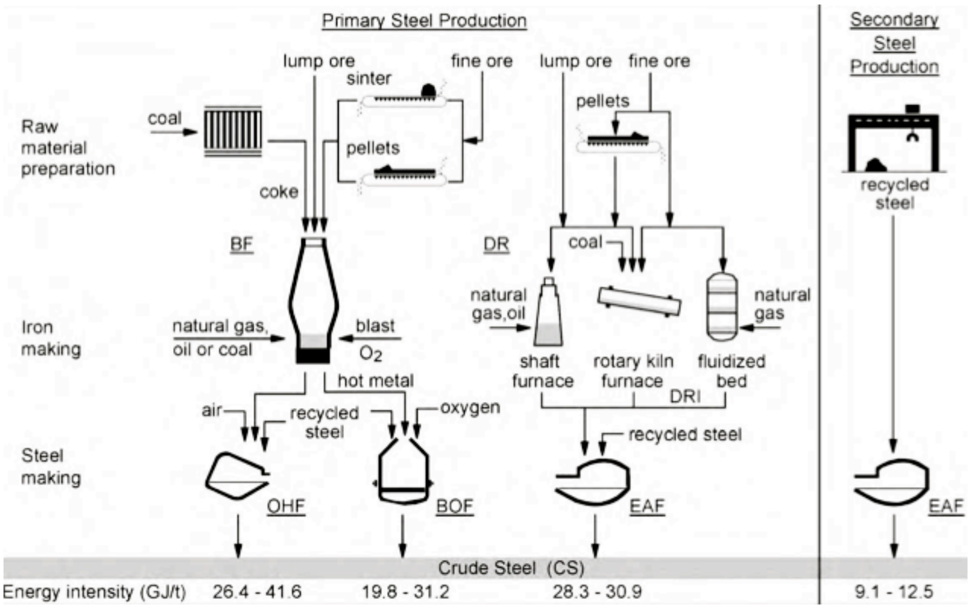



**Figure 2.5: Steel production routes & energy intensities (Source: Chukwuleke, 2009)**

## 2.4 Structure of Steel Industry in India

In contrary to the global trend, the Indian steel sector is dominated by secondary steel production following the electric route. More specifically, the highest percentage of steel is produced in EAF and IF. According to the latest report by the Indian Ministry of Steel, for the period April 2012 to December 2013, the IF route accounted for 33% of the total crude steel production with an output of 19 million tons of crude steel, overruling the EAF route, which contributed with a percentage of 24%. Together, electric furnaces surpassed the BOF route for which a share of 43% was reported. The Ministry noted that IF has emerged as a key driver of crude steel production in the country. According to the World Steel Association, for the whole year of 2012, the electric route contributed with a percentage of 67.5% to the total crude steel production, whereas the oxygen route accounted for 31.2% and the open-hearth route only for 1.3%. The production of DRI for 2012 was at 19.7 million tons keeping India in the first place in DRI production worldwide, which is the case since 2003 (WSA, 2013). Total capacity in DRI keeps increasing over the years and at the moment holds a value of approximately 35 million tons. Moreover, as mentioned in the previous part, DRI production in India is mostly coal-based and figures from the Indian Ministry of Steel for 2012 indicate that from the total DRI production for the period April-December 2012, coal-based DRI accounted for 78%, whereas gas-based contributed with a percentage of 22%. Figure 2.6 presents the total crude steel production in India by process and the DRI production by process for 2012.

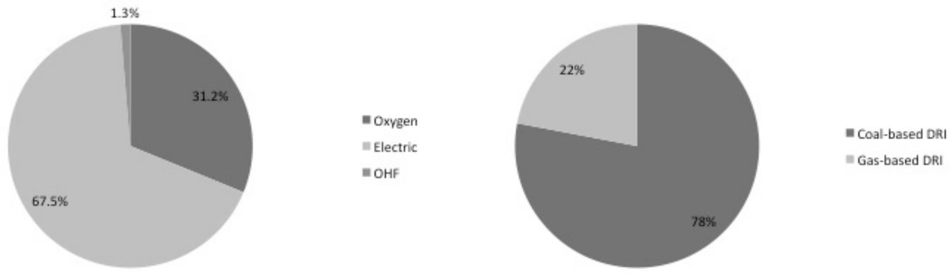



**Figure 2.6: Crude steel production in India by process and DRI production by process for 2012 (Data from WSA, 2013 and Ministry of Steel, Government of India)**

Figure 2.7 retrieved from a presentation for the German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit, GIZ) on the Indian steel industry for 2011, using figures from the Steel Association of India (Joint Plant Committee), presents an overall picture of the structure of the Indian steel sector based on the different processes and the raw materials used. Additionally, it provides an overview of the different routes for steel production. It needs to be noted that figures may vary from source to source, on the number of installed units for example. The steel industry in India is highly fragmented with a broad variety of process routes based on different raw materials and also comprises of hundreds of small mills of various types (GIZ, 2011). Furthermore, it is again highlighted that the IF process holds the largest share in official steel making from iron products, followed by the EAF. It can be therefore concluded as well, that the steel sector depends largely on steel scrap sources. For the case of iron making, DRI obviously shows a record performance dominating the sector. The significantly high performance of the DRI sector can be related to the conclusion made above, because DRI is used as a substitute for steel scrap. Lastly, the huge significance of the re-rolling sector[7] is visible from this figure as it has the largest number of installed units and also contributes with the highest percentage to finished steel products in the country. However, re-rolling cannot be included in the official steel making processes as it is located one level after the actual production of steel and can thereafter be considered as an informal sector of steel making, having still a large impact.

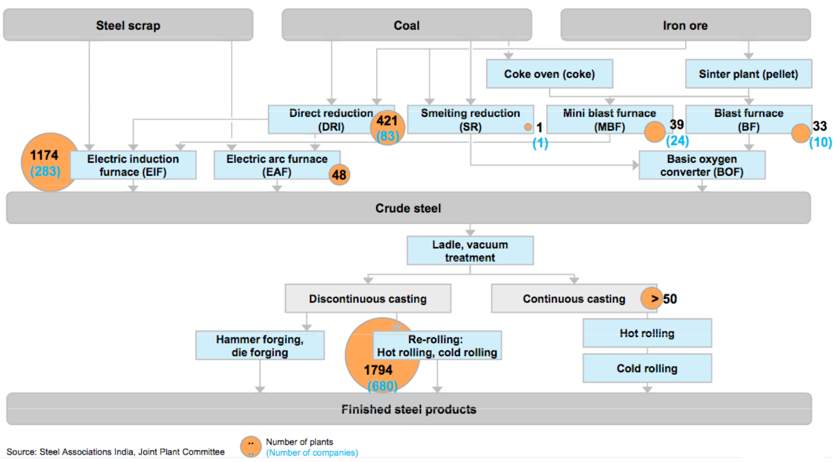



**Figure 2.7: Structure of steel industry in India. (Source: GIZ, 2011, Steel Association of India, Joint Plant Committee)**

[7] Steel scrap depending on its shape, weight and size can be directly re-rolled without melting in order to produce finished steel products.

## 2.5 Steel Scrap in India

### *2.5.1 Steel scrap from ship recycling*

The main structure of a ship consists mainly of recyclable materials, mostly metals such as steel, aluminum, copper etc. One of the most important and valuable outcomes from ship recycling is steel scrap. According to the impact assessment made for the EC on the proposal for a new Regulation on Ship Recycling, 74% of a ship's tonnage (LDT) is steel (COWI, 2009). Other studies mention a figure of approximately 75% to 85% (Mikelis, 2013). At the same time, steel scrap is one of the main drivers for the development of the ship recycling industry especially in India where there is high local demand and not many local steel scrap sources. The ship recycling yards of Alang & Sosiya hold 90% of the total ship recycling industry of the country. According to the Annual report of the Indian Ministry of Steel for 2012-13, during the year 2011-2012, 291 ships were beached in India and up to December 2012 a corresponding value of 300 ships, accounting for 3.0 million tons LDT.

There are different routes that steel scrap coming from obsolete vessels can follow. Depending on its form and shape, it can be reused directly in construction or road building if possible, re-rolled in steel re-rolling mills (SRRM), or melted and charged into electric furnace plants. As the steel industry in India is dominated by secondary steel production, it is clear that steel scrap is one of the most essential raw materials used for steel manufacturing in the MSP that are scattered around the country. Additionally, scrap coming from the ship recycling industry supplies a substantial share of steel scrap destined for re-rolling.

The Ministry of Steel mentions a percentage of 1%-2% for the contribution of ship recycling to domestic steel demand. A study by Dr. Mikelis, (former Head of the Ship Recycling Section of the International Maritime Organization) on the contribution of the ship recycling industry to the production of steel in the main ship recycling countries, provided an indication of the importance of steel scrap from ship recycling to the steel producing industry of India. The relative importance of ship recycling was calculated by comparing ships' scrap to imported ferrous scrap for the year 2011. The result was that steel scrap from end-of-life ships beached in India accounts for 28% of the total scrap imports, which is a quite high percentage and in that way highlights the strong connection between ship recycling and the steel industry of the country (Mikelis, 2013). Data on total steel scrap usage for steel production in India are not officially available and probably for that reason the contribution of ships' scrap to that amount was not provided by the study. If steel scrap from ships is compared to total crude steel production in 2011, the contribution of ship recycling to steel production is 1.9%, which confirms the figure provided by the Indian Ministry of Steel. However, it is essential to mention that in both cases, in the calculated percentages, steel scrap that is re-rolled directly in SRRM is not included and in that sense, the importance and contribution of ships' scrap to the local steel industry can be considered much higher.

### *2.5.1 Steel scrap for re-rolling*

In India, steel scrap re-rolling takes place in steel re-rolling mills (SRRM), which are part of the country's small and medium-sized enterprises. There are more than 1,800 SRRM spread across India with the highest percentage (75%) being small-scale units. Steel re-rolling is a key player in the overall supply chain of steel and has actually the highest contribution of all processes to the total steel production in India, providing 57% of the total finished steel products (UNDP, 2012). However, steel scrap that is reused or re-rolled is not included in the statistics for steel scrap used in steel making and at the same time data on the total steel scrap used for steel production were difficult to obtain for the case of India. This is mainly because steel scrap that is re-rolled is not melted in order to produce crude steel and therefore, re-rolling is actually considered as one of the final production stages of the overall steel-making process. During this stage, re-shaping of rough shapes into thin sheets, bars, profiles, pipes or wires takes place. Furthermore, the energy used for re-rolling is relatively small compared to other processes that constitute the initial production stages. Nevertheless, steel re-rolling plays a major role in the overall steel recycling process related to ship recycling in India and SRRM are in most cases directly linked to the ship recycling yards (SRY). Because most SRRM are of small-scale though, steel re-rolling can be considered as an informal sector that is hard to keep track off and monitor in order to acquire data and statistics. Additionally, there are environmental issues also in that case, related to low energy efficiency of the SRRMs as well as quality issues of the products from re-rolling.

From the total steel scrap that can be recovered from a ship, steel scrap for re-rolling accounts for 60% - 70% of the total LDT (Mikelis, 2013). It is important to note that re-rolling apart from the fact that it is less energy intensive compared to the other steel making processes, is also less capital intensive and for that reason, finished steel products that were manufactured from re-rolled steel can have a competitive price. However, there are quality issues when compared to steel products coming from melting of scrap. Based on the aforementioned, it is clear that ship recycling provides a significant amount of steel scrap that is then re-rolled in the SRRM of the area and is afterwards converted into rods and bars. These are then used mostly in the construction sector. Ships' scrap for re-rolling can be substituted by steel scrap from railways, pencil ingots from induction furnaces, semis from the integrated plants or imported steel scrap for re-rolling (SRIA, 2006).

### *2.5.2 Steel scrap imports*

Global trade in steel scrap is growing and as scrap is becoming more critical in steel production, countries that lack domestic sources are importing steel scrap. Table 2.2 presents the main scrap importing countries in the world, where it can be noticed that India is one if the biggest importers in the world. Table 2.3 includes the major scrap exporters worldwide. From the figures, it is obvious that the US and the EU are the biggest net steel scrap exporters in the world, although at the same time they also import substantial volumes of scrap.

| Year / Country | 2008 | 2009 | 2010 | 2011 | 2012 | % 2012/2011 |
|---|---|---|---|---|---|---|
| **Turkey** | 17.415 | 15.665 | 19.192 | 21.460 | 22.415 | +4.5 |
| **Korea** | 7.319 | 7.800 | 8.091 | 8.628 | 10.126 | +17.4 |
| **India** | **4.579** | **5.336** | **4.643** | **6.175** | **8.180** | **+32.4** |
| **China** | 3.590 | 13.692 | 5.848 | 6.767 | 4.974 | -26.5 |
| **Taiwan** | 5.539 | 3.912 | 5.364 | 5.328 | 4.955 | -7.0 |
| **USA** | 3.571 | 2.986 | 3.775 | 4.003 | 3.711 | -7.2 |
| **EU-27** | 4.809 | 3.270 | 3.646 | 3.714 | 3.412 | -8.1 |
| **Canada** | 1.674 | 1.408 | 2.226 | 1.911 | 2.343 | +22.6 |
| **Indonesia** | 1.899 | 1.484 | 1.642 | 2.157 | 1.944 | -9.9 |
| **Malaysia** | 2.293 | 1.683 | 2.292 | 2.050 | 1.816 | -11.4 |
| **Thailand** | 3.142 | 1.323 | 1.282 | 1.877 | 1.701 | -9.4 |

**Table 2.2: Main steel scrap importers, in million tons scrap steel. (Data from BIR, 2013)**

| Year / Country | 2008 | 2009 | 2010 | 2011 | 2012 | % 2012/2011 |
|---|---|---|---|---|---|---|
| **USA** | 21.712 | 22.439 | 20.556 | 24.373 | 21.397 | -12.2 |
| **EU-27** | 12.799 | 15.779 | 19.033 | 18.813 | 19.214 | +2.1 |
| **Japan** | 5.344 | 9.398 | 6.472 | 5.442 | 8.459 | +57.9 |
| **Russia** | 5.128 | 1.202 | 2.390 | 4.042 | 4.349 | +7.6 |
| **Canada** | 4.084 | 4.792 | 5.154 | 4.832 | 4.248 | -12.1 |
| **Australia** | 1.708 | 1.925 | 1.636 | 1.745 | 2.245 | +28.7 |
| **S. Africa** | 1.271 | 1.144 | 1.224 | 1.436 | 1.632 | +13.6 |

**Table 2.3: Main steel scrap exporters, in million tons scrap steel. (Data from BIR, 2013)**

India holds the 3rd position in steel scrap imports globally with a figure of approximately 8 million tons scrap imported excluding end-of-life ships that arrive there for recycling (BIR, 2013). Its imports presented a rise of 32.4% for 2012 compared to the previous year, which represents the highest increase in imports in all major importing countries. It is essential to note that there are occasional differences between the data provided by the BIR and the WSA, especially for the case of steel scrap usage and trade. In the study by Mikelis, the figure of 8 million tons imported scrap is initially presented. However, the figure of imported ferrous scrap used to calculate the contribution of ships' scrap is retrieved from the WSA report of 2012 and is equal to 3.5 million tons scrap. In the present study, the figure provided by the 2013 BIR report was used in the data analysis. It is also noticeable that the first seven scrap importing countries are all included in the list of the largest steel producing countries. Additionally, Turkey, China and India, which are again three of the five countries that hold the largest share of the ship recycling industry, are at the same time major importers of steel scrap (Mikelis, 2013). This fact can lead to an initial conclusion of a relationship between high crude steel demand and production, limited steel scrap sources and high scrap imports in the countries that at the same time lead the ship recycling market. India mostly imports steel scrap form the USA, the EU and a small percentage from South Africa. Figures 2.8 and 2.9 provide a visual representation of the main flows taking place for the scrap exports of the EU and the US, where also the part that India plays as an importing country can be seen.

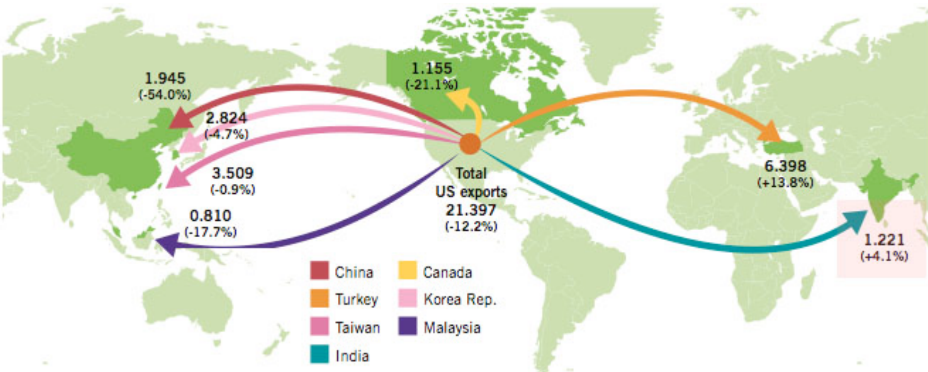



**Figure 2.8: Main flows of US steel scrap exports for 2012, in million tons. (Source: BIR, 2013)**

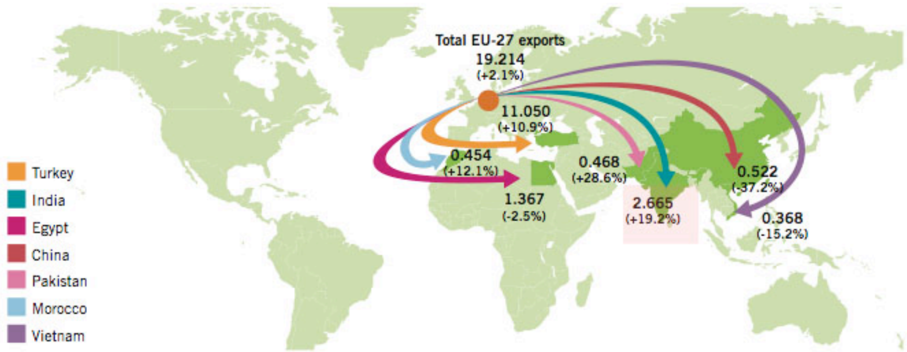



**Figure 2.9: Main flows of EU steel scrap exports for 2012, in million tons. (Source: BIR, 2013)**

## 2.6 Climate Change & the Indian Steel Sector

Apart from the fact that the iron and steel industry is one of the key factors for the country's economic development, energy use and emissions intensity in the industry are specifically high for the case of India. Considering the top steel producing countries worldwide, India is actually the country with the highest energy intensity and GHG emissions coming from the iron and steel industry, followed by China, Brazil, Poland, US, France, Japan and Germany (Deloitte, 2004). Additionally, there is high potential for energy savings in the iron and steel sector and a lot of research is carried out at the moment in this field. According to the 2012 report on global trends of $CO_2$ emissions by the PBL Netherlands Environmental Assessment Agency, in 2011, India was one of the top five $CO_2$ emitters in the world holding the 4$^{th}$ position with total emissions of 1.9 billion tons $CO_2$, which represented a 6% share of the total global emissions and a 6% increase from the previous year (and 75% from 2002). It is also interesting to mention that the emissions of India and China that rose significantly, as these countries were not at all affected by the economic recession, were responsible for the largest part of the total increase in the total emissions globally.

Available data for 2007 from the 2010 Report in GHG emissions in India by the Indian Network for Climate Change Assessment (INCCA), show that $CO_2$ emissions from the iron and steel industry were equal to approximately 117 million tons $CO_2$ and represented the 28% of the total emissions from industries in the country, excluding emissions for the production of electricity (see Figure 2.10). The iron and steel industry hold the second largest share of the total emissions, following the cement industry. Additionally, Figure 2.11 presents an overview of the $CO_2$ emissions in the country for 2007, where it can be seen that the iron and steel industry accounted for 8% of the total emissions (including electricity).

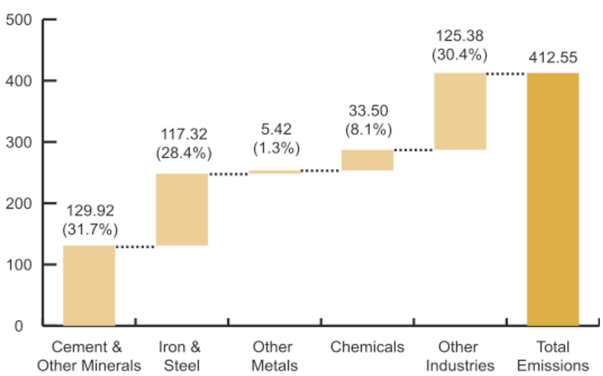



**Figure 2.10: GHG emissions per industry sector in India, in million tons $CO_2$ equivalent (Source: INCCA, 2010)**

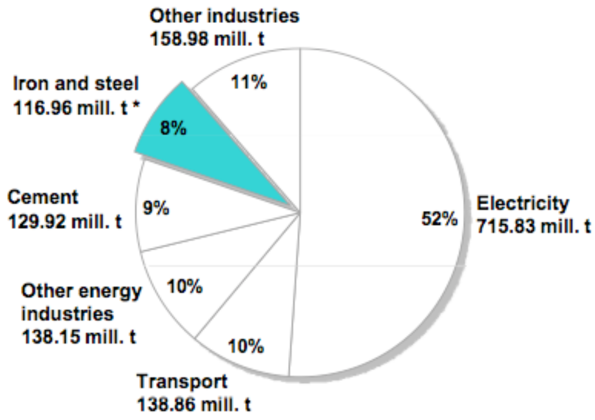



**Figure 2.11: $CO_2$ emissions by sector, in million tons. (Source: GIZ, 2011)**

What is more important to consider is that the average emission intensity of the iron industry in India is 33% above global average and therefore there is a large potential for improvement in that sector in order to cut down total national emissions (see Figure 2.12). Additionally, reducing agents consumption in BF, which is mainly coal, is also 36% above global average and also above the consumption in all major steel-producing countries (GIZ, 2011).

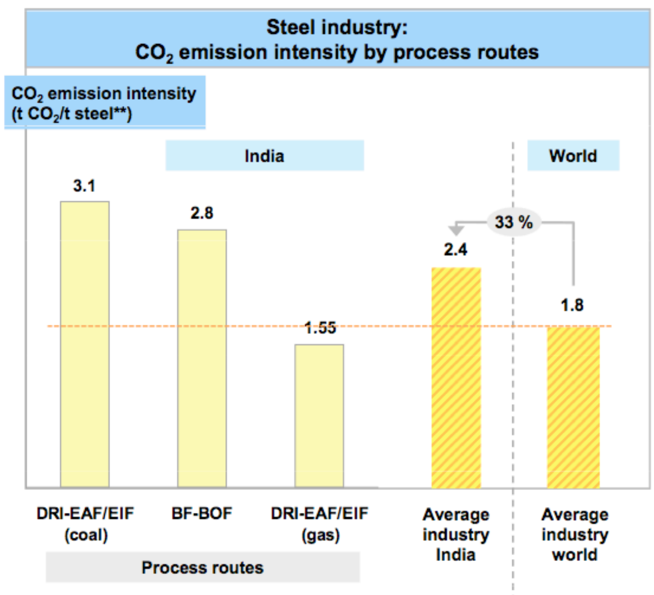



**Figure 2.12: $CO_2$ emission intensity of the steel industry by process. (Source: GIZ, 2011)**

## 2.7 Relevant Conclusions on Ship Recycling

Based on the analysis of the Indian steel industry and the way it is currently structured, a general idea of the contribution of ship recycling can be acquired. Steel scrap recovered from end-of-life ships is either re-rolled in SRRMs or melted in EF to produce crude steel and therefore contributes to secondary steel production. The routes that ships' scrap can follow for steel making is presented in Figure 2.13.

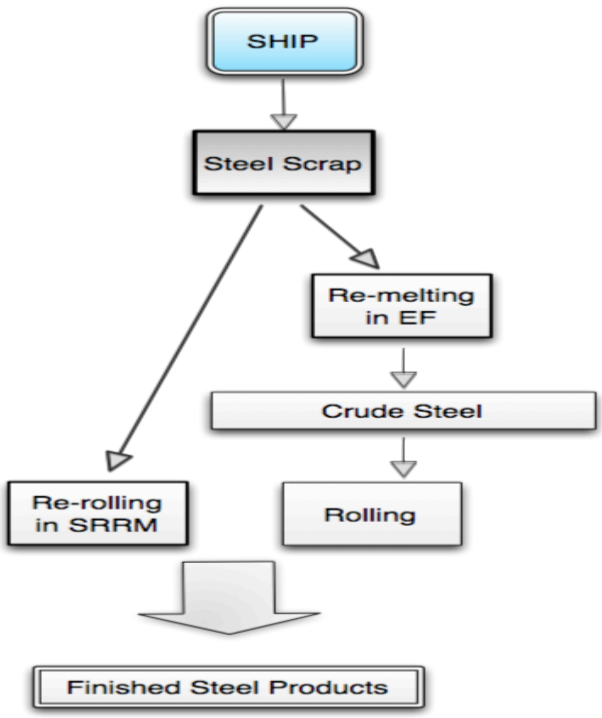



**Figure 2.13: Steel scrap from ship recycling utilized for steel production.**

# **Chapter 3:** Data Analysis

**CONTENTS**

System boundaries – Scenario & Assumptions – Flow Diagram – Data collection, Sources & Limitations

# 3. Data Analysis

## 3.1 System Boundaries

The brief legal analysis on ship recycling provided in Chapter 1, revealed one the main dilemmas and reasons for debate concerning ship recycling at the moment: the geographical restriction (or not) to European ships destined for recycling. Of course, that does not mean that there are no other differences between the content of the two main Conventions (Basel and Hong Kong Convention). As mentioned in Chapter 2, HKC adds various new elements when compared to BC. Apart from that, it needs to be noted that the BC was not specifically designed for the shipping industry. Furthermore, the issue of internalization of external costs and consequently the difference in the level of responsibilities that arises from the HKC is an important subject as well. It is often argued mostly from the side of environmental organizations, that the HKC imposes heavier demands on the ship recycling facilities than on ship owners because of the standards that the SRFs need to meet in order to be able to accept EU ships for dismantling. However, the main and most fundamental and controversial modification is that the HKC as well as the proposal for a Ship Recycling Regulation (SRR) by the EC, will actually allow EU ships to be sent to non-OECD countries for recycling, whereas this is considered illegal in the context of the BC. This subject is one the main contentious topics that initiate the whole discussion concerning the two alternative legal instruments. For that reason, the methodology will assume this simplistic but important legal alteration.

The scope of the HKC as well as the SRR covers only EU-flagged ships and it therefore makes sense for the focus of the study to be on European ships as well. However, it is essential to make a distinction between EU-owned and EU-flagged ships. Available data and future projections on the volumes of ships dismantled in developing countries of South Asia make a distinction between EU-flagged and owned ships, EU-owned but not flagged and EU-flagged and not owned ships (see Table 1, Chapter 1). One of the main objectives when working towards more sustainable ship recycling is that ship owners should take responsibility over their end-of-life ships so that the 'polluter pays principle' can be followed. This responsibility can easily be (and currently is) avoided by re-flagging (see Appendix IV). For that reason, in the present research EU-owned ships will be taken into account, even if the flag of registry is different in the end of their life.

Furthermore, another important reason behind this choice is the responsibility of the EU for the current unsustainable situation in the field of ship recycling. European shipping companies account for a large share of the global fleet. In addition to that, a significantly high percentage of ships dismantled each year in substandard facilities of developing countries by circumventing the BC, are EU-owned. According to data provided by the EC (DG Environment) for 2009, a percentage of 40%-45% of the total volume of ships recycled in India that year, were EU-flagged. Even from the non EU-flagged ships, a large share originally belongs to European companies. Last but not least, according to future projections, an upward trend in scrapping volumes of EU-flagged ships is expected, which will intensify the problem in future years.

Apart from the restriction in the origin of the ships sent for recycling, there has been a focal point on the destination as well. The focus of the research was on the country of India. The reason behind this choice is that among the top ship recycling countries, India holds the largest share of the industry over the years. As it has already been stated, the beach of Alang is one of the largest and most notorious ship breaking yards of the world. Lastly, it was essential to limit the scope of the study in order to consequently facilitate the data acquisition. Finally, in that sense, the results and recommendations could be more applicable.

The present analysis will focus on the environmental trade-offs related to the recycling of European ships in India. However, as the issue of ship recycling involves many interrelated topics even when narrowing down the scope to the environmental impacts, a limitation had to be applied in that sense as well. In India, ship recycling is a vital industry because it supplies the country with steel scrap, which is widely used afterwards for the production of crude steel. Chapter 2 provided information through which it can be concluded that steel scrap in India can be considered as a very valuable raw material for steel making while at the same time local resources of scrap are limited. The present study investigated the environmental impacts that would occur if European ships were not sent to India for recycling and consequently the ships' scrap steel was not available. Of course, all the other relevant sides of the problem, such as local pollution during the actual ship recycling activity because of hazardous materials are not neglected. However, the aim of this study is not to carry out a complete impact assessment, but to provide more insight to an aspect that has not been extensively examined so far, which is the relationship between ship recycling and the steel market from an environmental point of view.

## 3.2 Scenario & Assumptions

### *3.2.1 Setting the scenario*

The scenario was based on the assumption that all European ships that were beached in India for 2012, were actually not recycled in India. This leads to the assumption that the steel scrap coming from EU ships was not available in India for the same year. The required figure on the number of EU ships dismantled in India for the year 2012 was obtained from the NGO Shipbreaking Platform. The Shipbreaking Platform published in February 2013 a list of European ship owners that sent their end-of-life ships to the beaches of South Asia for recycling during 2012. The result was a record number of 365 ships in total. The list also included the specific destination for each ship and in that way the total number of ships could be calculated for the case of India.

The published list also included the LDT of each of the European ships that were sent for recycling. According to the literature, approximately 75% of the total LDT of a ship is steel. Therefore, from the total number of ships and the LDT of each, the corresponding total volume of steel scrap that EU ships provided that year in India could be calculated. It should be noted that the figure of the percentage of steel in a ship may vary from source to source, but a 75% was used as an average.

### *3.2.2 Substitution – Alternative materials to ships' steel scrap for steel making*

In order to identify the environmental impacts resulting in the absence of ships' scrap, the materials that can be used as a substitute of steel scrap from ships in steel making had to be investigated. In simple words, the following question had to be answered: What would be the alternatives ways to have the same output of steel that would have been produced from steel scrap coming from EU ships recycled in India?

This question is not very simple to answer for the specific country mainly because of the special characteristics of the Indian steel industry. For that reason, it was important to acquire an overview of the dynamics of the steel sector. The different routes that steel scrap coming from ship recycling can take for the production of steel were presented in Chapter 2. Thus, it was assumed that ships' scrap is reused directly, re-rolled or fed into electric furnaces. Different sources mention different figures for the percentage of steel scrap for re-rolling in the total LDT of an obsolete vessel that is recycled. These figures range from 50% to 60%. In the present study, from the total amount of steel scrap coming from EU ships recycled on the beaches of India, the assumption was made that 50% is re-rolled and 50% is melted and used as input for EAF or IF. In that way, from the total ships' volume in LDT, a calculation was made on the volume of ships' scrap that would be re-rolled and the volume that would be melted in electric furnaces for the production of crude steel.

### Substitutes to Steel Scrap for Re-Rolling

Steel scrap that can be re-rolled falls in the category of 'old scrap' and usually comes from defective or used products. Its form allows it to be directly used for re-rolling in SRRMs in order to produce finished steel products for specific applications. The ship recycling industry in India generates a substantial quantity of steel scrap for re-rolling. The share of scrap coming from ships can be substituted by steel scrap from other sources such as railways, pencil ingots produced mainly from induction furnaces, semi-finished products such as steel billets from integrated steel plants (ISP) and imported scrap for re-rolling.

For the present study, pencil ingots produced in small-scale electric induction furnaces will be considered as the main substitute for steel scrap for re-rolling. The analysis did not take into account steel scrap recovered from other local sources like railways, as it falls in the same category of 'old scrap'. Furthermore, steel slabs or billets from ISPs will also not be included as one of the possible substitutes of ships' scrap. The reason behind this choice is that semis are usually produced in integrated steel plants (ISP), where iron ore is used as the basic raw material for production of crude steel, which is then normally rolled into finished shapes in-house. This means that although semis are rolled in order to produce final products, this is usually done within the large scale ISP and not in independent small scale re-rolling mills which are used for re-rolling ships' scrap for example. In that way, rolling is actually just considered as the final stage of the whole steel making process. Consequently, it is not likely that steel scrap coming from ship recycling, which is usually re-rolled in SRRM located close to the SRF, would be substituted by the output of large-scale ISP. Finally, the case of imports again has not very high probability, as scrap imports usually include steel scrap for melting in EF and not semis for rolling.

### Substitutes to Steel Scrap for re-Melting

Steel scrap for re-melting is actually scrap that is not possible to be reused or re-rolled directly in its existing form. Therefore, it has to be re-melted in electric furnaces in order to produce liquid steel and then final steel products after rolling. As it has been extensively analyzed in Chapter 2, direct reduced iron is widely used in India for the production of crude steel and mainly as a substitute for steel scrap because of the limited local resources.

Therefore, for the case of ships' steel scrap for re-melting, the substitution can be:

- DRI
- Steel scrap imports.

### *3.2.2 Environmental impacts*

For each case (steel scrap for re-rolling and steel scrap for re-melting) there are two substitution scenarios based on the alternative materials, which can be used for steel making. In order to investigate the related environmental impacts for each case, the energy and emissions intensity of the processes through which these materials are produced was taken into account. In that way, the corresponding energy consumption and $CO_2$ emissions to produce the required amount of the materials were calculated. Additionally, a qualitative assessment was carried out, through which the different processes were evaluated from an environmental point of view taking into account their overall environmental impacts in terms of efficiency, pollutants etc., as presented in Chapter 2.

For the case of DRI, the volume of required DRI was set equal to the volume of ships' scrap that is melted in EF. In that way, taking into account the energy intensity of the DRI production process, the total energy consumption and the resulting $CO_2$ emissions to produce the total DRI volume was calculated. To substitute steel scrap for re-rolling the energy consumed to have the equivalent output of steel ingots for re-rolling from IF was assumed.

However, in the IF route, DRI and steel scrap are also used as input for the production of ingots. As mentioned in Chapter 2, DRI and scrap are combined in IF in different proportions depending on the availability. For the present analysis, it was assumed that 50% DRI and 50% scrap would be used as input for the IF. Additionally, the material efficiency[8] had to be included as well. In order to produce a ton of solid steel product from an IF, a higher volume of input material is needed. The material efficiency was assumed to be 80%. In that sense, the volume of ships' scrap for re-rolling was set equal to the required volume of output from the IF and consequently the related material input for the IF was calculated. For the case of steel scrap, it was assumed that this volume would be locally available. For the case of DRI, the additional energy consumed and $CO_2$ emitted for its production was added to the energy and emissions resulting from the IF process itself. It needs to be noted that environmental impacts related to the next steps for the final production of steel, i.e. the EAF process and the re-rolling process were not taken into account, as these would remain the same.

Imported steel scrap is a substitute to ships' scrap for melting in EFs, mainly in EAFs as most of the IF units are gradually switching to DRI or local scrap (Steel Mint, 2013). For that substitution scenario, the energy and emissions intensity can be considered to be equal to the ship recycling activity itself, if the final voyage of the ship is taken into account. In most cases, when it is decided that a ship is going to be scrapped on a beach of India for example, this transit is combined with a last shipment of cargo in a nearby area for economic reasons. Therefore, this can be assumed to be equivalent to the shipment of imported steel scrap. Of course, the environmental impacts depend on the distance in nautical miles, the type and energy efficiency of the ship, the exact port of destination etc. Nevertheless, there will not be substantial differences and for that reason, this case will not be taken into account as a substitute to steel scrap for melting.

A sensitive part of the present analysis is the fact that the comparison between the production processes of the substitution materials and the actual ship recycling activity providing steel scrap might not be considered totally fair in terms of energy use and carbon emissions. Ship recycling in India is a very labor-intensive activity and hardly any energy is consumed during the whole process. However, there are significant environmental impacts related to extensive pollution from hazardous waste. For that reason, it is important to stress the issue that the present study presents one part of the 'equation'.

### 3.3 Flow Diagram of the Data Analysis

Figure 3.1 presents the flow diagram summarizing all the above and provides a simple picture of the methodological process that was followed for the data analysis. The two main substitutes to steel scrap from EU ships can be seen in the red boxes at its left and right side and the arrows present the routes, which the raw materials follow for the final production of steel products. The focus of the study is on the related environmental impacts of the two alternative processes in order to finally present the environmental trade-offs that take place. The doted frame represents the part that is actually essential for the present analysis.

[8] Material efficiency in the specific case is a measure of how efficient raw materials are used for the production of crude steel. (during steel production a significant volume of by-products and waste materials such as slag, sludge and dust are generated)

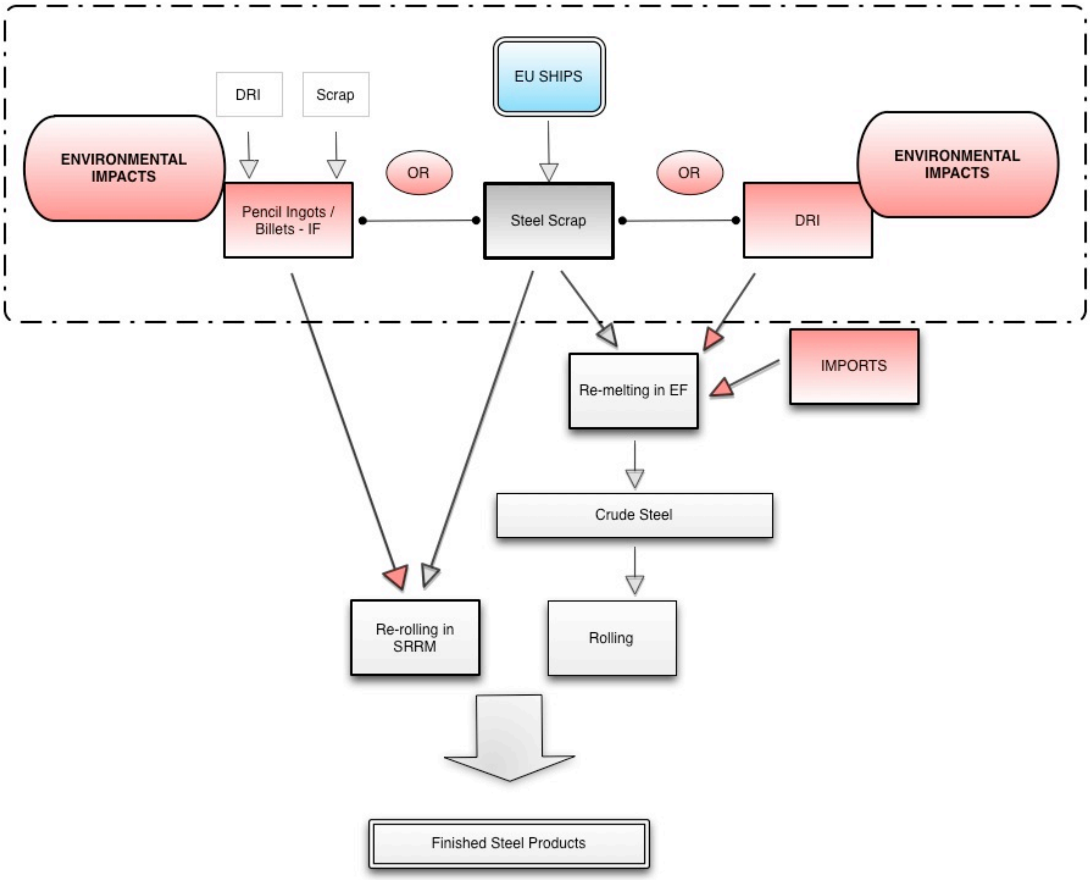



Figure 3.1: Data Analysis Flow Diagram.

## 3.4 Data Collection, Sources & Limitations

The scenarios on the substitution of steel scrap from EU ships were created taking into account the overall background of the Indian steel industry provided in Chapter 2. This was based on statistical data and future projections from the World Steel Association, the Bureau of International Recycling, the Indian Ship Recycling Industries Association and the Indian Bureau of Mines. The number and volumes of European ships recycled in India for 2012 were retrieved from the list published by the NGO Shipbreaking Platform. The percentages of the steel scrap for re-rolling and re-melting found on a ship were assumed as an average based on various studies and reports on the subject. Finally, average figures had to be assumed for the energy and emissions intensity of the DRI production process and the IF route in India, using available data from the Indian Ministry of Steel, the Indian Bureau of Mines and other reports and field studies on the Indian steel industry found in the literature.

There is of course a level of uncertainty in the calculations made, because of the number of assumptions and the fact that data acquisition for the country of India was challenging. Additionally, it needs to ne noted that because the steel sector consists of numerous small scale plants, for which there were no available data, figures on average energy and emissions intensity for specific iron and steel making processes found in the literature were not completely representative for the specific case study. Even in reports focusing specifically on the case of India, given figures were based on best available technologies (BAT) that are usually not followed in the mini iron and steel plants that are spread out around the country. Therefore, an additional margin over the average was assumed for energy consumption taking also into account results from field studies on specific plants that provided figures on the energy consumption in the surveyed plants and the average deviation from the BAT.

# **Chapter 4:** Results & Discussion

**CONTENTS**

Contribution of Ship Recycling to Steel Production - Additional $CO_2$ Emissions - Overall Environmental Impacts - Environmental Trade-offs – Discussion

# 4. Results & Discussion

## 4.1 Contribution of Ship Recycling to Steel Production

According to the list provided by the NGO Shipbreaking Platform, in 2012, a total number of 250 ships owned by European companies were recycled in India representing 70% of the total number of EU ships recycled that year on the beaches of South Asia (India, Bangladesh and Pakistan). Taking into account the total number of ships recycled in India in 2012, EU-owned ships accounted for a percentage of 47%. This percentage makes sense, as approximately 40% of the global fleet is EU-owned (BIOIS, 2010). The two main recycling locations were Alang and Mumbai, which held a share of 90.8% and 9.2% of the total recycling activity in India, respectively. The specific volume of ships in LDT ranges from a minimum of 2 thousand tons, to a maximum of 23 thousand tons LDT. The corresponding total volume of EU ships in LDT was around 2.3 million tons (LDT). When comparing this figure to the figure used in the study of Mikelis (2013) for the total volume of ships recycled in India in 2011, which was equal to 8.5 million tons, EU ships for the year 2012 represent a share of 27%. Assuming that an average 75% of the total volume of a ship is recyclable steel, a figure of approximately 1.7 million tons of steel scrap provided by EU ships is acquired. From the total volume of steel scrap, the assumption is that 50% of that is re-rolled and 50% is re-melted in electric furnaces, which gives a figure of 847 kt of steel scrap for each case. The contribution of ship recycling to steel production and consequently the relative importance of recycling of European ships in India was investigated by comparing the steel scrap volumes form ships, to the materials for substitution as well as the total steel production of the country.

For the case of steel scrap for melting the substitute material is initially considered to be DRI. According to the 2013 Statistical Report of the WSA, total DRI production in India for 2012 was equal to 19.7 million tons. The total volume of steel scrap from EU ships represents 4.2% of the total DRI production of the country. In other words, if steel scrap from EU ships was not available in India that year, DRI production would have to increase by 4.2%. For the case of ships' re-rollable steel scrap, the alternative material is assumed to be ingots as the output of induction furnaces. The total output of steel through that process in India, was 19.1 million tons for 2012 according to the latest annual report from the Indian Ministry of Steel. Therefore, if EU ships' scrap for re-rolling was not available in India, the annual output from IFs would increase by 4.4% for 2012.

For the case of imports, the comparison was made between EU ships' scrap for melting and imported steel scrap in India for 2012. This is because as mentioned, scrap for re-rolling is not usually imported because of the required big size and shape of steel pieces. Thus, the share of ships' scrap that would be re-rolled in SRRMs is not included. In 2012, India imported around 8 million tons of steel scrap and EU ships' scrap for melting represents 10.3% of that volume. In that sense, scrap imports would increase by 10.3% if EU ships were not recycled in India for the year 2012. This is a significant increase as India is already a major scrap importer and in 2012 was the 3$^{rd}$ largest scrap importing country in the world. Finally, the share of the total ships' scrap represents 2% of the total steel production of India for 2012, which was equal to 77.6 million tons steel that year.

It is assumed that substitution of steel scrap from ship recycling would be either from 100% DRI or 100% imported scrap. However, a more realistic approach would be to assume that a combination of the two would supply the required materials for substitution. If it is assumed that the total volume of ships' scrap for melting would be substituted by 50% DRI and 50% scrap imports the results are different. In that case, DRI production in India and scrap imports would increase by 6.0% and 5.1%, respectively.

Table 4.1 summarizes the contribution of recycling of EU-owned ships to the steel industry of India for 2012.

| Material | **Increase**<br><br>*Assuming 100% substitution of scrap for melting from DRI **or** 100% substitution from imports* | **Increase**<br><br>*Assuming substitution of scrap for melting from 50% DRI **and** 50% from imports* |
|---|---|---|
| **DRI** | 8.1% | 6.0% |
| **IF output (ingots)** | 4.4% | 4.4% |
| **Imported steel scrap** | 10.3% | 5.1% |

**Table 4.1: Increase in materials required for substituting steel scrap from EU ships in India.**

## 4.2 Additional $CO_2$ Emissions

### *4.2.1 Steel scrap for re-melting - DRI*

In order to investigate the impacts in terms of additional $CO_2$ emissions resulting from the substitution of EU ships' steel scrap for melting by other materials, two substitution scenarios were investigated: one with 100% substitution of scrap by DRI and one where it is assumed that 50% will be covered by scrap imports and 50% by DRI. For the case of imports, no additional energy or emissions is considered. Therefore, for the first case, it is assumed that the required amount of DRI is equal to the total volume of ships' scrap for re-melting. Based on the latest figures from the Indian Ministry of Steel, 78% of DRI is produced from coal and the rest 22% from natural gas. Consequently, it is assumed that the required material will be 660 kt coal-based DRI and 186 kt gas-based. Average energy intensities for these two cases, based on the literature, are 20 GJ/ton DRI for coal-based and 14 GJ/ton DRI for gas-based. In that way, the energy consumption for each case and consequently the total, in order to have the required output can be calculated. The result is 15.8 PJ energy consumption to produce the required amount of DRI substituting ships' scrap. The $CO_2$ emissions from DRI production can be calculated, taking into account the average emission factor for coal-based and gas-based DRI to be 2.5 ton $CO_2$/ton DRI and 1.0 ton $CO_2$/ton DRI, respectively. This results in approximately 2.9 Mt $CO_2$ emitted in total. For the second case, where imports are included, all figures can be divided in half, as only 423.5 kt of DRI will be required for substitution, assuming that the rest of the scrap destined for melting in electric furnaces will be imported. Thus, the corresponding figures will be 7.9 PJ additional energy consumed for DRI production and 1.5 Mt of emitted $CO_2$.

### *4.2.2 Steel scrap for re-rolling – Induction Furnace*

Based on the analysis of the steel industry in India, the most common substitute for steel scrap for re-rolling, are pencil ingots and billets produced from induction furnaces. Therefore, the total volume of output materials from IF that would be needed to substitute the ships' scrap, is set equal to the scrap for re-rolling coming from EU ships. In that sense, the energy consumption and corresponding $CO_2$ emissions for the production of this amount of material can be calculated.

The average specific energy consumption (SEC) in an IF is around 700 – 1000 kWh/t-liquid metal (Gandhewar et. al, 2007). However, in the mini plants that are scattered across the country, energy consumption is most of the times high above average. The average material efficiency is around 70%-80%. In that way, in order to obtain an output material of 847 kt, an input of 1.5 million tons is required, assuming 80% efficiency. It needs to be taken into account that the main input to IF is a combination of steel scrap for re-melting, DRI and PI. The proportions may vary depending on the availability of materials, which is a fact that can make the analysis complicated. In India, DRI and steel scrap are mostly used as input in IFs combined with a small percentage of PI in some cases. Nevertheless, what is important to note is that the input material is again related to ships' scrap, which can be widely used instead of DRI. Assuming an average share of 50% DRI and 50% steel scrap as input and 80% material efficiency, 762 kt of each would be required in order to have the desirable output. For this case, it will be assumed that the required steel scrap is locally available and the additional energy and emissions for the production of the input material are only related to DRI production. In the same manner, as it was calculated in the previous case, the resulting energy consumption and emissions for the production of the required DRI, are 14.2 PJ and 1.7 Mt $CO_2$ respectively.

In the IF route the rest of the consumed energy is in the form of electricity. Assuming an average electricity consumption of 800 kWh/t and an output of 847 kt the corresponding figure for electricity consumption is then equal to 593 GWh. The emission factor for power generation in India is equal to 960 gr $CO_2$/kWh, which then gives a figure for total emissions of 0.57 Mt $CO_2$. Therefore, the total $CO_2$ emissions for the production of the required alternative material to substitute steel scrap for re-rolling from EU ships will be 2.2 Mt $CO_2$, including emissions from the production of the required volume of DRI.

### *4.2.3 Total additional $CO_2$ emissions from substitution of EU ships' scrap*

Figures 4.1 and 4.2, present a picture of the additional $CO_2$ emissions (in million tons (Mt) $CO_2$ emitted) that would result from substituting steel scrap from EU ships if it was not available in India for 2012. Figure 4.1 presents the additional emissions for the case of 100% substitution of steel scrap for melting by DRI, where total emissions are equal to 5.2 Mt $CO_2$. Figure 4.2 can be considered to present a more realistic picture, as substitution of steel scrap for melting is divided between imports and DRI, where it is assumed that imports have no additional emissions. This case results in total additional emissions of 3.7 Mt $CO_2$.

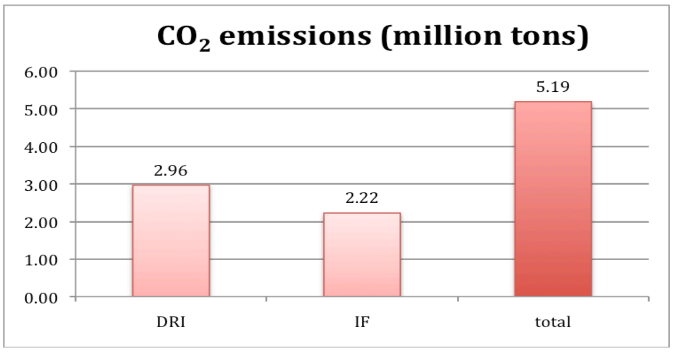



**Figure 4.1: Additional $CO_2$ emissions from substituting EU ships' steel scrap in India for 2012.**

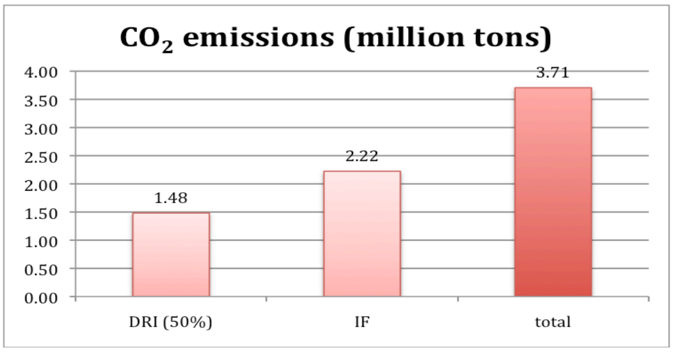



**Figure 4.2: Additional $CO_2$ emissions from substituting EU ships' steel scrap in India for 2012, assuming 50% substitution for scrap for melting by imports.**

## 4.3 Impacts on Total Emissions of Indian Steel Industry

The results for $CO_2$ emissions are more interesting when looking at their relative importance for the total steel industry in India. In Chapter 2 it was mentioned that the iron and steel industry of India is a significant source of emissions in the country, mainly because of the specific iron and steel processes that dominate the sector. The latest available data on $CO_2$ emissions in India by sector are for the year 2007, provided by INCCA. The metal industries accounted for the 28.4% of the total GHG emissions in the industrial sector. More specifically, $CO_2$ emissions from iron and steel production were equal to 117 Mt $CO_2$. If the additional $CO_2$ emissions to substitute steel scrap from EU ships are compared to the total emissions from the iron and steel industry, they represent a share of 3% to 4.4%. That means that in absence of EU ships' scrap for steel making in 2012, the $CO_2$ emissions of the industry would rise by 3% to 4.4%.

Although these figures may not seem so significant at first, for the specific case of India they can be considered important. India is on the top five $CO_2$ emitting countries and more specifically, the energy and emission intensity of the steel sector is above global average. This results from the low-level technologies used and the specific nature of the industry relying mainly on coal-based DRI and small-scale IF plants. Decrease of emissions, especially for the industrial sector is a priority in India and therefore, a rise of 4% in emissions is noteworthy. Additionally, what should be taken into account is that the materials that can substitute ships' steel scrap, and especially DRI, show very low potential in energy and emission savings because of the related processes and the raw materials used. To sum up, the shift that the steel industry would have to take if steel scrap from ship recycling was not available brings some additional burden to the environmental impacts of the industry in terms of $CO_2$ emissions.

## 4.4 Overall Environmental Impacts

Apart from the additional energy consumption and $CO_2$ emissions, there are other various environmental impacts related to each of the two cases analyzed above representing the substitution of ships' scrap. As it has already been described in Chapter 2, steel making in India is in most cases below global standards in terms of environmental awareness and protection. Especially in the case of DRI production and steel making through the IF route, this issue is even more crucial. Summarizing the information already provided on the environmental impacts of these two main processes, high levels of air pollution, extensive solid waste generation and considerable consumption of water would be the main related impacts. For the case of DRI, bad quality of non-coking coal containing high levels of ash would result in significant smoke and fugitive dust emissions, apart from the total $CO_2$ emissions. Additionally, generation of solid waste in the form of slag from the IF process combined with no proper disposal or treatment, would result in water and soil pollution in the area. It should be noted that what intensifies the negative impacts from these processes in India is the case of MSPs. Small-scale DRI and IF plants in India, which provide the largest share of total iron and steel output, usually have very limited or no pollution control arrangements.

Similarly to the case of additional $CO_2$ emissions, coal-based DRI production in order to substitute ships' scrap for melting has overall the most significant environmental impacts of the substitution materials. Those are mainly related to air pollution from fugitive dust emissions and significant solid waste generation. Additionally, pollution issues are intensified as gas and solid waste generation increases due to the bad quality of raw materials used for production. Waste generation from a DRI unit of typical capacity in India, producing 100 tpd DRI, would include 10-15 tons of dust, 25-30 tons of coal char[9] and 2.5-3.5 tons of kiln accretion[10] per day (Chatterjee, 2010). Dust generation is one of the most important issues

[9] Unburnt coal, a solid by-product of DRI production that is disposed of as waste (APPCB, 2006)

[10] Heavy solid lumps that buildup and need to be removed from the kiln (Chatterjee, 2010)

related to DRI production, as in most cases, air pollution control equipment is very limited, malfunctioning or not existent. Air pollution in the area surrounding a DRI plant, caused by dust generation, can have significant effects on human health as well as plants and crops (APPCB, 2006). Solid waste from DRI production includes coal char and kiln accretion. Solid waste management and disposal also represents a major problem related to the operation of DRI plants as large amounts of solid waste are produced each day. A 100 tpd DRI plant requires 100 acres of land for disposal of solid waste per year (APPCB, 2006). Therefore, apart from no proper handling of waste because of limited knowledge and environmental awareness, there are problems due to significantly large areas required for disposal. Solid waste from DRI plants leads to soil pollution and is hazardous for crops and plants in the area.

For the assessment of the overall environmental impacts resulting from the substitution of steel scrap coming from ship recycling, the focus was mainly on the DRI process. This is because DRI units have the most severe environmental impacts and this is an issue already causing a lot of concern in India. Taking into account the figures presented above, the waste generation from DRI production as a substitute to ships' scrap for melting can be calculated. The required amount of coal-based DRI to substitute steel scrap from EU ships would be 660 kt DRI in the case of 100% substitution by DRI and 330 kt DRI in the case where 50% of the ships' scrap for melting would be substituted by scrap imports. Therefore, for the first case, this would result in the production of around 66-99 kt dust, 165-198 kt solid coal char and 17-23 kt kiln accretion. In the second case, the figures for waste generation can be divided in half giving the corresponding results of around 33-50 kt dust, 83-99 kt coal char and 8-12 kt accretion. The results are summarized in Table 4.2.

| **Waste from coal-based DRI production** | **Waste generation in kt (thousand tons)**<br>*Assuming 100% substitution of scrap for melting from DRI* | **Waste generation in kt (thousand tons)**<br>*Assuming 50% substitution of scrap for melting from DRI* |
|---|---|---|
| **Dust emissions** | 66.0 – 99.0 | 33.0 - 49.5 |
| **Coal char** | 165.0 – 198.0 | 82.5 – 99.0 |
| **Kiln accretion** | 16.5 - 23.1 | 8.3 - 11.5 |

**Table 4.2: Waste generation form coal-based DRI production to substitute steel scrap from EU ships in India.**

These figures can strengthen the conclusion that DRI production to substitute steel scrap from ship recycling would result in serious environmental impacts related to significant waste generation combined with improper handling of waste.

## 4.5 Environmental Trade-offs

Taking into account the results of the analysis, the trade-offs in terms of gains and losses, or positive and negative impacts related to ship recycling and focusing on steel-making in India, can be summarized. Figure 4.3 presents a simple illustration of these trade-offs, where the positive impacts related to ship recycling are presented with green color on the topside, and the negative with red color on the bottom. It is important to keep in mind that this representation is qualitative, as the issues involved are of different nature and can therefore not be actually compared in a quantitative way. Therefore, the position and sizes of the bubbles including the different impacts in Figure 4.3 do not reflect any order of importance.

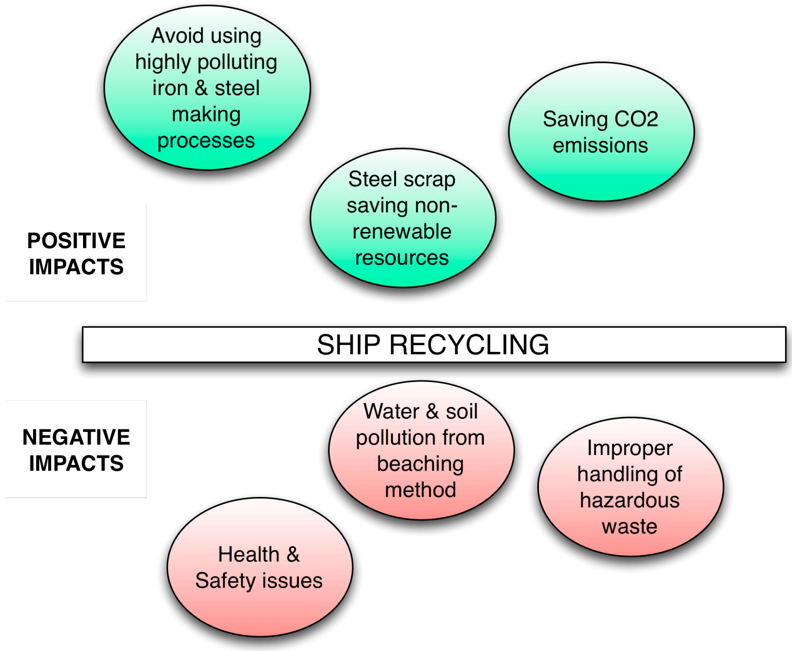



**Figure 4.3: Trade-offs related to ship recycling and steel production in India (qualitative).**

Summarizing what has already been described for the special characteristics of the Indian steel industry and the contribution of ship recycling to steel production, the positive side of ship recycling with regards to steel production is presented. By utilizing steel scrap for melting from EU ships recycled in India, the production of DRI as a substitute for scrap can be limited. In that way, the pollution issues related to the DRI production process followed in small-scale plants can be avoided. More specifically, when looking at $CO_2$ emissions related to the DRI process but also of the steel industry as a whole, ship recycling can be factor in reducing overall $CO_2$ emissions. Additionally, steel scrap can contribute to saving non-renewable resources such as iron ore and coal that would otherwise be widely used for steel production. On the other hand, the negative environmental and to an extent social impacts resulting from the ship recycling activity itself are presented as the 'down-side' of the issue. To acquire steel scrap from end-of-life ships and utilize it as a raw material for the production of steel, the beaching method is followed in India. Therefore, the negative impacts of ship recycling can be included as impacts of the whole steel-making process that will take place afterwards. These were presented in Chapter 1 and are also summarized on the bottom side of Figure 4.3. Hazardous substances contained in ships combined with no proper handling of waste lead to extensive water and air pollution of the areas where the dismantling activities take place. Additionally, health and safety hazards for workers related to these activities cannot be ignored and are a very important part of the trade-offs taking place, even though they might not be considered as an actual environmental impact. However, people are part of the environment, and the toxic substances coming form ships that can cause health issues to workers are the same that can cause serious pollution to the natural environment.

## 4.6 Discussion

### *4.6.1 Assumptions & data limitations*

It is obvious that the whole analysis was based on a hypothetical scenario and certain assumptions. This means of course that the results have a level of uncertainty. The assumptions made on the substitution of steel scrap coming from ship recycling were made after an extensive analysis of the Indian steel sector that revealed the related trends and dynamics. However, it should be kept in mind that the steel industry as any other industry follows a market-based way of functioning. In every case, choices are made based on the most cost effective option. For example, in the specific case of substituting steel scrap from ship recycling in India, the preferred alternative option would be based on availability and of course price. In that sense, the material that would substitute ships' scrap would probably be the easiest and cheapest to produce. From the present analysis and the assumptions made, importing steel scrap for example, looks like the most environmental friendly alternative to steel scrap from ship recycling. Nevertheless, India is trying to be more and more independent from the global scrap market because of the fluctuating prices. For that reason, there is a trend towards the use of DRI for steel production, which is a cheap way to locally produce a high quality scrap substitute. If however, the cost of DRI production would be at some point higher than the price of scrap in the global market, the industry would shift to importing steel scrap. However, the present study did not include an economic analysis.

For the case of data used for the analysis, some uncertainty is of course included as well. Data collection for the Indian steel industry related to specific energy consumption and emissions for certain processes was a challenging process, especially for the case of DRI and IF units. These processes in India are mainly followed in small-scale plants scattered around the country, and not much statistical data on energy and emission intensity were available. For that reason, assumptions on average values needed to be made. These were based on an extensive literature review on reports focusing on the specific case as well as personal communication with people involved in the field. However, these values can be considered representative and can give a good picture of the related impacts if these uncertainties are taken into account.

### *4.6.2 Sensitivity analysis*

Some additional cases were examined in order to have an even better insight on the resulting impacts related to EU ships not being recycled in India for 2012. First of all, an extreme scenario was set, assuming that ships' steel scrap for melting would be completely substituted by scrap imports. In that way, the 'saved' emissions by avoiding the required DRI production were calculated. If the total steel scrap required was substituted by imported scrap, then the additional emissions would be only related to the re-rollable share of scrap that would be substituted by ingots coming from IFs. As a result, the additional $CO_2$ emissions would be equal to 2.2 Mt $CO_2$, representing $CO_2$ savings of around 52% compared to the case of 50% substitution by DRI. Additionally, other environmental impacts related to pollution from the DRI process as well as consumption non-renewable resources would be avoided. As a result, it is obvious that the main positive environmental effects from ship recycling with relation to steel making, result from limiting the production of DRI as a material used for steel production.

What is also obvious from the analysis of the DRI process, is that one the main reasons that DRI production in India is so highly polluting and energy intensive is the fact that unlike the rest of the world, it is mostly coal-based. As it has been mentioned beforehand, in 2012, 78% of total DRI was produced using coal and only 22% using natural gas and these were the figures used for the analysis. For that reason, it is interesting to examine the emission savings if DRI production was 100% gas-based. The additional $CO_2$ emissions from DRI production in order to substitute ships' scrap would then be equal to 847 kt $CO_2$ and would result in $CO_2$ savings of 2.1 Mt $CO_2$. This amount represents a reduction of 71% in total emissions from DRI production compared to the previous assumption (78% coal-based). The total additional emissions for the substitution of EU ships' scrap would be equal to 3 Mt $CO_2$ and would mean that the total industry emissions would rise by 2.5%. These figures reveal a huge potential in emission savings if DRI industry in India would switch to gas-based production. However, this is not a very probable scenario because of limited natural gas resources.

# **Chapter 5:** Conclusions & Recommendations

**CONTENTS**

# 5. Conclusions & Recommendations

## 5.1 Conclusions

The main objective of the Thesis was to investigate the environmental trade-offs related to ship recycling. The issue of ship recycling has gained a lot of attention recently mainly because of the negative impacts it has in developing countries of South Asia, where the recycling activity is concentrated. These impacts result form the recycling activity itself and the way it is being carried out in these countries. However, at the same time the main reason why ships are recycled is because of the valuable materials that can be recovered, with the most important one being steel scrap. In that way, an initial and simple trade-off can be recognized. In order to acquire a more deep and complete view, the research focused on a specific case study. The country of India was chosen because it holds the largest share of ship recycling activity worldwide. Additionally, the research was restricted to the case of European ships recycled in India because of the legal debate currently taking place concerning the location where EU ships should be recycled. After an extensive research on the topic of ship recycling as a whole, it was discovered that one of the least researched angles is the contribution of recycling of ships to the steel making industry. However, this topic is a crucial one, as it is the driver for the ship recycling activity in the first place and especially in countries like India with large steel production and high demand for steel scrap. Moreover, as the subject of the study was on Energy and Resources, the relationship between ship recycling and steel production from an environmental and resource point of view was decided to be the focus of the research. In summary, the main objective was to investigate the contribution of steel scrap coming from the recycling of EU ships in India to the steel industry and production in order to obtain a better insight on the environmental trade-offs taking place.

In order to meet this objective, a hypothetical scenario was developed, assuming that all EU ships recycled in India in 2012 were not recycled in India, and as a result, the related steel scrap was not available. The alternative materials that could substitute this scrap for the production of steel were investigated as well as the related environmental impacts for their production.

The main finding of the research was that in order to substitute steel scrap coming from EU ships, which is used as input in EFs for melting, production of DRI or scrap imports would have to increase by 8.1% or 10.3%, respectively. For the case of substituting ships' scrap that is re-rolled in SRRMs, steel production from IF units would have to increase by 4.4%. Additionally, a case where a combination of imported scrap and DRI was assumed as a substitute to ships' scrap for melting was studied. The result was that DRI production and scrap imports would have to increase by 6.0% and 5.1%, respectively.

The investigation of the environmental impacts from the production of substitution materials revealed that substituting steel scrap from EU ships, would result in additional $CO_2$ emissions of 3.7 Mt to 5.2 Mt $CO_2$, depending on the amount of scrap imports complementing the substitution (assuming that imported scrap would have no additional $CO_2$ emissions). These results mean that total emissions of the Indian steel industry would increase by 3% to 4.4% in order to substitute steel scrap from recycling of EU ships. In other words, each ton of steel scrap coming from EU ships in India and used for steel production, could result in 2 to 3 tons of $CO_2$ emissions reduction. Furthermore, DRI production in order to substitute scrap from EU ships, apart from additional $CO_2$ emissions, would cause additional severe environmental impacts. These are mainly related to significant amounts of fugitive dust emissions and solid waste generation, intensified by the bad quality of raw materials used and would lead to extensive air and soil pollution. Fugitive dust emissions from DRI, which would be produced as a substitute for ships' scrap, would range from 33 kt to 99 kt and solid waste in the form of coal char from 83 kt to 198 kt.

The most important conclusion that can be drawn from this research is that ship recycling has a particular importance for the specific case of India. This is mainly because of the special nature of the Indian steel industry. India is the 4th largest steel producing country in the world and steel demand and production is projected to witness a rise. As the steel industry in India is mostly based on secondary production, steel scrap demand will also increase. Ship recycling is an important source of steel scrap. At the same time, India is the largest DRI producer in the world and DRI is the main substitute to steel scrap for the production of steel. Future projections state that steel production in India will be more and more dependent on DRI. However, DRI production in India is mostly based on small-scale plants resulting in high energy consumption and $CO_2$ emissions and extensive pollution. As a result, ship recycling can play a significant role in the Indian steel industry by providing steel scrap for steel production and help avoiding the environmentally unfriendly DRI process. India is a developing country and for that reason there is an attempt to rely as little as possible to steel scrap imports because of high and fluctuating prices of scrap in the global market. In that sense, ship recycling would have completely different impacts for the case of another country. Furthermore, national $CO_2$ emission levels are already high, especially for the case of the iron and steel industry. Emission intensity of the industry is above global average and emissions reduction should be an important priority. Any increase in emissions resulting from the absence of ships' scrap would be noteworthy in an industry already struggling to reduce its emissions.

Taking into account the aforementioned, ship recycling can have positive environmental impacts and can contribute to $CO_2$ savings related to steel production in India. Availability of steel scrap from end-of-life ships could change the shift of the Indian steel industry to more sustainable and environmental friendly steel production. However, the present study concerns solely the relationship of ship recycling to steel production. For that reason, the final results were presented in the form of trade-offs, as there are various negative environmental impacts related to the ship recycling activities taking place in the country. Extensive soil and water pollution due to improper handling and disposal of toxic substances contained in ships as well as health and safety issues for workers in the ship recycling yards are the main hazards related to ship recycling. These issues are of major importance and should not be neglected as they present a counter-effect on the benefits of ship recycling for the steel industry.

The present study provides some insights into the relationship between ship recycling and the steel industry for the case of India. Therefore, the main conclusion can be that with relation to steel recycling, the recycling of ships in India can have positive environmental effects if at the same time the hazards resulting from unsafe and polluting practices in ship recycling yards can be diminished. The main aim was to fill in some gaps in the overall picture of ship recycling with relation to steel production in India, as it is one of the least researched aspects. In that way, it is obvious that the conclusions from the present research present only one part of the 'equation'.

## 5.2 Recommendations

### *5.2.1 Policy-making*

Like many issues that are interesting or raise concern when they are examined from an environmental perspective, ship recycling is currently the topic of discussion in many cases. Debates on policies that should be followed especially for the recycling of European ships are very frequent between environmentalists, 'green' politicians and related industries. However, ship recycling is an issue involving many other aspects of environmental, economic and social nature, and at the same time, all aspects are interrelated. What is obvious for issues of that nature is that in order to create a successful policy, a holistic view is essential. All different angles should be examined and all environmental, social and economic factors as well as the way they affect each other should be taken into account.

The main finding of the study was that ship recycling has a particular importance in India because of the special characteristics of the Indian steel industry, and can ultimately have positive environmental effects related to steel production. Therefore, the main recommendation would be that, the relationship and dynamics between ship recycling and steel making should be taken into account when designing any relevant policy that can have an effect on ship recycling in India. It is concluded, that the relationship can result in additional environmental impacts like $CO_2$ emissions or pollution from iron and steel production. Therefore, policies should tackle the issues of poor working conditions and low environmental standards in ship recycling yards in order to allow the full environmental benefits of recycling to be realized.

### *5.2.1 Further research*

Ship recycling has been taking place in developing countries of South Asia for many years. However, after 2008, the issue became more and more crucial as environmental organizations revealed and put focus on the poor working conditions in ship recycling yards and the environmental pollution resulting from the ship recycling activities taking place on the beach. Since then, there has been a big amount of research concerning ship recycling from that perspective. However, only during the last years, because of the legal debate and the proposals for new Regulations governing the recycling of EU ships, other sides of the issue started being investigated as well.

What this study revealed is that more research should be carried out on the relationship between ship recycling and steel production, especially for the case of India. Moreover, in order to achieve this, more research on the Indian steel sector and its special characteristics is crucial. The difficulty for the specific analysis was many times the lack of available data on the steel sector if India. Therefore, more research and gathering of data especially on energy and emission intensity of certain steel making processes in the country is required. More specifically, monitoring of the informal sector of steel re-rolling as well as the small-scale DRI and IF plants is essential. Additionally, statistical data on total steel scrap use for steel production in India should be collected. In that way, the contribution of steel scrap form ship recycling to the steel industry as a whole can be more easily investigated.

Furthermore, more research on the dynamics of the steel sector from a market perspective could provide more insight on the role of ship recycling in this industry. The way scrap market prices affect steel production is a very important topic for example. A next step could be to include economic factors in this analysis, taking into account costs of production of materials for steel making and labor costs of workers in the ship recycling yards as well as in the steel making plants. Additionally, an interesting aspect would be to investigate the environmental impacts in terms of additional $CO_2$ emissions and energy consumption when improving the conditions of the actual ship recycling process.

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# Appendices

## Appendix I

### Toxic materials that can be found on a ship: Source of pollution in a ship. (Source: MacDonald, WWF-India, 2009)

- **Asbestos:** It is used as engine packing and insulation material in boilers and turbines and in water, steam, insulation, and refrigeration pipes. Banned since 1986, but still many ships still operating with asbestos.

- **PCBs:** Are usually found as anti-freezing agents and oils. The use of PCBs has been banned since 1975.

- **PVC and PBBs:** Plastics and constituents of plastics might produce hazardous fumes on burning. PBBs were listed as one of six controlled substances under the Restriction of Hazardous Substances Directive enacted into European law in February 2003.

- **Other non-polymer chemicals:** Commonly found in refrigerator ships but also in other ships, they are generally contained in turbines, air conditioners, and engines. They may also be found in lead acid batteries, resins, radioactive materials, and anti-rust paints, or paint stabilizers.

- **Organic pollution:** Cow dung and other excreta often left in ships pose a health risk for workers.

- **Heavy Metals:** Found in batteries and paints, and in substantial quantities in the chemicals stored in ships.

- **Organotin:** Used as an anti-fouling substance; banned since 1988.

- **Oil sludge:** Produces hazardous polyaromatic hydrocarbon gases on evaporation. It is hazardous for marine life if there is an oil spill.

- **Ballast and bilge water:** This is water on the ship used to clean or wash out contaminated matter like lead from batteries and sulphuric acid from equipment. They leach through drains and into the soil.

- **Other non-hazardous solid waste:** Broken ceramic tiles, wood pieces, expanded polystyrene packing, decorative and insulating material, cement, and other waste material litter.

## Appendix II

### Hazardous or harmful factors in ship scrapping: Identifiable hazards associated with ship recycling. (Source: Bailey, 2000)

- Asbestos
- Polychlorinated Biphenyls (PCBs)
- Lead
- Chromates
- Mercury
- Fumes of welding & cuffing
- Radiation
- Noise
- Vibration
- Air pollution
- Low-level radium sources
- Organic liquids (Benzene etc.)
- Battery, Compressed gas cylinders, fire-fighting liquids, etc.
- Chemical materials
- Work using plasma and gas torches
- Explosive(s)
- Work using cranes and lifting equipment
- Saws, Grinders and Abrasive cutting wheels
- Accident factors: falling, upsetting, electric shock, etc.

## Appendix III

### Environmental benefits from steel recycling. (Source: US EPA, http://www.epa.gov/)

- Energy savings 75%
- Savings in virgin materials use 90%
- Reduction in air pollution 86%
- Reduction in water use 40%
- Reduction in water pollution 76%
- Reduction in mining wastes 97%
- Reduction in consumer wastes 105%
- Reduction of $CO_2$ emissions 58%

Every ton of new steel made from scrap steel saves:

- 1,115 kg of iron ore, 625 kg of coal, and 53 kg of limestone

## Appendix IV

### Relevant EU Legislation & Policy related to ship recycling

From a legal point of view, there is a broad range of EU legislation in place that can be applied to end-of-life ships sent for recycling (EC, 2007b). The relevant EU legislation covers both the related environmental and safety requirements of the recycling activities themselves as well as the transfer of the ship to the place where it is going to be dismantled. In general, EU legislation on environmental protection can be applied to the management of ships that are no longer operational and are therefore considered as waste.

The **Waste Framework Directive** (WFD) adopted by the European Commission in 2006, offers some basic concepts and definitions related to waste management, such as definitions of waste, recycling and recovery and also explains how to make a distinction between waste and by-products. It also includes a set of requirements related to environmental protection during recovery or disposal of waste. It requires that *"waste should be managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odors, and without adversely affecting the countryside or places of special interest"* (EC, 2006a). This framework can be applied to the case of ship recycling as the actual process of dismantling can be considered as handling or recovery of waste.

The same year, the EC adopted the **Waste Shipment Regulation** (WSR), which concerns the shipment of waste and currently regulates the transfer of end-of-life vessels within the EU or between the EU and third countries. The main aim of this Regulation is to strengthen, simplify and specify the procedures for controlling waste shipments in order to improve environmental protection. In that way, it reduces the risk of waste shipments not being controlled. The Regulation introduces an obligatory notification system and a standard consignment note for shipments of waste. Furthermore, waste shipments should be inspected, sampled and monitored by the Member States (EC, 2006b). In the EU, the WSR implements the requirements of the Basel Convention (BC) concerning the export of hazardous waste outside the OECD as well as the Ban Amendment (BA).

The EC has also taken initiative and developed its own processes for improving the state of ship recycling until the HKC enters into force. In 2007, the EC adopted a **"Green Paper on better ship dismantling"** and a year later a Communication proposing **"An EU strategy for better ship dismantling"** (Blanco, 2012).

The Green Paper actually provides an overview of the basic facts on ship dismantling and explains the problems. Some of the main points for improving European management of ship dismantling mentioned in the Green paper are:

- Better enforcement of EU waste shipment law;
- Strengthening EU ship dismantling capacity;
- Provision of technical assistance and transfer of technology and best practices to recycling states;
- Encouragement of voluntary action;
- Establishment a ship dismantling fund

as well as several other more specific measures (EC, 2007).

The EU strategy for better ship dismantling proposed a number of measures for immediate improvement of ship dismantling conditions, focusing also in the interim period before the entry into force of the IMO HKC. These measures include:

- Preparations for establishing measures on key elements of the HKC, such as surveys, certification and inventory of hazardous materials on board, as soon as possible after its adoption;
- Encouragement of voluntary industry action through measures such as awards for exemplary green recycling; publication of guidance, such as a list of 'clean' ship dismantling facilities;
- Technical assistance and support to developing countries for safety training programs and basic infrastructure for environmental and health protection;
- Better enforcement of current waste shipment rules such as more checks at European ports; more cooperation and information exchange between EU authorities; and establishing a list of ships that are ready for scrapping.

The strategy also proposed a feasibility assessment to be carried out on the following actions:

- Development of a certification and audit scheme for ship recycling facilities worldwide and evaluation of how EU ships can be encouraged to use such a scheme;
- Making warships and other government vessels not covered by the Convention, subject to EU rules for clean dismantling;
- Establishment of a mandatory international funding system for clean ship dismantling (EC, 2008).

To sum up, the current legal state concerning ship recycling in the European level is that the WSR sets the requirements at EU level for the management and shipments of end-of-life vessels. A ship is considered as waste when it is "discarded" by its owner. The export of a "discarded" ship, which contains hazardous substances, to a non-OECD country is prohibited under the WSR (EC, 2007b).

### Circumvention & loopholes to the BC – Re-flagging

Although the BC can provide very important and strong regulation related to movements of hazardous waste, its applicability to the recycling of end-of-life ships has been highly debated. As this Convention was not formed specifically for the shipping industry and even more for ship recycling, there are some key issues that so far create loopholes and make the enforcement of the law difficult for the specific case. These mainly concern the question of identifying the moment when a ship actually becomes waste, the definition of the waste generator and exporting State and the combination of the BC with regulations concerning ships (CIEL, 2011).

The BC can only be applied after the moment a ship is considered as waste and additionally, this time is important as it defines the state that is responsible for this waste. If the decision to dismantle a ship by the ship owner is taken when a ship is in international waters or in the waters of the recycling state, the BC cannot apply to that case (EC, 2012b). Moreover, ships may carry cargo during their last voyage to the SRY in order to maximize their profit, and as a result are not yet considered as waste. It is common for ship owners to 'hide' the fact that a ship is destined for recycling by not declaring their intention to dismantle a ship when leaving an EU port, and in that way they can circumvent the BC (GPI, BAN, 1999).

Moreover, the issue of reflagging or change of owners during the last voyage can also bring complications to the enforcement of the regulation (CIEL, 2011). Every ship has to be registered under a flag. The flag state, as defined by the United Nations Convention on the Law of the Sea, has overall responsibility for the implementation and enforcement of international maritime regulations for all ships granted the right to fly its flag (EC, 2012b). In that way, if a ship owner changes the flag of a ship, the ship is then under a different legal regime. If for example, the flag of a ship that is owned by a German or Greek company is changed to a flag of Panama, the waste exporter is then immediately the state of Panama, which is not included in the OECD list and therefore the movement of waste is not considered illegal. Apart from that, a change of flag in that case would mean that the WSR could not be applicable as its scope is limited only to EU-flagged ships.

An effort to make the BC more suitable for addressing ship recycling activities was the development from the Parties to BC, of voluntary guidelines for the SRI, entitled: "Technical Guidelines for the Environmentally Sound Management of the Full and Partial Dismantling of Ships" (Mikelis, 2012a). However, as these were just voluntary guidelines, the practical and legal difficulties in enforcing the BC remained.

### Reactions & criticism to the HKC

Although the HKC can be considered as an important legal step and an answer to the advocates of more sustainable and 'green' ship recycling, there is still a large amount of criticism and controversial views on whether it sufficiently addresses the issue. Some have viewed it as insufficient in addressing the environmental harms caused by the SRI, while others have welcomed it as a step in the right direction. The key argument of the HKC critics is that it does not provide an equivalent level of control as the BC. The main reasons behind this argument is that the HKC does not consider the beaching method as illegal and does not mandate pre-cleaning of ships from hazardous materials before they arrive in SRF (Mikelis, 2012a). Furthermore, there is strong criticism on the fact that the HKC puts most of the costs and liabilities of waste management on the importing state and not the polluter, who in this case is the ship owner. Last but not least, one of the most important differences is that the HKC does not criminalize the illegal transfer of hazardous waste, as the BC does. In that sense, according to the HKC, it is not illegal to export end-of-life ships that constitute hazardous waste to non-OECD countries as long as the SRF where they are going to be dismantled in authorized. In that way, the HKC comes into direct clash with the WSR and the BA and complications related to the implementation are created, as it can be argued that there is a duplication of legal measures.

### Reactions & criticism to the SRR

The Commission's proposal for a SRR has been seen as an attempt to unilaterally detract the EU from the binding regime established by the BC (CIEL, 2012). The key arguments of the EC behind this decision are based on the insufficient ship recycling capacity in the OECD countries as well as the fact that the BC cannot be effectively applied to the case of end-of-life vessels. However, both these arguments have been questioned or rejected mainly by environmental organizations. They, from their side, support the opinion that the OECD countries have capacity to dismantle all EU- flagged ships and further capacity would quickly develop if a steady supply of end-of-life vessels was available in Europe (NGO Shipbreaking Platform, Greenpeace, 2013). Furthermore, their position is that instead of putting the BC out of force for the case of ship recycling all together, additional measures should be implemented to strengthen its enforcement and facilitate its applicability. Apart from that, it is a fact that the loopholes created by re-flagging will continue to exist also in the case of the new Regulation, as the focus will be only on EU-flagged ships and ship owners will continue to change the flags of their ships prior dismantling. Additionally, from a strictly legal perspective, it can be concluded that the Commission's proposal, which removes ships from the EU's Basel application is in breach of the EU and its Member States' international legal obligations under the Basel Convention and it can therefore be considered illegal (Kraemer, 2012).