MSc Program
Environmental Technology & International Affairs

European Circular Economy Strategy
Analysis Of Steel, Aluminium and Copper Scrap Flows between the EU-28 and the World

A Master's Thesis submitted for the degree of
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supervised by
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Affidavit

I, **CHRISTOF BRUNNER**, hereby declare

1. that I am the sole author of the present Master's Thesis, "EUROPEAN CIRCULAR ECONOMY STRATEGY ANALYSIS OF STEEL, ALUMINIUM AND COPPER SCRAP FLOWS BETWEEN THE EU-28 AND THE WORLD", 75 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

In 2014 the European Commission implemented the European Circular Economy Package to promote a shift of Europe´s economy towards a circular economic system.

In order to successfully achieve this change, a well founded knowledge about the availability of resources, the flow of substances and the markets of recovered raw materials gained by recycling has to be obtained.

Within the course of this thesis, questions arising related to international trade and domestic market for steel, aluminium and copper scrap are discussed. Therefore, exports, imports and specific prices of the metals traded between the EU-28 and the world from the year 2000 to 2014 are examined. Additionally, the structure of the material flows and relations between different variables as well as possible tendencies are explained by statistical methods and analysis of time series. Moreover, the issue of End-of-Life Vehicles with unknown whereabouts and their impact on the interior scrap market of the EU is mentioned.

Summarizing the outcome of the discussion, export quantities for steel and aluminium scrap follow a positive linear trend, while the underlying function of copper scrap export is polynomial with its vertex in the year 2011. All import quantities behaved similarly but mirrored. A visual analysis of the data series for prices suggest a correlation between import and export figures for all three scrap metals. For steel, as example, this presumption is supported by a positive result of a linear regression. Besides, the specific import prices are almost over the whole observed time range significantly higher than the import levels. This alteration is assumed to be triggered by different composition of material flows, and for steel scrap the evidence is provided.

Furthermore, recommendations related to the implementation of the Circular Economy addressed to legislative body of the EU are expressed. First, the recycling industry shall be pushed to ensure high recycling rates and also the sorted disposal of scrap according to their special attributes shall be promoted. Second, the possible impact of an interior oversupply of scrap within the Single Market upon domestic prices has to be considered. Hence, imposing tariffs on scrap exports or subsidizing the secondary raw metal production industry offer possible regulative measures. Furthermore, directives addressed to the problems related to the unknown whereabouts of End-of-Live Vehicles have to be adjusted accordingly, as there is still a substantial loss experienced by the interior scrap market of the EU-28.

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1. Introduction

1.1 Definition Circular Economy

According to the European Commission (2015), the objective of a circular economy model is to preserve the intrinsic value of goods or materials for the economy. Thus, the consumer shall use the products as long as possible. If a merchant has fulfilled its purpose for the buyer, two routes shall be preferred over simply discarding it.

First, goods shall be reused in order to minimize waste, to lower the usage of raw materials, to curb energy consumption as well as to reduce carbon emissions. Reuse means that the product is intended to continue fulfilling its task for what it was initially designed for. If necessary, the merchant shall be overhauled and repaired before its durability is extended through a resell. Second, and only if a further reuse is not promising, the product shall be recycled and gained secondary raw materials shall be returned to the manufacturing and production course. In summary, the main target of the circular economy approach is to close the loop of the product lifecycle to ensure sustainable growth. Subsequently, a scheme is provided to illustrate the circular economy model (European Commission, 2015a).

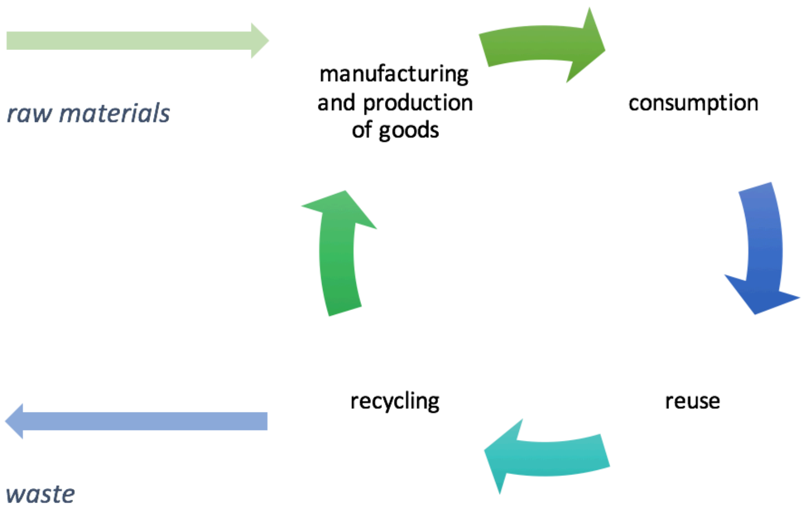


Figure 1: Circular Economy System.

1.2 European Circular Economy Package

In 2014, the European Union adopted the European Circular Economy Package. The aim of this bundle is to promote the transition of the European Single Market towards a sustainable circular economy model. The European Commission predicts, that the implementation of a circular economy is crucial, as it will help to target EU urgencies. Key points, such as job market development, sustainable economic growth, industrial innovation, climate protection and energy are expected to advance positively under the usage of this economic approach. According to Henry (2016), the circular economy may generate over 170.000 jobs within the waste management segment until 2035. Moreover, up to € 600 million in annual savings for the participants in the European Single Market are expected. In order to meet the specified objectives and to increase the competitiveness of Europe's economy, possible actions have been elaborated. Namely, the EU Action Plan for the Circular Economy and various reviewed legal proposals on waste and waste management. But the Action Plan can be seen as a overall description rather than a summary of clearly expressed actions, as the name might indicate (European Commission, 2017b; European Commission, 2015b). More precisely formulated, the aim of this strategy is to support national governments to tackle the shift of the economy. Providing the right regulatory framework and setting trigger measures to target the most important stakeholders, i.e. businesses and consumers, is fundamental. The EU is willing to do so and actions in strategic divisions are implemented to promote job market development and unchain growth potential. The range of these activities is broadly spread. For instance, increasing the funding of promising research and innovative projects is mentioned as well as support for development of new strategic approaches to handle potentially hazardous materials (European Commission, 2015b).

However, since the European institutions represent the most important legislative body for the European Single Market and its contestants, a lot of the measures affect proposals of amendments to directives. Therefore, the EU distinguishes between four main affected divisions.

First, the manufacturing industry is instructed to meet specific objectives related to product design which are favourable for a circular economy whilst using innovative and efficient production techniques. Design of new products shall be enforced by certain deliberations to support the reuse and recovery of used merchandise. Enhancing the durability of the product has priority. But, optimizing the design of the object to ease disassembling and therefore enable economically feasible recycling should not be neglected. This expansion of producer responsibility is addressed by the Ecodesign Directive 2009/125/EC and enhanced by different amendments (European Parliament and European Council, 2009). Moreover, the European Commissions aims to provide producers with benchmarks regarding aspiring waste management and resource saving practises within their sector. The intention is to reduce disposed waste quantities and safe resources by applying best available techniques (European Commission, 2015b).

Second, the European Commission identified the decision making process of consumers related to their product choices as essential for a successful implementation of a circular economy. Providing environmentally conscious buyers with information about the trustworthiness of eco labels is one way. If a certain degree of motivation from people to support ecologic initiatives is already present, their decision making should not be hindered by multiple green certificates. On the other hand, suggestions have been made to include environmental costs within the price of goods. This approach intent to influence the buy or not-buy decision of customers, which are focusing on price rather than on the sustainability of a product.

Third, the waste management industry is seen as the operating segment which is crucial to the implementation of the waste hierarchy, a key component of the circular economy approach. This pyramid illustrates a priority order starting with waste prevention, followed by reuse, recycling and waste to energy methods. Thus, various amendments to directives, such as the Proposed Directive on Waste or the Proposed Directive on Landfill, have been adopted. Moreover, pre-set targets which are binding for all Member States of the EU, in terms of recycling or landfill, have been agreed on. The recycling rate achieved by the EU Member States regarding municipal solid waste shall meet sixty-five percent as soon as possible. For discarded packaging material the same percentage is aimed to be met until the year 2030. Furthermore, landfilling of already separated waste shall be banned and maximal ten percent of the municipal solid waste shall be dumped on landfill sites (European Commission, 2017b; European Commission, 2015b).

Finally, the market for secondary raw materials has to be considered. Within the array of secondary raw materials fall recovered metal scrap, recycled paper, waste water or waste based fertilizers. Since limitations occur on this market, the European Union aims to ease these barriers. Especially the uncertainty related to the special characteristics of traded secondary raw materials is a typical example for such a restriction. Moreover, missing common principles of the EU and regulations associated to the state of secondary raw resources keep possible buyers at distance. Akerlof (1970), stated in his famous work “The Market for Lemons” that the presence of information asymmetry about the quality of a product leads to lower mean prices on the market and economic losses. This difference in access to information can only be reduced if money is invested. Therefore, the EU ambitions are to provide specific standards and to bear the resulting economic costs to promote usage of secondary raw materials (European Commission, 2015b).

Summarized, the European Circular Economy Package and the Action Plan contain suited measures to tackle key issues for a future success of the European Community and the Single Market. Moreover, a broad range of amendments to consisting directives have been adopted as well as new regulative measures to support Member States in the transition from a linear economic model towards a circular economy.

1.3 Problem / Relevance

In recent decades, a global awareness has been established to endorse the concept of a circular economy, as the benefit of such an economic system can be easily determined. In contrast to the conventional way of production and consumption of goods, the so-called linear economy, certain restrictions can be circumvented with this non-linear path. The characteristic model of a linear economy is limited by the continuous replenishment of raw materials and natural resources, cheap energy supply and the availability of suited waste disposal options (Haas et al., 2015). Besides, it is assumed that the necessary raw materials for manufacture are abundant, easily accessible and that their exploitation is economically feasible (European Commission, 2014). These presumptions, however, can be doubted. For instance, in some parts of the world, a shortage in sand is already a problem, even though one could believe that sand is relatively abundant and that the worlds deserts should last for a long time (The Economist, 2017). However, not only the obtainable amount of a resource matters, it is almost equally important where this source is located on earth. The European Union is particularly susceptible to this factor because huge amounts of natural raw materials have to be imported to meet the interior demand. In the year 2015, for example, over two tonnes of fossil material per capita were brought from outside into the Single Market (Eurostat, 2015).

Within the following sub-chapters, the reader’s attention should be drawn to the importance of shifting Europe’s economy model towards a circular economic approach. Moreover, the significance of aluminium, copper and steel for the Single Market is highlighted and expressed.

1.3.1 Raw Materials and Reserves

According to Rechberger (2016), the worldwide growth in resource use has increased exponentially over the last few decades, with only some countries exempted. Over fifty percent of the total reserve depletion has been conducted by humans within the last twenty-five years. The global annual production of aluminium, for instance, has experienced an upsurge from fifteen million tonnes in 1980 to over forty-five million tonnes in 2010. During the same period, data show an increase from eight million tonnes to sixteen million tonnes for copper and from 500 to 1.100 million tonnes for steel and iron production per year (Rechberger, 2016). The European Union is highly dependent on imports of raw materials and fossil energy carriers used to manufacture these metals. On the one hand, Europe´s economy is depleting its various ores and energy reserves on a large scale since the industrial revolution took place, as new technology and knowledge was applied to enhance production capacities (Exner, Held, and Kümmerer, 2016). On the other hand, todays largest reserves of many natural raw materials, copper (Chile) or coal (USA) for instance, are situated outside of Europe.

As a result, the EU-28 imported in 2015 roughly 321 million tonnes of different metal ores and 1.597 million tonnes of fossil energy carriers (Eurostat, 2015). This path of enormous depletion of raw materials, though, can not be followed indefinitely. Resources, but also more important reserves of natural materials, are limited. Previously mentioned copper and iron extraction are not the best fitting examples to point out a future scarcity, as they are relatively abundant on earth. The earth crust consists, for instance, of fifty parts per million copper. Hence, one could argue that the point of maximal copper production will never be attained, if economic considerations are not deliberated (Dorner, 2013). Nevertheless, scientists predict the peak of mining and processing mineral phosphorus, which is important for todays agricultural industry as a fertilizer, will be reached in 2030 (Cordell, Drangert, and White, 2009). Thus, one can conclude that at some point reserves of various essential materials might be consumed completely, or their obtainability is restricted due to economic reasons. This could result in an loss of the foundation of the the classic economic system, which is based on linear considerations

Through the constant growth in exploitation of natural raw materials, damage suffered by the environment is increasing. As stated by the Dorner (2013), copper ore has to have an average of 0,4 percent copper content to allow economically feasible mining. Considering this figure, for extracting one tonne of pure copper, 250 tonnes of ore have to be displaced. If one reflects Europe´s primary production of copper in 2010 with 3.5 million tonnes, the amount of evacuated material is enormous. Therefore, and without including the impact of the refining process on the environment, one can imagine the massive displacement of soil due to mining activities worldwide (Rechberger, 2016).

1.3.2 Recycling

To reduce the worlds hunger for raw materials, recycling of disposed goods offers a fitting solution. Especially the recovery of metals is feasible, as many of them do not suffer a loss of their special attributes during use. Steel, for instance, is recyclable to almost one hundred percent. As reported by the European Steel Association (2015), approximately half of the crude steel made in Europe is produced by re-melting recovered scrap metal. However, improvements to raise this figure to a higher level and thereby conserve iron ore is difficult. Steel scrap is a heavily demanded secondary raw material everywhere on the planet and steel has longevity in use. Especially the latter is the main reason that the primary production of raw steel from iron ore has to increase continuously. If the global economy experiences growth, the demand for steel will show similar movements, and the recycled quantities of steel scrap will continue to be too low to meet the increasing demand.

Additionally, recycling and reuse of steel scrap can be seen as a tool to preserve the strategic asset steel for the domestic economy. Within the European Union and the Single Market, the primary steel making sector generates a turnover of € 170 billion per year through the manufacturing of 170 million tonnes crude steel. This revenue is nearly equal to the total Gross Domestic Product of Greece in 2015 (The Worldbank Group, 2015). To demonstrate the strategic position of steel and other metals for the European economy, Germany´s processing industry is a well-suited example. In the year 2015 the percentage of the manufacture of vehicles for usage on roads and machine construction was roughly thirty-seven percent of the total € 1.947 billion value added by the national industry. Those two industrial sectors, however, rely heavily on the steady stream of various steel, aluminium and copper raw material (Statista, 2015).

1.3.3 Energy

Extraction and refining of metals from ore is accompanied by vast energy utilization. According to Gerspacher et. Al. (2011), iron and steel production is responsible for approximately twenty-seven percent of the total industrial energy consumption worldwide. The potential input per tonne output differs strongly between the two most common routes for crude steel fabrication.

The first pathway is by using a blast furnace combined with the basic oxygen process to produce unwrought steel. The raw material input consist of iron ore, coke, sinter and marginal amounts of scrap. One tonne of steel output made with this industrial process requires a total energy supply of fifteen gigajoule or 4166 kilo-watt hours.

The second pathway, the electric arc furnace procedure, for raw steel manufacturing only uses steel scrap as input. Therefore, the energy demand drops significantly compared to the blast furnace technique to approximately 350 kilo-watt hours per tonne crude steel.

Nevertheless, due to the constant increase in demand for steel products, the latter will not be capable to substitute the primary production completely. Subsequently, the potential to save energy within the sector of crude steel production is restricted by the availability of steel scrap (Feldmann et al., 2011; Gerspacher, Arens, and Eichhammer, 2011).

The process of primary aluminium production is even more energy intensive. Without taking into account the refining of aluminium oxide out of bauxite, 13.000-15.000 kilo-watt hours of energy are necessary to receive one tonne output. Secondary production with aluminium scrap as the only input material can diminish these numbers by ninety-five percent (European Aluminium, 2016b).

1.4 Goals of the Research and Research Questions

The basic principle of a circular economy is to extend the lifetime of a good or product within the economy to the maximum. In order to maintain high levels of reuse or recycling, it is crucial to gain as much information as possible concerning the distribution of goods and materials. Obtaining knowledge about the material flows within the system is important, but to have a certain degree of understanding regarding entering and leaving product streams is also extremely valuable. Consequently, the aim of this work is to display, analyze and comment on the changes in export and import of steel, aluminum and copper scrap between the years 2000 to 2014.

Following research questions will be discussed:

Q1: How was the dynamics of export and import of steel, copper and aluminum scrap between the EU-28 and the world from the year 2000 until the implementation of the European Circular Economy Package in 2014?

Q2: How was the development of related specific prices and is there a difference in the structural composition of these material flows? Can mass flows be traced?

Q3: Is the order of magnitude of scrap export and import quantities significant for the production of unwrought steel, aluminum and copper within the EU-28?

Q4: Which recommendations can be suggested considering the circular economy approach and the European Circular Economy Package?

2. Methodology and Data Collection

To allow a critical discussion about the matter concerned, the available figures are mainly prepared and provided as time series and graphs. Moreover, statistical analysis methods are applied to find possible relations between different variables such as export and import quantities, specific prices or comparable. These analytic tools and the sources of the underlying data are described in this chapter. Additionally, a literature review is conducted to elaborate on distinguished arguments within the course of the discussion.

2.1 Component Model and Time Regression

The concept of time regression is a deterministic model dependent on time. The aim is to find a certain, stabile pattern within the development of the time series. As a result, historical descriptions as well as predictions of the future trend can be made (Edel, Schäffer, and Stier, 2013).

The first step of utilizing the concept of a component model is the visualization of the statistics. By transforming the numbers of the data series into a diagram, one can already make initial estimations related to the model established in the next phase. Graphs with lines and markers offer usually a good first visual estimate.
Within the subsequent stage, a model has to be determined. As different time series depict various paths, exponential or linear for instance, the range of possible models is quite comprehensive. Finding the right configuration for the data sequence can be seen as decisive for the success of the analysis. To impose an appropriate model, the basic principle of additive dismantling of the time series is applied. This approach basically splits the time series into different components (Backhaus et al., 2015).

$$\mathbf{Y} = \boldsymbol{A} + \boldsymbol{K} + \boldsymbol{S} + \boldsymbol{u}$$

Table 1: Variables Component Model.

$\boldsymbol{Y}$	$\boldsymbol{A}$	$\boldsymbol{K}$	$\boldsymbol{S}$	$\boldsymbol{u}$
dependent variable	*trend component*	*economic trend*	*seasonal trend*	*random component*

The trend component (*A*) characterizes the long-term change of the response variable *Y*. This parameter can either be positive (increase) or negative (decrease) and linear or not. The economic trend (*K*) and the seasonal trend (*S*) represent cyclic fluctuations, whereby *K* displays the change in the economic situation, normally occurring over more then one year, and *S* the seasonal variations. The nature of these movements indicate their nonlinear behaviour. Those factors are seen as systematic components whereas *u*, the random error, is an unsystematic component (Backhaus et al., 2015). Since the used data is most probably not containing any seasonal and economic fluctuations, the trend component is the decisive factor. Since the focus of this work is rather to analyse past developments of exports and imports than establish predictions, linearity is implied to simplify the procedure. Therefore, the trend component is further specified as a linear model determined by following function:

$$\mathbf{Y} = \boldsymbol{\alpha} + \boldsymbol{\beta} * \mathbf{t} + \mathbf{u}$$

Variables α and β are unknown parameters and they have to be estimated under consideration of the existing figures. The trend parameter β depicts the constant growth or decline of the explained variable Y during one period. The estimation is completed by applying the statistical method of a simple linear regression, which is explained in the following paragraph (Backhaus et al., 2015).

2.2 Simple Linear Regression

The simple linear regression is a special case of the regression analysis with the purpose to support assumptions made related to the correlation between one dependent and one independent variable. It allows to establish estimates of changes of the dependent variable (*Y*) trough a variation of the explanatory variable (*X*). In order to create a fitting model to analyse the data samples, different aspects have to be considered.

First, as the relation of the response variable and the explanatory variable is certainly not exclusively, other factors have to be studied too. However, it is in the sphere of influence of the investigator to which extend this circumstance is reflected.

Second, a functional relation between *Y* and *X* has to be found and expressed in a model. The basic model of a bivariate linear regression function can be stated similarly to the previously mentioned trend component in the component model. (Schlittgen, 2000; Wooldridge ,2009)

$$\mathbf{Y} = \boldsymbol{\alpha} + \boldsymbol{\beta} * \mathbf{X} + \mathbf{u}$$

Y is the non-explanatory variable and defined trough the system. *X*, conversely, is the control variable. While expressing *Y* trough the scheme and *X*, a random disturbance occurs, namely u. This error can be seen as the combined unobserved factors that affect the explained variable. However, u is often set to have a mean value of zero to allow the definition of the constant α. The basic consideration is that errors can meet values below the regression line (positive value) or above (negative value) but accumulated it is assumed that they are zero.

The parameter β is the factor which determines the slope of the function. If *X* changes by one unit, *Y* changes by one unit times β if all unobserved factors stay fixed, which is an assumed ceteris paribus relation. This ceteris paribus relation has to be pointed out, because it is necessary and used for all interpretations and conclusions related to a linear regression in this work (Wooldridge, 2009).

The linear regression operates the method of least squares to find a curve and the belonging equation that is as close as possible to the observed *Y*-figures. So, the parameters of the function are set to minimize the quadratic deviations, so-called residuals, to get a conclusive approximation. Thereby, the coefficient of determination, or R^2 -value, is a highly important indicator of the quality of the model. The closer this key factor is to one, the better is the result of the regression and more *Y*-figures are predictable. This means that if the R^2 -value would be 0.80, eighty percent of the *Y*-figures can be determined by the related *X*-figures and the linear regression model.

Furthermore, the *P*-value has to be mentioned. To obtain proof whether a variable *X* has a statistically significant influence on variable *Y*, the null-hypothesis of the estimated coefficient beta being equal to zero can be tested. If this estimate is significantly different from zero, its respective *P*-value is very small, stating that the explanatory variable *X* is very important in the determination of *Y*. Hence, this parameter specifies if the hypothesis of the relation between the explained and explanatory variable is true. A *P*-value smaller than 0.05 indicates that the hypothesis must not be rejected. However, if the *P*-value exceeds this number, the null hypothesis has to be considered and the result of the regression is not usable for further interpretations (Neusser, 2011; Wooldridge, 2009).

2.3 Moving Average

The statistic method of moving averages is an appropriate technique to smooth data of a time series. By calculating average values of two or more different figures, which occur on dissimilar points of the time scale, the impact of fluctuations can be reduced. For example, if the first three events of a time series ($\mathrm{Y}\alpha, \mathrm{Y}\beta, \mathrm{Y}\gamma$) are used to establish the initial mean value of the moving average curve, the next determined figure of the moving average is calculated by using $Y\beta, Y\gamma$, again but $Y\alpha$ is replaced by $Y\delta$ which is equal to the next known number of the time series (Neusser, 2011).

2.4 Material Flow Analysis

The methodical approach of a material flow analysis depicts flows and stocks of a material within a system, which is clearly expressed by limits in time and space. The underlying key principle, the physical basic law of matter conversation, is useful to obtain the desired results. Hence, simply balancing all input, output and stock figures offers information about the sources and flows of the investigated material (Brunner and Rechberger, 2004). In the course of this work, however, the material flow analysis and the software tool STAN from the TU-Vienna is only used for visualisation purposes. Therefore, a closer description of this technique is not provided.

2.5 Data Collection and Limitations

2.5.1 Scrap Classification

In the recycling industry, a major distinction between old and new metal scrap is common. Old scrap is defined as the metal collected and recovered from municipal solid waste, construction waste or other comparable waste flows. Contrary, scrap metal accumulated during the manufacture of products (semi-fabrication) or the primary raw material production is stated as new scrap. This discrimination, however, is only the marginal basic categorisation. Within the literature numerous sub-classifications are noted, whereby the distinction feature is often the content of alloying elements, size of the waste units or source of origin (Institute of Scrap Recycling Industries, 2016).
New scrap has a special importance for the industry. The main argument in favour for new scrap is that the sources are obvious and also the structural composition of the material. Thus, this category of scrap is very suitable for the large scale secondary production, as not much effort regarding the special treatment and processing in order to the required grade of purity has to be done (ATM- Recyclingsystems, 2017; Aluminium Industry, 2017).

Within this thesis, however, all import and export data is related to the classification scheme of the Harmonized System. The constitution of the different scrap flows can contain new and old scrap as well. Post-consumer waste, which is not pre-treated by sorting and shredding or melting, is not considered since the trade with untreated metal waste is rather exceptional. Moreover, there is no clear distinction between new and old scrap under the Harmonized System.

Although End-of-Life Vehicles (ELVs) cannot be discriminated according to the Harmonized System and they are neither new nor old scrap, an exemption is made and the illegal trade with ELVs is elaborated too. However, the available data regarding the whereabouts of ELVs is very limited. Hence, different scenarios are provided to obtain an overview of the possible impacts on the interior scrap market of the EU.

2.5.2 Harmonized System

The World Customs Organization adopted the International Convention on the Harmonized Commodity Description and Coding System in 1983 and amended in 1986. The fundamental consideration of this treaty is to facilitate cross boarder trade and customs clearance for international trading partners. Establishing a common classification for commodities not only ease exchange of goods, it also supports data collection and allows expressive international trade data analysis. The Harmonized System consists of over 5.000 different product groups, each addressed with a particular numeric code. Until today, it is used by over 200 of the world´s states and economies as foundation of their tariff regime (World Customs Organization, 2017).

The Harmonized System Codes applied for the data sourcing of the following discussion are stated below (UN Comtrade, 2017a).

Table 2: Harmonized System Codes.

HS Code	Description
7204	*Ferrous waste and scrap, re-melting scrap ingots of iron or steel.*
7404	*Copper, waste and scrap.*
7602	*Aluminium, waste and scrap.*

This classification is, but only for some codes, further and more narrow defined by subchapters such as ***7204.10.00*** *- waste and scrap of cast iron*. Such specific data is not completely obtainable and a sub-classification of the discussed scrap metals is just available for steel. Therefore, the in table two listed trade codes have been used to select import and export records.

2.5.3 United Nations Comtrade Database

The United Nations Commodity Trade Statistics Database provides trade figures, which are reported on a yearly base by more than 170 countries. The annually released statistics contain over ninety-nine percent of the global retail trade and it is the largest data collection on international trade flows. Conveyed quantities are, if necessary, transformed to metric tonnes (tonnes) and economic values are adjusted to US-Dollars (USD) by using the exchange rate provided by each state or under consideration of monthly market rates. The different import and export figures are arranged according to the Harmonized System. All data related to exports and imports used in this thesis origin from this database (United Nations Statistics Division, 2017; UN Trade Statistics, 2017).

But, some limitations relate to the statistics have to be mentioned. First, the numbers are provided by the different Member States of the UN and they might have some national restrictions on communicating figures. Second, Member States are not obliged to report their trade statistics yearly. Thus, it could be that for a year some figures are missing if the data for a geographical area such as the EU-28 is considered. Third, there can be a variance in the valuation of the trade flows carried out by the reporting countries. For instance, different international commercial regulations regarding the terms of shipment are existent. For imports the Cost, Insurance and Freight (CIF) method should be used and for exports the Free On Board (FOB). Since the liability and the area of competence differs strongly between them and the contracts are subject to negotiation, the arising costs and therefore the specific price might vary. Nevertheless, as the EU is an economic union the assumption that all countries fulfil their duty and follow same reporting guidelines seems to be obvious (UN Comtrade, 2017b).
Furthermore, it has to be noted that the extracted import and export figures from the UN Comtrade Database are reported as trade flows between the EU-28 and the world,

although the number of Member States varied in the course of time. For all data collected from different sources than the UN Comtrade Database, an adjustment to represent all twenty-eight current Member States of the EU has been made. In some cases, however, when the availability of data did not allow defining the figures accordingly, records for Europe have been used. But, the deviation from the standard procedure is explicitly mentioned if applied.

2.5.4 World Steel Association (WSA)

The World Steel Association releases every year its Steel Statistical Yearbook (SSY) containing assorted figures on steel production, steel trade and usage. The underlying data is provided by the Member States of the WSA or various International Organisations such as the European Steel Association (EUROFER) or the United Nations Statistics Division. All the records used from the WSA to elaborate and discuss the research in this work are either from the SSY 2016 or from the issue of 2010.

2.5.5 International Copper Study Group (ICSG)

ICSG is an inter-governmental institution with the self set aim to enhance copper market transparency and endorse worldwide debates on matters linked to the metal. Therefore, a series of fact-books is issued annually which offer a broad range of data on copper production, usage and comparable. These fact-books have been used for the estimates regarding primary and secondary copper production in the EU.

3. Results and Discussion

Within this chapter the collected data is academically reviewed, analysis is provided and statistics are prepared for discussion. The structure of this chapter is related to the different types of secondary raw materials. Each sub-chapter is introduced by a general overview on the evolution of traded scrap quantities and related specific prices, followed by explanations on certain relevant time periods and arguments. Thereby, the aim is to answer the research questions expressed in chapter 1.3 and to provide a contribution to the scientific discussion about the topics concerned.

3.1 Steel Scrap Analysis

3.1.1 Development Export and Import Quantities

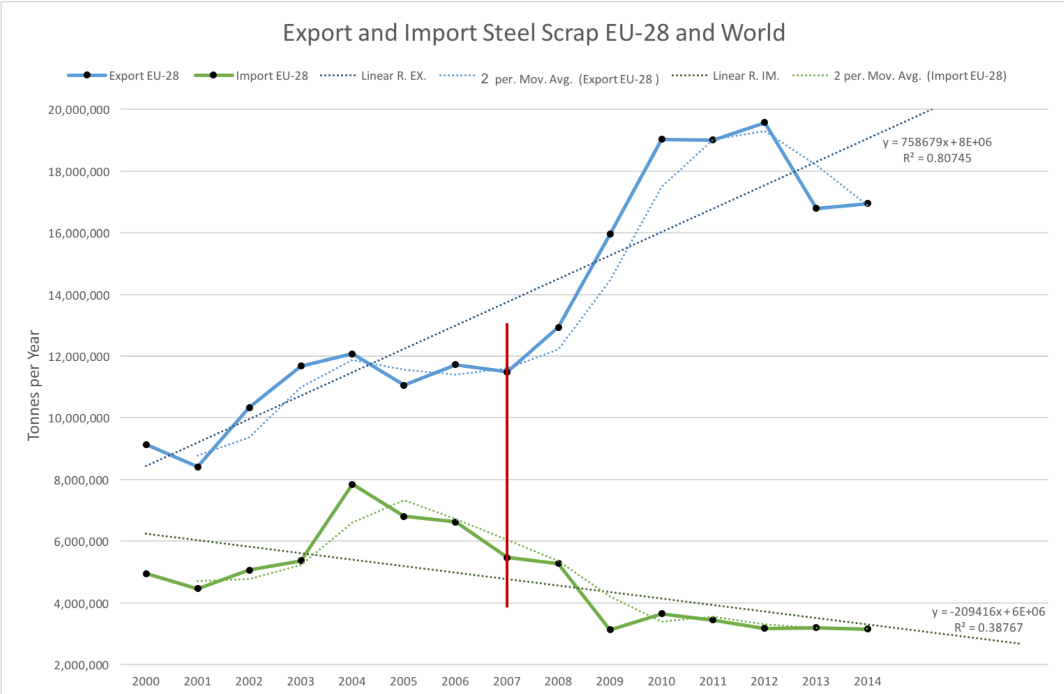


Figure 2: Export and Import Steel Scrap EU-28 and World, Data: UN Comtrade.

This line graph portrays the quantities of steel scrap exported and imported between the EU-28 and the world for the years from 2000 to 2014. Additionally, a red line is inserted to point out the start of the global financial crisis in 2007. The linear trend derived from the simple linear regression and accompanying formulas, $Yex = 758679X + 8\ 000\ 000$ for exports and $Yim = -209426X + 6\ 000\ 000$ for imports, suggest a steady growth for exports and a constant decrease of imports in the course of time. However, the coefficient of determination (R^2), which expresses how many of the Y figures are determined by the regression function, differs strongly between exports and imports. The R^2 value for exports is 0.8075, or more meaningful, roughly 80.8 percent of the variations of the scrap leaving the EU are explained by the linear trend and passing time. In contrary, over the observed period only 38.7 percent of the changes in import quantities are defined by the related regression.

A visual analysis of the curves and the moving average suggests that from the year 2000 to 2005 the development of exports and imports followed similar pattern. Imports surged sharply from almost 5 million tonnes in 2000 up to 7.8 million tonnes in 2004, the all-time peak value. Then they started to decline gently again. Within the same time period, exports of steel scrap increased from roughly 9.1 million tonnes to a high in 2004 of 12 million tonnes followed by a slight drop to 11 million tonnes in 2005.
Beginning with the years 2005/2006 the figures for scrap exports and imports began to divergence suddenly. The export of steel scrap skyrocketed from 11.5 million tonnes in 2007 to the unsurpassed peak of 19.6 million tonnes in 2012. Thereby, figures experienced a rise of over ten percent in the year 2007, followed by two consecutive years of about twenty percent annual growth compared to levels of the previous years. After hitting the maximum value, exports fell gradually to 16.9 million tonnes in 2014. Observations of the development of steel scrap imports over the same time interval, illustrate an opposite movement. The constant decrease of imports has already been starting in 2004, after the maximum of 7.8 million tonnes was reached. But, this decline was intensified between 2008 and 2009. Abruptly the numbers fell by approximately forty percent from 5.3 million tonnes to a low of 3.1 million tonnes. Then, imports recovered for a short time period and managed to reach the 3.6 million tonnes mark one year later. However, this positive trend was only briefly and since then imports experienced a slight but continuous decrease.

To sum up, between 2000 and 2005 the figures and especially the moving average for imports and exports show similar developments. Since then, however, changes in numbers went opposite directions. Whereas exports boomed by an impressive double-digit percent range from 2007 to 2010, imports decreased moderately from 2004 until 2014 with only one significant drop of forty percent in 2009.

3.1.1.1 Effect of the Financial Crisis on Steel Scrap Exports

Between 2007 and 2010 exports of steel scrap experienced a remarkable upsurge, most probably due to the aftermath of the economic crisis. The financial crunch diminished economic growth on a global level and the accumulated GDP of the world declined from USD 63.346 trillion to USD 60.046 trillion within the year of 2008. During the same time period, the GDP of the EU-28 decreased from USD 19.11 trillion to USD 17.08

(Worldbank 2017). Because steel products are widely-used in various industrial sectors, construction or automotive for instance, an economic downturn is set to lower demand for crude steel. Moreover, due to the fact that steel scrap is nowadays a main raw material for the crude steel fabrication, this lower request for steel products retroact on the usage of steel scrap. In 2007 the mutual EU-28 secondary production of raw steel with electric arc furnaces, a production technique that uses mainly steel scrap as input (Chapter 3.1.4), was close to forty percent of the total output of crude steel (World Steel Assosciation, 2016). Therefore, a decrease in the output of raw steel production leads to a massive decline in demand for steel scrap. Thus, it seems to be obvious that the economic downturn has affected the intensity of scrap employment. Subsequently, a relation between the financial crisis and export figures of steel scrap is assumed and investigated.

Table 3: Linear Regression Impact Financial Crisis on Trade in Steel Scrap.

Observations	13			
R-squared	0.8960			
	Coeeficient	**Robust Standard Error**	**T-value**	**P-value**
Specific Export Prices	-0,136281	0,093022	-1,47	0,181
Financial Crisis	0,191606	0,090885	2.11	0,068
Lag 1	0,877327	0,197183	4.45	0,002
Lag2	-0,184032	0,175700	-1,05	0,326
Constant	7,871279	3,955000	1,99	0,082

Table three shows the results of a linear regression with the aim to find a relation between the export of steel scrap and the financial crisis of 2007. Moreover, the influence of lagged observations of the dependent variable is reflected by the determined variables of *L1* and *L2* (Lag one represents the year 2006, Lag two the year 2005 if the year 2007 is observed). These additional explanatory parameters are added to increase the quality of the method and improve the significance of the outcome. It has to be noted that due to this lagged observation the coefficient is not a multiplier, as usually in this thesis, but it is expressed as a percentage per year. Besides, robust standard errors are a commonly used technique in statistical inference in order to protect the results from possible biases and disturbances (Wooldridge 2009). Since this research is not a statistical piece, this technique will not be elaborated on and it is only used for this regression. To allow the measurement of the effect of the financial crisis on exports of steel scrap, a dummy variable is installed and a multiple linear regression is conducted. The value of the dummy variable is zero from the year 2000 to 2006 and one afterwards. This strategy offers the opportunity to see explicitly the changes triggered by the economic downturn. Besides, this analysis also considers the influence of specific prices of exports on traded export quantities.

The result of the regression suggests that the effect of the economic crisis led to an escalation of steel scrap exports by 19.1 percent on average. This finding is supported by the low *P*-value (0.068), which shows that the alternative hypothesis (the implied connection between financial crises and steel scrap export) is valid and significant. Thus, the alternative hypothesis cannot be rejected in favour of the null hypothesis, which would reveal no linkage between the financial crisis and the level of exports. Additionally, the coefficient of determination R^2 extents to almost 0.9.
Contrary, the result of the regression also proposes that the specific price for exports has no significant effect on the traded quantities because the *P*-value (0.181) is exceedingly high and the alternative hypothesis has to be rejected.

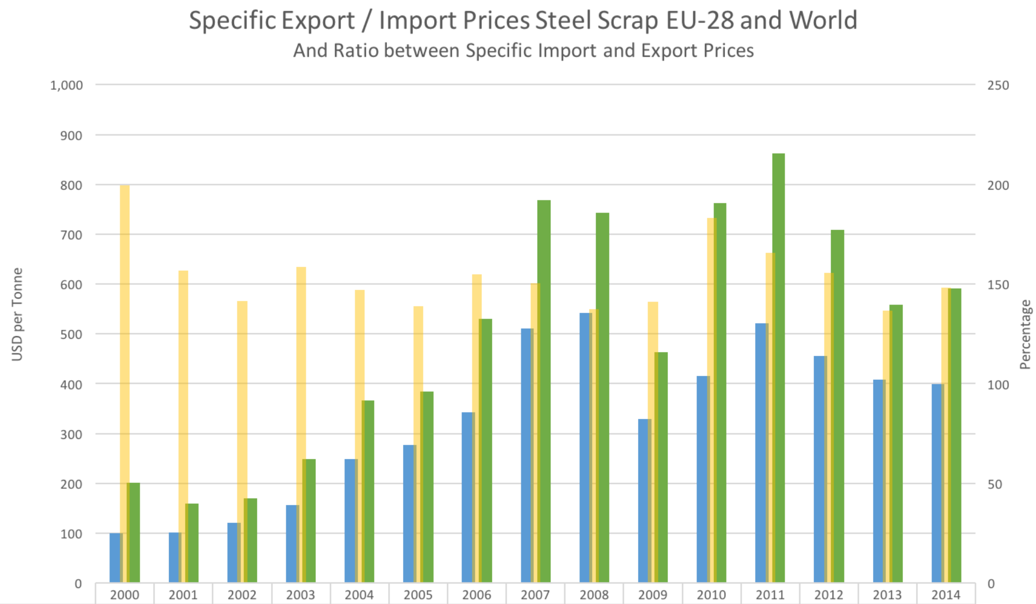
3.1.2 Change of Specific Import and Export Price

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Specific EX Price	100.500	101.700	120.600	157.200	249.500	276.400	342.400	511.200	541.500	328.900	416.00	521.300	455.200	408.300	398.500
Specific IM Price	200.600	159.500	170.400	249.200	366.800	384.200	530.800	769.00	743.300	463.600	761.700	862.700	708.700	558.200	591.00

Figure 3: Specific Export / Import Prices Steel Scrap EU-28 and World, Data: UN Comtrade.

Figure three illustrates the development of specific export and import prices of steel scrap beginning with the year 2000 and ending in 2014. Price for exports climbed steadily from around USD 100 per tonne in the year 2000 to USD 542 per tonne eight years later. Within the same time range, the import price surged from initially USD 201 per tonne to USD 743 per tonne in 2008. After this impressive escalation, however, both values experienced a dramatic one-year drop. During this period the export price lost almost forty percent in value and the import price dropped by thirty-seven percent. Nevertheless, this downturn was only short-lived and both indices recovered again. The import price increased between the year 2009 and 2011 from USD 463 per tonne to USD 863 per tonne, hitting an all-time high. The rise of the export price was quit impressive too, from USD 329 per tonne in 2009 to USD 521 per tonne only two years later. But, a significant decrease led to absolute prices of USD 591 per tonne for imports and USD 399 per tonne for exports in the year 2014.

Summarized, the price of steel scrap exports managed to increase by over 400 percent and the import figure by over 250 percent between the year 2000 and 2008. Afterwards, a one-year downturn followed but both indices recovered within two years and peaked close to 2008 levels again. Since then, a negative trend was constantly pushing import and export prices down.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Specific EX Price	100.500	101.700	120.600	157.200	249.500	276.400	342.400	511.200	541.500	328.900	416.00	521.300	455.200	408.300	398.500
Specific IM Price	200.600	159.500	170.400	249.200	366.800	384.200	530.800	769.00	743.300	463.600	761.700	862.700	708.700	558.200	591.00
Ratio IM Price/ EXPrice	200	157	141	159	147	139	155	150	137	141	183	165	156	137	148

Specific EX Price · Specific IM Price · Ratio IM Price/ EXPrice

Figure 4: Specific Export / Import Prices Steel Scrap EU-28 and World and Ratio between Specific Import and Export Prices, Data: UN Comtrade.

This bar chart displays the specific export and import price of steel scrap between 2000 and 2014. Additionally, the yellow data series depicts the ratio between import and export price. The peak value of the ratio is in the year 2000 with the import prices being twice as high as the export price. In 2010 this all-time high was almost reached again with import figures being 1.83 times higher than export records. The lowest ratio can be seen in the year 2013, with a percentage of 137 between specific import and export price.

3.1.3 Discussion Traded Quantities and Related Prices

Taking a holistic view on the data provided in the previous chapters, interesting details related to the development of these numbers can be observed. The first mechanism to mention is, that growth and decrease of the steel scrap import and export price seem to follow same patterns during the period of review. The moving average particularly underlines and supports this assumption. Even the impact of the financial crisis resulted in almost parallel decreases of nearly forty percent for both, export and import price. Furthermore, a linear regression conducted for the figures between 2000 and 2014 suggests that a positive change of the specific export price leads to an increase of the specific import price by the factor of 1.5. Correspondingly, this outcome is strengthened by an extremely small *P*-value (0,000054) and an R^2 -value which expresses that over 95 percent of the import prices are explained by this regression. As a result, one can state that a positive correlation between the specific export and import prices is present.

As already stated in the outline, steel scrap is a valuable raw material for economies and crude steel fabricators. Furthermore, its availability is restricted and, to a certain extend, steel scrap can be seen as scarce. Therefore, it is traded on a global market to balance differences in domestic and external demand and supply. To allow further findings, the concept of a supply and demand model is useful. This simple microeconomic approach suggests that in a competitive market the price of a commodity is established by matching demand and supply (Stiassny, 2010). Between 2001 and 2004 exports and imports of steel scrap, domestic crude steel production of the EU-28 as well as the specific export and import price increased steadily but with different orders of magnitude (World Steel

Assosciation, 2010). The simultaneous occurrence of growths in steel scrap export and import quantities combined with an increase in crude steel production could indicate that imported scrap is used for steelmaking and large amounts of new scrap generated during the primary production are exported again. This presumption is discussed in the following chapter (3.1.4) The rise of the import price and imported amounts of steel scrap between 2001 and 2004 can be explained by the demand and supply model because the domestic production increased likewise. Domestic demand is intensifying trough higher outputs of crude steel and interior supply is limited as steel scrap is restricted. Hence, more commodities have to be imported to meet the demanded amount. As the net-imports of steel scrap show a negative movement this scarcity of scrap is further intensified. Thus, the mechanisms and rules of the supply and demand model force the price of imported steel scrap to escalate.

In contrast to import records, the positive developments experienced by the figures attributed to the export price are rather not related to the local production, if the same microeconomic model is considered. The surge of output from steel plants should actually lower quantities of steel scrap exports since domestic demand is rising and consequently local prices are forced to increase. Therefore, it is relatively less attractive to export scrap and it is more beneficial to sell it to interior customers. But, steel scrap is a globally traded commodity and the microeconomic approach is not appropriate to explain this development. Besides, during the time period from 2001 to 2004 not only the performance of steel factories within the EU-28 experienced a constant rise. The worldwide raw steel production increased by approximately twenty-five percent compared to merely eight percent of the EU-28. This difference in output figures represents also a difference in demand. Through this intensified production, the prices are forced to rise even more externally than within the EU Single Market. But, it has to be noted that a structural difference between the raw steel production industry from the EU-28 and the rest of the world exists. From 2001 until 2004 the share of the total steel production of smelters and refiners using the electric arc furnace process was approximately thirty-seven percent in the EU-28 and only thirty-three world wide (World Steel Assosciation, 2010). However, this deviation is not expected to affect the demand structure insofar that the much lower growth in output of the EU-28´s steel industry could be compensated and distort the previously expressed relations. Hence, the boost in export quantities and the increase of the related price can be explained by the difference of output levels between the domestic and the steel industry abroad.

Furthermore, comparing the dissimilar evolution of imported steel scrap amounts and the specific price, the export figures and the domestic production from 2004 until the beginning of the financial crisis in 2007 is remarkable. The export and import price increased by forty percent and 110 percent respectively, domestic production experienced a growth of four percent and export quantities declined marginally during these years. The total imported steel scrap quantities from the world to the EU-28, however, weakened by over thirty percent. Considering these trends can lead towards two different assumptions.

First, deliberating the demand and supply model, the impressive increase in prices needs to have an increase in external demand as an underlying cause. Both, export and import price levels surged impressively and therefore the demand for steel scrap outside the EU-28 must have boomed too. From 2004 until 2007 the global crude steel production climbed by twenty-five percent compared to four percent in the EU-28 (World Steel Assosciation, 2010). This development suggests that the worldwide demand for steel scrap has increased more substantial outside the EU-28 than in the interior market.

Second, the slowdown in steel scrap imports combined with the export quantities, which remained more or less the same although export prices skyrocketed by forty percent, allow the obvious assumption that there has been a substitution process taking place. The significant higher export price should have promoted shipments out of the EU-28, however, the almost three times higher increase of the specific import price might have tempted producers to find substitutes on the domestic market. Due to the complexity of material flows within the steel making industry, however, this assumption cannot be proven wrong or right.

Also, the graphs and figures presented may indicated that there is a fundamental difference in the structural composition of export and import steel scrap. Hence, it has to be emphasized that during the whole considered time range the price of imports is significantly higher than the price for exports. If one assumes that the specific attributes of a product justify a higher price, the imported steel scrap must show characteristics, which are worth striving for, compared to the exported scrap. This, combined with the coexistence of imports and exports of scrap raises questions, especially since the origin of the underlying data sets is derived from the same source and the same discrimination for imports and exports have been applied. As the used classification is not the lowest level of distinction, the composition of the traded material flows can possibly differ. The steel making procedure offers a unique opportunity to discuss further on these issue. Therefore, the next section provides an insight into the two key production processes for crude steel.

3.1.4 Primary Steel Production in the EU-28 and Trade in Scrap

Two main manufacturing routes fundamentally distinguish the primary steel production. Through the traditional lane, iron ore is melted and reduced in blast furnaces and the generated pig iron is then refined in a converter. In order to receive the special physical attributes of unalloyed crude steel, high degrees of hardness but low brittleness, the application of the basic oxygen process is necessary. As the coke used to fire the blast furnace pollutes the pig iron with carbon, the total carbon content has to be reduced afterwards. The carbon shares of pig iron smelted in blast furnaces differs, but they are typically within the range of three to six percent. Primary crude steel, however, is set to have a carbon content lower than two percent to assure its related and desired characteristics (Lohse, Laumann, and Wolf, 2016). To achieve this target values, the molten pig iron is mixed with limestone to support slag production and up to twenty-five percent of steel scrap to cool the liquid raw iron. Then oxygen is injected under high pressure and the carbon, along with other contaminations, is converted to slag. As a result, crude steel with the desired quality and slag are the tangible finished products (The American Steel Institute, 2017).

The second main pathway of today´s crude steel production is the fabrication via electric arc furnaces (EAF). The input for this type of crude steel manufacturing is, to a large extend, steel scrap. Although other raw materials such as pig iron or iron sponge can be used too, the research centre Jülich (2017) states that in Europe mainly steel scrap is manufacture by EAF processes. In order to melt the raw material, graphite electrodes are set closely to the metal and an inducted voltage creates an electric arc with extreme temperatures between the electrodes and the metal. Consequently, the solid metal content is melting and after less than one hour the furnace can be tapped. Since the characteristics of the produced output are related to the attributes of the used raw material, EAFs are

often used to recycle high-quality scrap and produce accordingly high-grade crude steel (Forschungszentrum Jülich, 2017; Eckhart and Kortus, 2013).
Besides, this production procedure has some benefits compared to the blast furnace route. First, the EAF allows to control the melting process very precisely, which is seen as a big advantage especially if stainless steel is produced. Second, as not burning oxygen is providing the required heat for melting, slagging of possible expensive alloy elements can be avoided. Third, a blast furnace has to be operated all day long during its whole lifetime, which is between ten and fifteen years nowadays, because a restart is very costly (Feldmann et al., 2011). This fact, combined with the significant higher investment costs of blast furnaces, restricts the operator's ability to react on short time market changes in demand and supply to avoid overcapacities. Moreover, the energy consumption per unit of crude steel can be curbed by using an EAF to less then ten percent (350-400 KWh/t crude steel produced in EAFs) of the energy needed by production with the traditional process (Ilschner and Singer, 2017).

These mentioned differences in the two major steel producing lines in Europe might allow a closer description of the evolution of import and export of steel scrap. Especially the difference in the employment of raw materials, iron ore and little steel scrap for basic oxygen process production versus almost only steel scrap for the electric arc furnace, have to be pointed out.

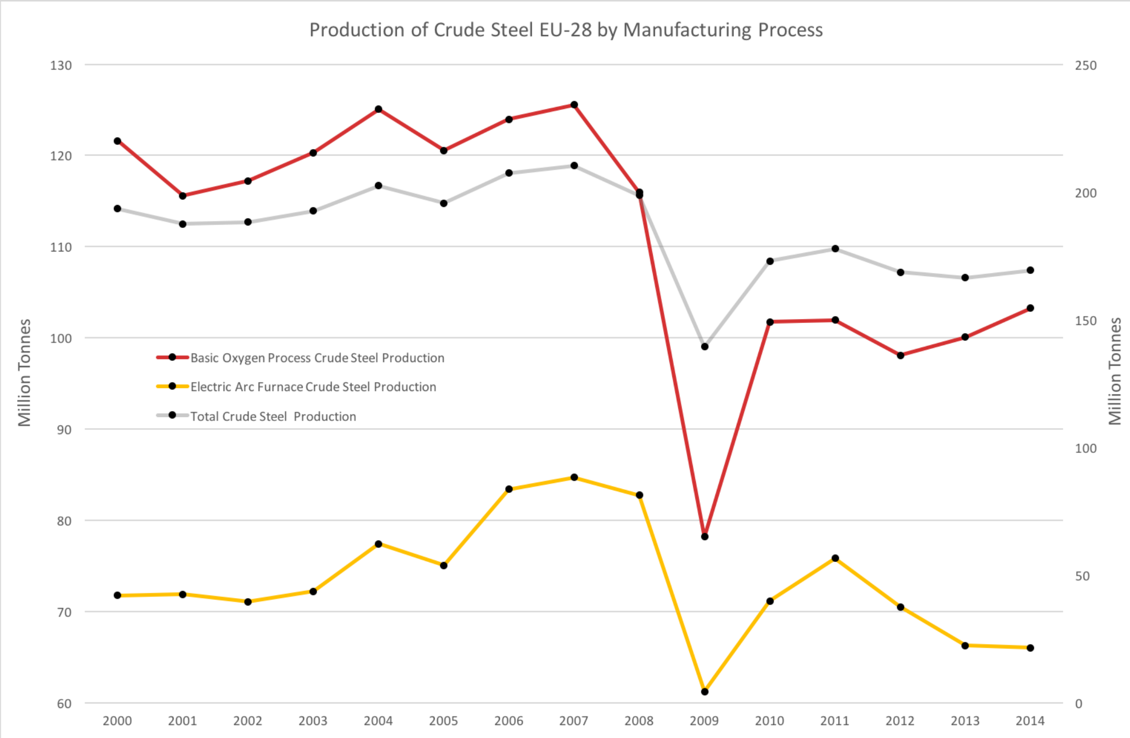


Figure 5: Production of Crude Steel EU-28 by Manufacturing Process, Data: World Steel Association.

This graph shows the produced quantities of crude steel, differentiated by production method, of the EU-28 Member States between the years 2000 and 2014. Additionally, the total crude steel production is depicted, however, scaled by the secondary axis on the right hand side of the diagram. From the beginning of the observed period until 2007, both production routes increased modestly. The output figures of the electric arc furnace (EAF) raised by eighteen percent whereas fabrication by the basic oxygen process (BOP) increased slightly by four percent. Between 2007 and 2009, however, both processes for crude steel production suffered a setback. Figures for BOP steel making dropped by roughly thirty-eight percent and EAF output was diminished by twenty-eight percent. Nevertheless, numbers started to recover again and BOP production surged by around thirty percent within 2010. Similarly, the EAF route experienced a positive development from sixteen percent in 2010 compared to 2009 levels and another seven percent one year later. From this point, though, the statistics dropped until 2014 by over twelve percent for EAF production while figures for the second method stayed on a constant level. Besides, the accumulated raw steel production fluctuated from 2000 to 2008 between 187 million tonnes and roughly 210 million tonnes. From this point, however, the figures show an impressive drop of approximately thirty percent until 2009. Then the gathered output numbers recovered again but never reached the level previous to the global economic downturn again.

Summing up, the data series portray a positive trend until the financial crisis in 2007. Then, two successive years with a massive downturn can bee seen and from the year 2011 EAF fabrication decreased while BOP production remained constant. Overall, the total raw steel production of the EU-28 dropped substantially after the financial crisis and remained on a lower level since then.

The development of the figures for combined crude steel making offers a noteworthy insight. Through the decline in demand for raw steel, triggered by the economic crisis, the output decreased dramatically and never managed to reach pre-crisis levels again. Due to the nature of the production methods, it could be assumed that the total capacity of the EU-28´s steel-manufacturing sector was reduced as a direct reaction to the global crisis. The secondary production route with the electric arc furnace allows a short-term decommissioning since the furnace is solely working on electricity and their total output is usually smaller as well as investment costs compared to the blast furnace route (Feldmann et al., 2011). To lower production of the primary making, however, is much more complicated since a blast furnace should be operated non-stop during its lifetime. From an economic point of view, the investment cost for a blast furnace with the necessary complementary industrial facilities, such as applications for coke production, are particularly high. For example, the total investment in a new blast furnace build 2006 in Germany was roughly 340 million Euro (ThyssenKrupp Steel AG, 2006). Therefore, a company running blast furnaces is rather reluctant do stop production as a large share of the production costs are already paid. Despite this circumstances, ArcelorMittal, one of the big players in crude steel production in Europe, has decided to restricted output of seven out of twenty-five operating blast furnaces starting in 2012. Four of them have been set to shut down permanently (Kessler, 2012). However, it has to be mentioned that the steelmakers remained reluctant in the short range as the total capacity of the EU-28 steel producers was only reduced by four percent from the year 2007 until 2012 despite a drop in demand of over thirty percent (Biesheuvel, 2016). This delay in reactions to the changed market situations clearly expresses the inflexibility of the steel-producing sector due to its capital intense fabrication methods. Nevertheless, this negative trend to abandon enduring overcapacities by shutting down blast furnaces has to continue in future and will cause major political and social challenges. According to Bünder (2017), is Thyssen-Krupp, a German steel producer, set to reduce costs initiated by the blast furnace production by over € 500 million within three years. The main arguments are that the primary production not even cover the capital costs with the recent drop in price and that prospects do not indicate a change in this development in the near future (Bünder, 2017).

To sum up, the primary steel production sector of the EU-28 is taking actions to cut overcapacities. Due to the capital intensity of the blast furnace route, however, the adjustment of capacities to the lower demand for crude steel caused by the global economic downturn of 2007 is taking place with some years of delay.

3.1.5 Structural Differences of Exports and Imports

With the knowledge obtain from literature and the data analysis of the previous chapters, an examination of possible differences in the structural composition of exports and imports is made. The coexistence of exports and imports of a commodity at the same time, in combination with the roughly one and a half times higher specific price for imports, is, from an economic viewpoint, interesting. If one is referring to the demand and supply model, the price for one good is determined by the demand and supply. Thus, there is only one possible price for uniform products in a perfect market with no market failure. Hence, one possible explanation to justify these substantial differences in price is that the material flows do not have exactly the same properties and the market fails.

Since, the specific import price is significantly higher over the whole observed period, the product features of the imported scrap seem to be worth to pay more then for domestically available scrap. One of these special characteristics can be a certain degree of resistance against corrosion, triggered by weathering or water. Crude steel, without any alloying metals added, is not protected against any type of oxidisation. For many applications in the industry, however, this is a very important key feature of steel and therefore one of the most important steel types is stainless steel (British Stainless Steel Association, 2017). According to the British Stainless Steel Association (2017), the production of this special material requires the alloying of crude steel with at least 10.5

percent chromium. To facilitate the further work, high quality or high-graded steel is discriminated as stainless steel with no further distinction regarding other alloying metals.

Besides, the literature review suggests (Forschungszentrum Jülich, 2017) that in Europe the EAF route is mainly feed with steel scrap as raw material and the EAF production is especially suitable to manufacture high-grade steel due to optimized production control. Nevertheless, it has to be mentioned that also the BOF production can be used to manufacture high-grade steel. But the relation between high quality scrap input and high quality crude steel output is explicitly mentioned for the EAF route. It is expressed that this method is appropriate to use steel scrap with specific attributes, as the output will have the same characteristics. Thus, the analysis aims to display developments, which indicate a relation between the production of high grade steel in EAFs and imported steel scrap.

Table 4: Change in Scrap Export and Import Quantities and Production in the EU-28, Data: UN Comtrade and World Steel Association.

	Exports	Imports	BOP Production	EAF Production
2008	12,60%	-3,40%	-7,80%	-2,30%
2009	23,30%	-41,20%	-32,60%	-26,40%

A special focus on raw steel flows and the production, differentiated by type of manufacturing, of the years 2008 and 2009 offers a noteworthy insight. In 2008 the export of steel scrap increased by roughly thirteen percent and output of steelworks using the BOP dropped by eight. On the other hand, the production figures for their counterparts, working with an EAF, decreased by only two percent and imports fell by roughly three percent. Besides, it has to be noted that the ratio of EAF production and the overall steel making climbed steadily during this time and it reached an all time high of forty-four percent in shares of the EU-28 total production in 2009. (World Steel Assosciation, 2016) Yet, in this year of relative peak EAF production, a drop of output figures from twenty-six percent was simultaneously experienced with a plunge in imports by forty-one percent. Within the same year, figures for BOP manufacturing decreased by thirty-two and exports increased by twenty-three percent. If one compares the negative development between the years 2008 and 2009 from import quantities (from -3.4 to -41.2 percent) and

the amounts for EAF production (from -2.3 to –26.4 percent) with the export and BOP figures, it can be depicted that both values increased more then tenfold while their counterparts only doubled (export quantities) and quadrupled (BOP production). Since, this decrease of EAF production is within the same range as the decline of imported steel scrap, combined with the fact that EAV is the main application for steel scrap and that the share of the secondary production of the total steel making output was peaking in these years, one could suggest a relation between EAF production and imports.
Hence, linking this assumption with the knowledge that EAF manufacturing is well suited to fabricate high-graded steel, it can be speculated that imported scrap has more preferable attributes than comparable domestically available scrap.

Nonetheless, it has to be noted that the EAF technique is not only applied for high-grade steel production and steel scrap is use by both manufacturing paths. In 2009 the total output of stainless steel in the EU-28 was approximately six million tonnes compared to sixty-one million tonnes of EAF production (International Stainless Steel Forum, 2016). Hence, the assumption that imported scrap is rather suitable for high quality manufacturing then the scrap which is exported, has to be further promoted by the following bar chart.

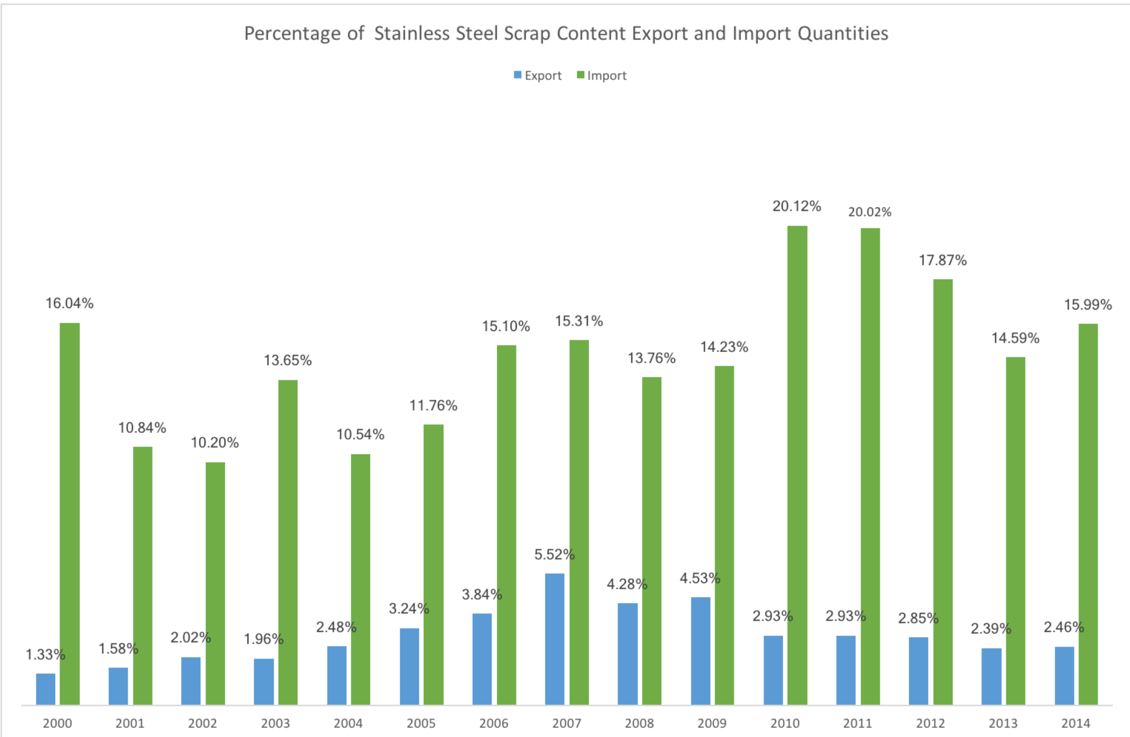
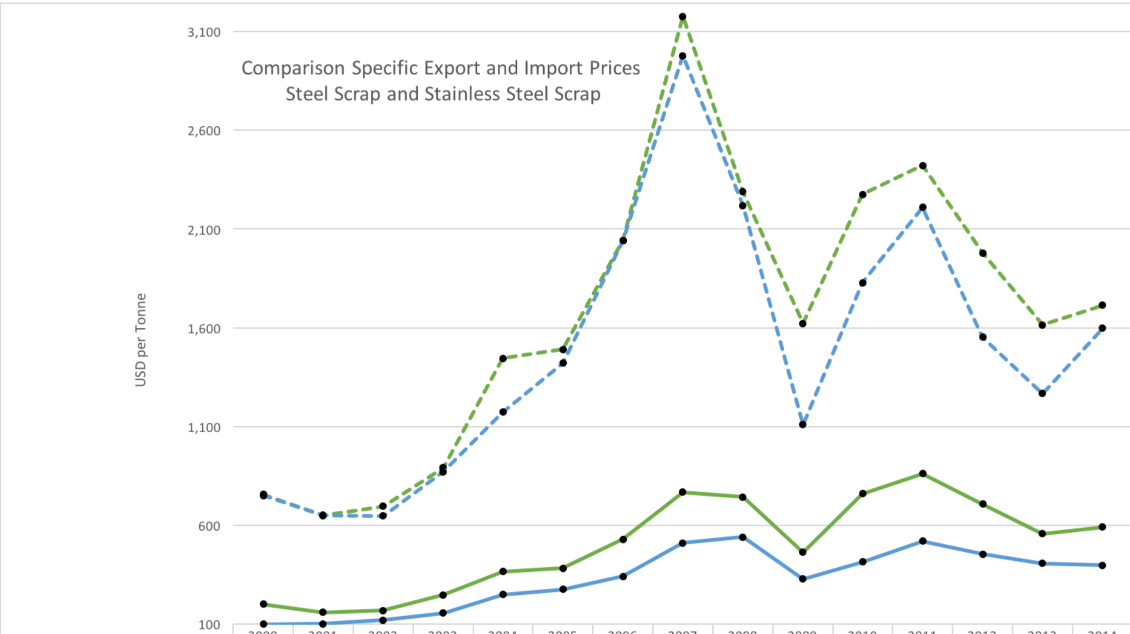


Figure 6: Percentage of Stainless Steel Scrap Content Export and Import Quantities, Data: UN Comtrade.

This graph exemplifies the content of stainless steel scrap of the exports and imports from the EU-28 to the world between the years 2000 and 2014. It can bee seen that the share of stainless steel is always higher within the import figures compared to the exports. Also, it can be noted that during the years of the financial crisis relatively more stainless steel scrap was exported than before or afterwards. As the total content of high-graded steel in the structural composition of the imports is always substantially higher then within the exports, the assumption that the bought steel scrap outside of the EU Single Market is rather used for the EAF production is strengthen. How much this circumstance is affecting the specific price determination of the traded steel scrap is further specified within the subsequent paragraph.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Sp. Price IM Stainless Scrap	758	652	697	892	1446	1490	2043	3176	2288	1623	2276	2421	1979	1614	1715
Sp. Price EX Stainless Scrap	751	651	649	871	1175	1421	2041	2977	2220	1110	1829	2210	1554	1268	1599
Sp. Price IM Total Scrap	201	159	170	249	367	384	531	769	743	464	762	863	709	558	591
Sp. Price EX Total Scrap	101	102	121	157	250	276	342	511	541	329	416	521	455	408	399

Figure 7: Comparison Specific Export and Import Prices Steel Scrap and Stainless Steel Scrap, Data: UN Comtrade.

This illustration shows the specific export and import price of the total traded steel scrap and the specific import and export price of the stainless steel scrap content between the EU-28 and the world. A visual analysis indicates that all four data series follow, to a greater or lesser extend, similar patterns. Moreover, a simply linear regression made for the specific price of the total imported steel scrap (*Y*) and the specific price of the imported stainless steel scrap (*X*) demonstrate a strong correlation between them. The total steel scrap price can be explained by the stainless steel price with an R^2 - value of 0.87 and an extremely small *P*-value (0.0000004). Hence, the result of the regression is statistically significant. The same method applied for the export records depict an *P*-value of 0.000025 and an R^2-value of 0.75. Therefore, the relationship between the specific export price for stainless steel and the specific price for the total exported steel scrap is also important.

To sum up, it can be stated that the prices for stainless steel scrap have a strong relation to the specific price of the total exports and imports of steel scrap. Moreover, the multiple higher price level of stainless steel scrap over almost the whole investigated period suggests a strong influence on the degree of the total specific export and import prices. Hence, a review of these figures, adjusted by excluding the contribution of high-graded steel from the specific export and import price, results in following pictorial representation.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Sp. EX Prices Stainless Excl.	92	93	110	143	226	238	275	367	467	292	373	470	423	387	368
Sp. IM Prices Stainless Excl.	94	100	111	148	240	237	262	334	497	271	380	473	432	378	377

Figure 8: Specific Export and Import Prices Stainless Steel Excluded, Calculations based on UN Comtrade data.

Figure eight portrays the specific export and import prices of the steel scrap flows between the EU-28 and the world without the stainless steel scrap from the year 2000 to 2014 considered. Although the export price exceeds the import figure from time to time, usually the import price surpasses their counterpart. Besides, both prices develop within the same order of magnitude during the whole observed period. Therefore, it can be noted that the differences in costs for steel scrap are mostly due to structural composition differences.

Hence, the existence of customs on imports of steel scrap, which could be argued as a reasonable explanation under consideration of the figure three and the constantly 1.5 times higher import price, can be rejected. This is also supported by legislation of the EU since the European Commission has neither imposed any tariffs on imports or exports of steel scrap nor for aluminium or copper scrap (European Commission, 2017c). Nevertheless, it has to be stated that there is a major difference in the valuation of export and import flows within the UN Comtrade Database that could clarify the slight remaining differences. According to the guidelines on reporting international trade statistics to the UN Statistic Division, Member States are instructed to apply different international shipping agreements on imports and exports. Imports are set to be assessed under Cost, Insurance and Freight (CIF) agreements, while Free On Board (FOB) contracts shall be used for exports (UN Comtrade, 2017b). The main purpose of these transnational shipping treaties is to assign liabilities of the business transaction or the delivery of the goods to buyer and seller. If it is agreed on FOB terms, the vendor delivers the commodity to the mean of transportation dictated by the purchaser, which are in most cases vessels. Once the good is loaded the buyer has to bear the risk of loss or damage as well as all further costs arising. With CIF the danger of loss or damage also passes to the buyer once the freight is on board of the vessel, however, the seller has to pay the transport and must insure the goods on behalf of the customer at its own expenses (International Chamber of Commerce, 2010). Still, it has to be mentioned that this kind of agreements and the related conditions are negotiable and the provided explanation is only a general description. Due to the differences of this delivery terms, however, the valuation, if according to the recommendations of the UN made, of imports and the related specific prices is relatively higher than the assessment for exports. To which extend this circumstance is affecting the valuation of exports and imports of the different scrap sorts and thus price levels is not easily to determine since the UN only placed recommendations how to assess the material flows and the terms of delivery are subject to negotiations.

To sum up, focusing on the crude steel production while define them trough the different fabrication route indicates a relation between the import of steel scrap and the EAF production. Besides, the literature suggests that EAFs are especially suited to produce high grade steel out of high grade scrap. After the external shock of the financial crisis, import quantities and EAF output dropped within the same relative range of percentage. This development combined with the information provided from the literature suggests that import flows are used in EAFs for high-quality steel production. Therefore, the structural composition of the imported quantities is assumed to have more demanded attributes than comparable exports. This assumption is endorsed by the outcome of the analysis of the stainless steel content of the trade flows.

3.1.6 Steel Scrap Flows and Illegal Trade of End-of-Life Vehicles

To follow the path of steel scrap, which is imported or exported is a highly difficult task and it would certainly burst the framework of this work. Nonetheless, to illustrate this circumstance and to gain an overview of the issue, a simplified material flow system for the crude steel manufacturing procedure is provided. Furthermore, it has to be noted that for aluminium and copper scrap the scheme would look very similarly, hence it is not explicitly expressed again.

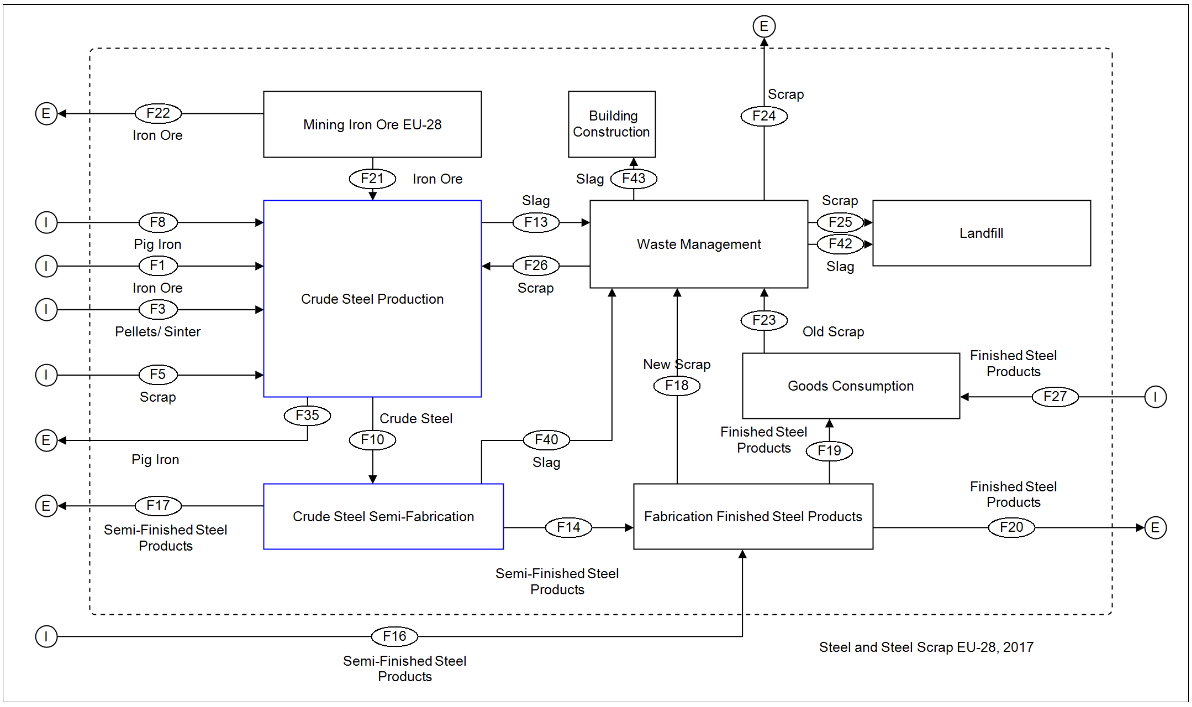


Figure 9: Steel Production and Scrap Flows EU-28, Illustration based on various sources.

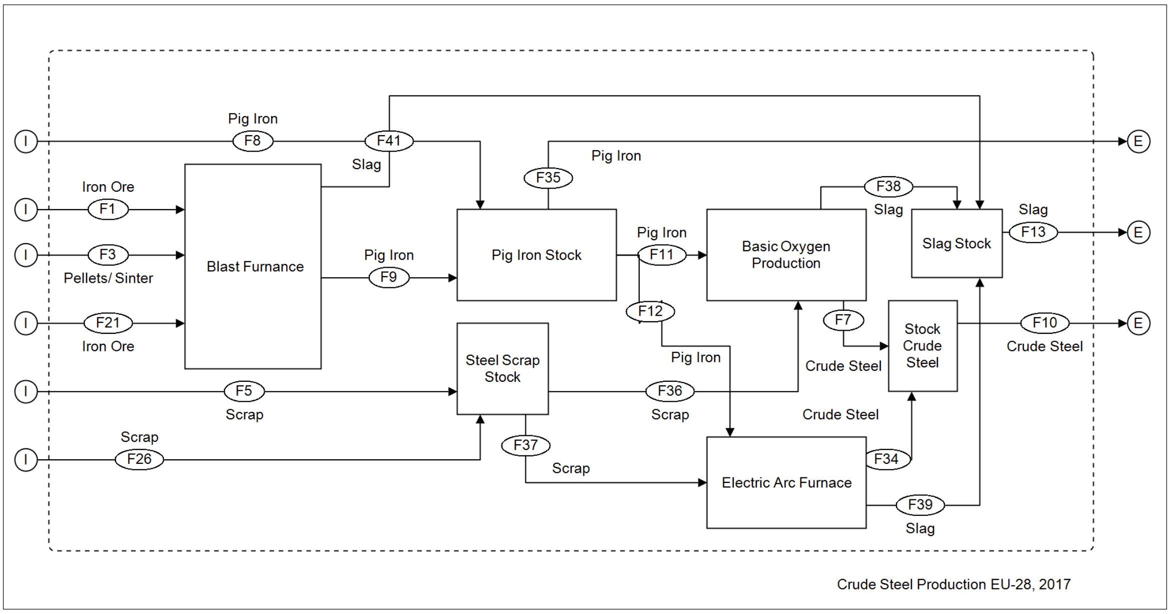


Figure 10: Sub-process Crude Steel Production, Illustration based on various sources.

This material flow systems present the domestic flows of the raw steel production and related procedures within the EU-28 followed by an illustration of the sub-process of Crude Steel Production. With over forty flows, numerous processes and sub-processes, even this very abridged system is difficult to handle and to determine precisely. To allow

a meaningful analysis, figures and data for most of the processes and flows must be found. Hence, some constrains had to be made in the course of this thesis and only the outflow of scrap due to illegal trade of ELV´s (Chapter 3.1.6.1) further discussed. The domestic distribution and occurrence of scrap is not detailed further.
Besides, a graphic representation to demonstrate the significance of the trade in steel scrap related to the fabrication of crude steel within the EU-28 is provided.

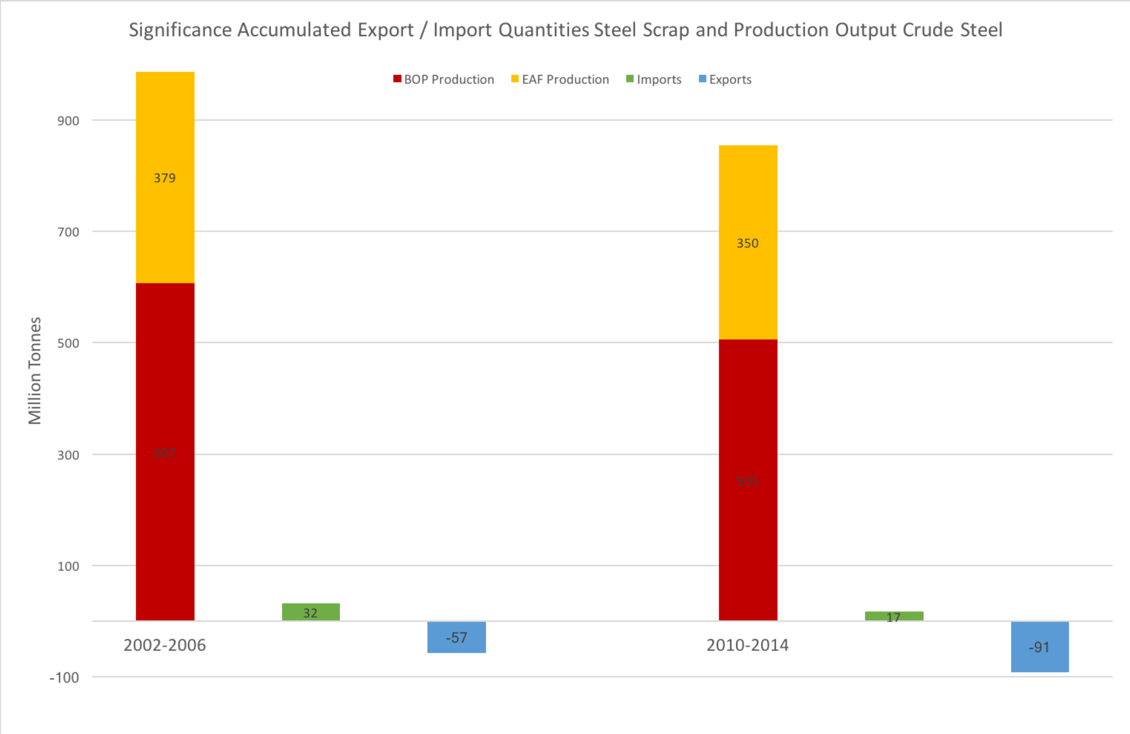


Figure 11: Significance Accumulated Export / Import Quantities Steel Scrap and Production Output Crude Steel.

This bar chart shows the accumulated flows of exports and imports of steel scrap between the EU-28 and the world and the total steelmaking of the EU-28. In order to achieve a meaningful result, the records for two time periods, consisting of four consecutive years each, have been summed. Besides, the preceded and subsequent years close to 2007 were not considered to avoid a major distortion of the outcome due to the financial crisis. The comparison of the statistics from period I (2002-2006) and period II (2010-2014) suggest that imports of steel scrap dropped by almost fifty percent while export numbers climbed by sixty percent. This development is not surprising since during period I the production increased and thus a higher demand for steel scrap can be assumed. Regarding the production levels, it can be noted that a minor decline of roughly seven percent for the

EAF production and approximately seventeen percent for the BOP route from period I to period II is shown. In period I the percentage of the net-exports related to the total domestic production of the EU-28 was merely 2.5. For the second period, however, this ratio emerges positively to a level of 8.6 percent. This outcome has to be interpreted with caution as the total output of raw steel dropped from the first time range to the second by over 130 million tonnes while the net-exports increased from twenty-five million tonnes to seventy-four million tonnes. The production with EAFs actually dropped by only twenty-nine million tonnes. This evolution allows the assumption that if the EAF route is seen as the main user of steel scrap the more steel scrap was available in the second period and thus the significance of steel scrap net-exports for the steelmaking is rather negligible. However, is the appliance of steel scrap in the BOF production with roughly twenty percent estimated, the net-exports meet relatively precise the numbers of decreased scrap utilisation. Hence, one could assume that only the surplus of steel scrap arisen in the EU-28 is sold abroad and the significance is not given.

3.1.6.1 Illegal Trade of End-of-Live Vehicles

In September 2000 the European Parliament and the European Council implemented the Directive 2000/53/EC on End-of-Life Vehicles. The stated objectives are to avoid waste generated by dismantling ELVs and to reduce final disposal quantities. To achieve these aims, recycling targets were agreed on to support recovery of precious secondary raw materials from discarded vehicles. Moreover, this directive is set to advance the ecological performance of all stakeholders to ELVs, with a special focus on the recycling industry. So, in Article 5(3) of the Directive 2000/53/EC it is expressed that Member States shall install a structure to accumulate, recover and reprocess ELVs in an environmental compatible way. Furthermore, the de-registration of vehicles should only be possible if a Certificate of Destruction, issued by an authorized facility, proofs that a ELV has been disposed accordingly. This policy was implemented to hinder illegal dismantling and illegitimate export of ELVs. Although, the European Commission found that the directive was full implemented to national legislation in all Member States, the issue of illicit trade in ELV is still not solved yet (European Parliament, 2000; European Commission, 2017a).

The investigation on illegal shipment of ELVs and the data related are object to some substantial limitations.
First, not all cars that are not used anymore are delivered to official acknowledged recovery facilities as determined by the Directive 2000/53/EC. Hence, no complete registration of the actual arising amount of ELVs is available and little knowledge about their origin too. In the context of the whereabouts of the vehicles deregistered but neither traded as used cars nor officially treated as ELVs, illegal dismantling is mentioned. Some of them might be just brought to a nearby scrap dealer for recovery. Actual numbers of unauthorised treatment facilities differ broadly within the literature. In the year 2006, roughly 1250 facilities in France operated with authorisation while approximately 850 were running business illegitimately. However, other estimates suggested that the number of illicit shredding sites handling ELVs is lower than ten percent compared to their legally acting counterparts (Schneider et al., 2010).
Second, the distinction between used cars and ELVs is subject to national legislation of the Member States of the EU. Therefore, each country has different laws and regulations, which makes a broader data sourcing to obtain reliable numbers difficult. Besides, this classification is crucial since the restrictions of export of ELVs, they are declared as hazardous waste if not depolluted, are much more stringed then for second hand cars. The distinction according to national legislation offers opportunities for illegal shipment of ELVs under the guise of lax regulations for used cars (Schneider et al., 2010; Oeko-Institut e.V., 2016).
Third, even the actual number of arising ELVs within the European Union per year is not clear. The amount stated in literature differs between official records from approximately seven million ELVs annually to assumption of other studies in the range of fourteen million ELVs per year (van der Have and Schaap, 2016; Oeko-Institut e.V., 2016; Eurostat, 2017). Subsequently, the further investigation on illegal export of ELVs is subject to significant restrictions and some assumptions have to be established.

The German Oeko-Institute e.V. is currently conducting a study on the assessment of the Directive 2000/53/EC on End-of-Life Vehicles with special focus on the issue of not registered ELVs. Hence, they published data for four different years with estimates on the quantity of ELVs with unknown whereabouts. These numbers are used for the further observation since it appears to be the most reliable statistics related to this circumstance. Moreover, the order of magnitude of this figures suit similar estimates stated in the literature (Helmers, 2015). According to the Oeko-Institute e.V. (2016), the number of ELVs with not known location in the European Union was more then 4.1 million in 2008, approximately 3.4 million in 2009 and for the year 2012 more then 3.5 million. One year later the figure was roughly 3.6 million. To be able to make a statement, the mean of these estimates, 3.65 million, is used as the figure for ELVs with unknown whereabouts within the EU.

Furthermore, to investigate how much secondary raw materials are lost due to the illegal export of ELVs, statistics associated to the structural material composition of ELVs is provided.

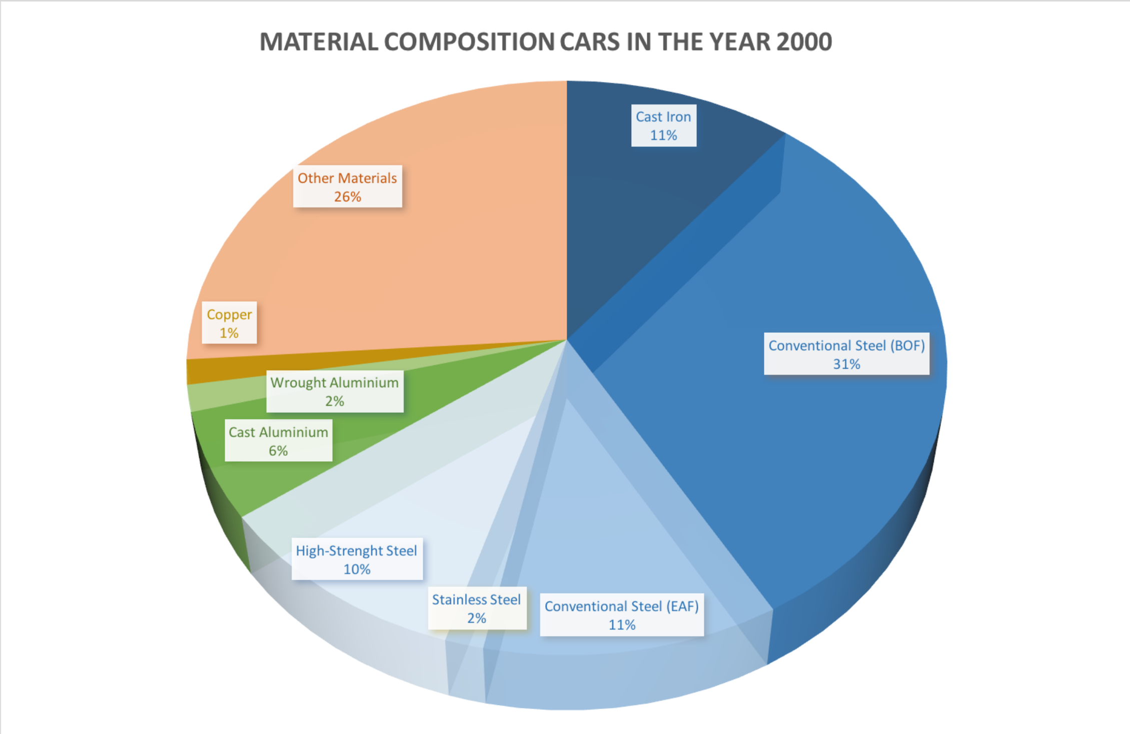


Figure 12: Material Composition Cars in the Year 2000, Author´s elaboration- Source: Cheah 2010.

This pie chart illustrates the material composition of cars in the year 2000. Roughly two-third of the mass of an automobile was related to the usage of iron and steel products at this point. The total aluminium content was eight percent and the share of copper was only one percent. However, here again, restrictions of the research occur. Within the automotive sector a development towards lightweight design to adapt to new challenges, such as limits for CO2 emissions, combined with the obtainability of new innovative materials result in different material compositions for cars. Steel can be replaced by

higher graded steel which enables the use of less material while keeping the required stability or aluminium is employed which is much lighter than steel. Furthermore, a substitution of metal use by the enhanced employment of fibre-composite components is possible (Friedrich, 2013). Therefore, the exact composition of an ELV can only be estimated as the content of the several materials differs in the course of time.
Besides, the average mass for ELVs has to be determined. Between the year 2007 and 2014 the mean mass of ELVs within the EU was 1120 kilograms (Eurostat, 2017). Although the average mass of automobiles has been steadily increasing over the last decades, according to Helmers (2015) by 1.6 percent per year, for this work the above-mentioned figure is applied.

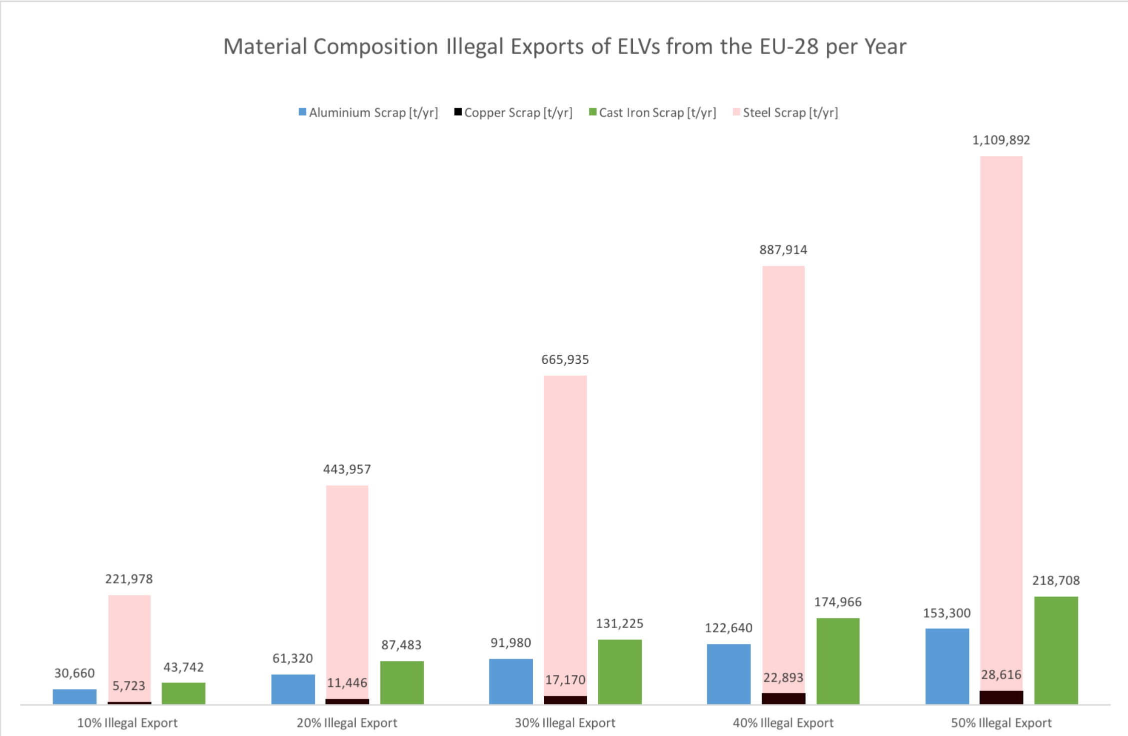


Figure 13: Material Composition Illegal Exports of ELVs from the EU-28 per Year, Data: Various Sources.

This bar chart provides an insight on possible losses of secondary raw materials related to the illegal export of ELVs from the EU-28 for the interior scrap market. Since the data availability is restricted, five different scenarios are displayed on the X-axis. The percentage and numbers are permanently related to the ELVs with unknown whereabouts per year. If the number of illegally exported ELVs would meet the thirty percent scenario, approximately five percent of the average annual steel scrap export between 2000 and

2014 is lost for the internal scrap market of the EU-28. In economic terms and under consideration of the average specific export price for the same time range, this damage for the domestic scrap market is equal to USD 218 million per year. Furthermore, including the other materials into the discussion the loss in monetary terms almost doubles with a total value of USD 424 million per year. Thereby, it has to be pointed out that especially the aluminium scrap contributes largely to this number. With an average specific export price between the year 2000 and 2014 of USD 1360 compared to only USD 328 for steel scrap, the significantly lower share in the material composition of the ELVs is balanced. This finding is important as the technology of lightweight construction within the automotive sector is utilizing more aluminium than the figures for the material composition of cars in 2000 indicate. Ducker Worldwide (2016) states, that the average aluminium content developed positively from fifty kilograms in 1990 to 140 kilograms in 2012 and it is expected to grow further and to hit the 170-kilograms mark by 2020. The numbers provided previously are, however, calculated with an aluminium content of ninety kilograms per ELV. Subsequently, one can argue that the quantity as well as the economic loss suffered by the EU´s scrap market initiated by the illegally exported scrap through ELVs will, if the unknown whereabouts remain steady, increase within the next years considerably.

Although many uncertainties exist about the various dimension affecting ELVs, it can be summarized that this issue has a strong influence on the domestic availability of scrap as a secondary raw material. The calculated numbers for the thirty percent scenario show a loss of almost one million tonnes of scrap per year that is equal to an economic value of roughly USD 420 million.

3.2 Aluminium Scrap Analysis

3.2.1 Development Export and Import Quantities

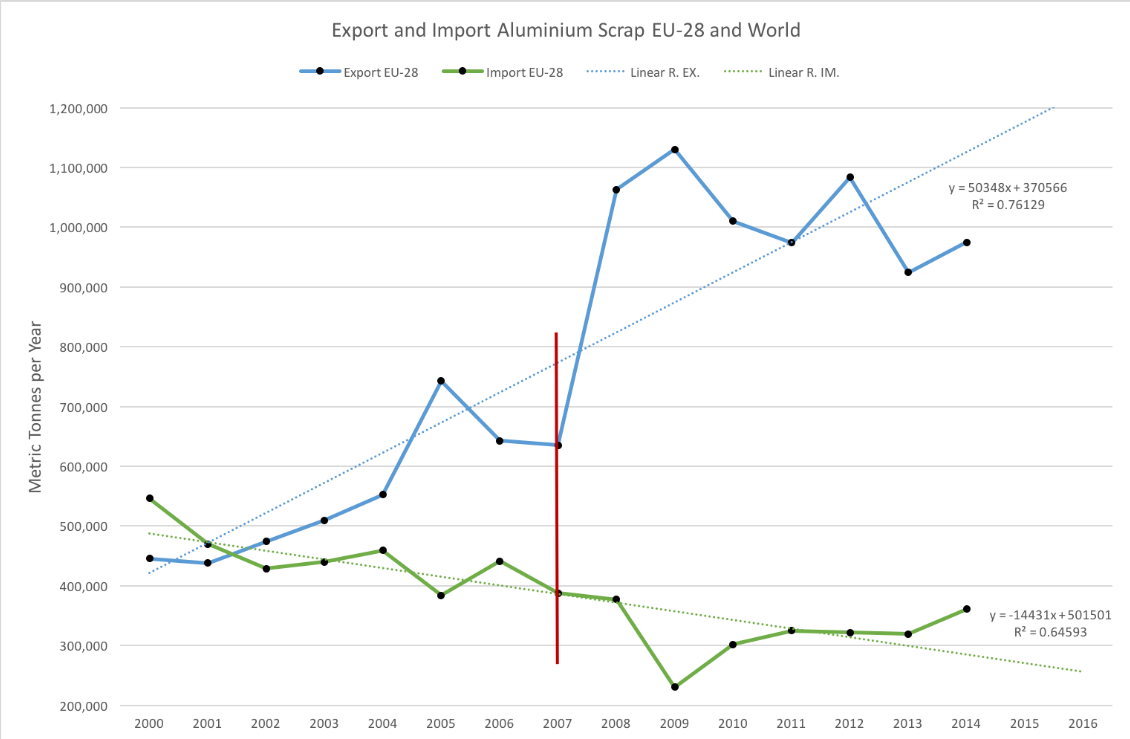


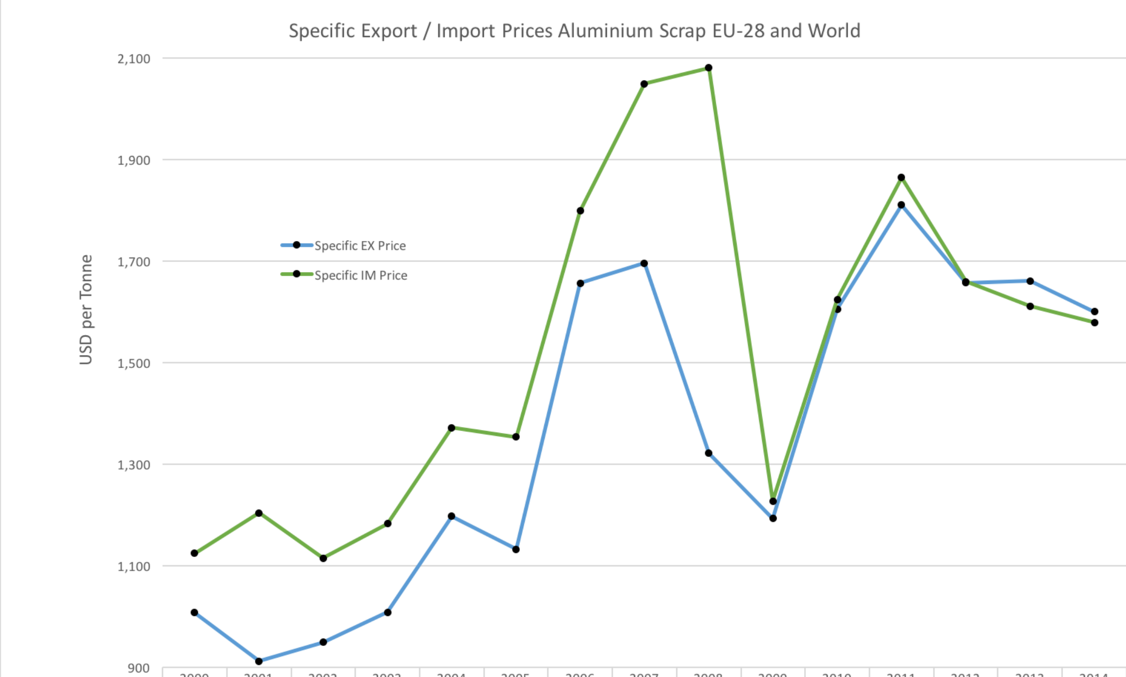
Figure 14: Export and Import Aluminium Scrap EU-28 and World, Data: UN Comtrade.

Figure fourteen depicts in- and outflows of aluminium scrap from the EU-28 and its global partners, EU Member States excluded, from 2000 to 2014. An analysis of the time series via linear regression offers a first estimate on the evolution of these figures in the course of time. Exports, defined by the linear regression equation $Yex = 50348X + 370\,566$ and a R^2-value indicating a determination of seventy-six percent, obtain a better approximation by this approach than the import function $Yim = -14431X + 501\,501$ and its coefficient of determination with a total below sixty-five percent. The explaining variable in this regression (X) is the passing time and the corresponding P-values indicate the zero hypothesis as not relevant.

The numbers for exports of aluminium scrap increased between 2000 and 2005 from 0.45 million tonnes to 0.74 million tonnes. The corresponding figures for imports behaved reversely and dropped from initially 0.55 million tonnes to 0.38 million tonnes respectively. After experiencing this interim peak, exports dived slightly till the year of the financial crisis in 2007. The probably most significant movement of both, export and import quantities, occurred right after the global economic crisis. Scrap metal shipments out of the EU-28 raised steeply from 0.64 million tonnes in 2007 to 1.13 million tonnes only two years later. This development is equal to a growth of more than seventy-five percent compared to 2007 levels. Then, aluminium scrap exports oscillated from the year 2009 to 2014. First, exports sank rapidly over a two-year period from 1.13 million tonnes to 0.97 million tonnes ensued by a one-year upturn to 1.08 million again. Subsequently, another decline was experienced to 0.92 million tonnes in 2013 succeeded by a final growth to 0.97 million tonnes one year later. Imports of aluminium scrap, however, plunged dramatically from 0.39 million tonnes in 2007 to hit solid bottom in 2009 with only 0.23 million tonnes of incoming scrap remaining. After reaching this all-time low, imports increased to just over 0.3 million tonnes in 2010 and then started to stabilize around 0.32 million tonnes.

Overall, the outstanding development of both mass flows is undoubtedly close to the year 2007. Before this date, exports increased steadily from 0.45 million tonnes to 0.64 million tonnes in 2007, with only the year 2005 as exception. In contrary, imported aluminium scrap quantities declined more or less constantly between the year 2000 and 2008 from 0.55 million tonnes to 0.38 million tonnes.

3.2.2 Change of Specific Import and Export Price



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Specific EX Price	1,007	911	949	1,008	1,197	1,132	1,656	1,696	1,321	1,193	1,605	1,811	1,657	1,661	1,600
Specific IM Price	1,124	1,203	1,114	1,182	1,372	1,354	1,798	2,049	2,080	1,227	1,624	1,865	1,659	1,611	1,579

Figure 15: Specific Export / Import Prices Aluminium Scrap EU-28 and World, Data: UN Comtrade.

This graph highlights the evolution of the specific import and export price for aluminium scrap between the years 2000 and 2014, valid for the EU-28. The export price started with a one-year decline from USD 1.007 to USD 911 per tonne in the observed period while its counterpart managed to increase from USD 1.124 to USD 1.203 per tonne in 2001. From this point, the figure for aluminium scrap exports grew constantly until 2004 where a value of USD 1.197 per tonne was reached. The import price suffered a small setback from 2001 to 2002 of seven percent, however, it begun climbing again until the level of USD 1.372 per tonne was reached in the year 2004. Starting with the year of 2005, an impressive upsurge for both indicators is illustrated. Within two years, the price for the export of aluminium scrap skyrocketed by roughly fifty percent or from USD 1.132 to USD 1.696 per tonne. During the same time period, 2005 until 2007, also the import price grew enormously from USD 1.354 to USD 2.049 per tonne. While latter remained more ore less on the achieved level one year longer, the export price dropped significantly from USD 1.696 to USD 1.193 per tonne between 2007 and 2009. In 2009 the specific import price followed this negative development and fell dramatically from USD 2.080 to USD

1.227 per tonne or respectively by forty-one percent within one year. Since then, both figures show a similar behaviour and remained within a tight range of absolute values compared to each other. They managed to increase their value to approximately USD 1.840 per tonne in 2011. From this point on, a steady decline can be displayed and in 2014 the import and export price was close to the USD 1.600 per tonne mark.

To sum up, both prices improved considerably from initially USD 1.007 per tonne for exports and USD 1.124 per tonne for imports to USD 1.696 and USD 2.046 per tonne in 2007. Then, the figures plunged massively to hit bottom at approximately USD 1.200 per tonne in the year of 2009. From this point, a recovery allowed an increase until 2011 a peak of USD 1.830 per tonne was reached. However, since then a downturn pushed the prices close to USD 1.600 per tonne mark in 2014.

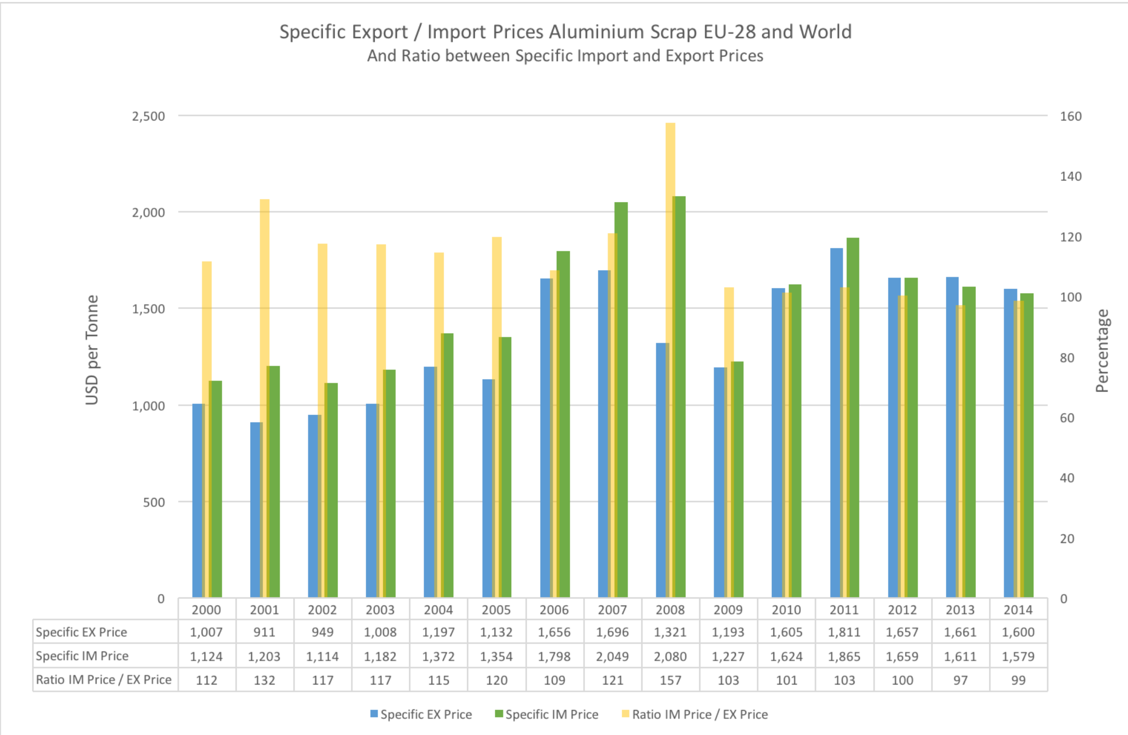


Figure 16: Specific Export / Import Prices Aluminium Scrap EU-28 and World and Ratio between Specific Import and Export Prices, Data: UN Comtrade.

This bar chart portrays the specific export and import price for aluminium scrap from the EU-28 and the ratio between import price and the price for exports. The data series illustrates that the ratio of import price to export price was fluctuating from the year 2000 until 2007 within the limits of 109 to 121 percent, with the year 2001 as an exemption where the 130 percent mark was broken. In 2008 the ratio peaked at almost 160 percent and from this point on the number dropped dramatically within one year and remained constant at around 100 percent until the end of the observed period. The development that the import price of aluminium scrap basically remained equal to the specific export price from 2009 until 2014 has to be emphasised. Especially since comparable results of copper and steel scrap within the same time range demonstrate different evolutions.

3.2.3 Discussion Traded Quantities and Related Prices

It can be noted that from the year 2000 onwards exports and imports of aluminium scrap developed contrariwise while the related specific prices behaved rather similarly in their evolution. The inverted correlation of the traded scrap metal flows can also be described by applying a linear regression. The outcome function, $Yim = 599.090 - 0.2754X$, $R^2 = 0.78$, P-value $= 0.000011$, suggests that a change of thousand tonnes in exported material triggers a decrease in imports by roughly 275 tonnes under ceteris paribus conditions.

Furthermore, the steady reduction of imports and the constant increase in exports of aluminium scrap allows the assumption that the interior market for aluminium scrap is subject to changes. Either the manufacturers of the EU-28 need less scrap or the domestic supply has increased. Therefore, the primary and secondary production of aluminium in the EU-28 is examined. However, it has to be pointed out that there is a major difference to the previously mentioned crude steel production. While both manufacture procedures for raw steel can be feed with steel scrap, the usage of recycled aluminium is only possible in the secondary production. Moreover, within the aluminium manufacturing there is a distinction between wrought aluminium alloy and cast aluminium alloy (Technische Universität Freiberg, 2005). Wrought aluminium alloy has much higher requirements towards the purity of the raw material. For instance, silicon content of less then three percent is obligatory for the fabrication of wrought aluminium alloy. Thus, up to twenty percent of primary or unwrought aluminium is added to produce these aluminium grade (Frischenschlager et al., 2010). According to Kranert (2017), scrap of aluminium usually contains more then the stated three percent of silicon. Hence, the secondary production with scrap as input is almost completely used to produce cast aluminium and no primary aluminium is required. Under consideration of this factual knowledge, the assumptions of a rise in supply of scrap or a decline in demand shall be demonstrated by elaborating on production data.

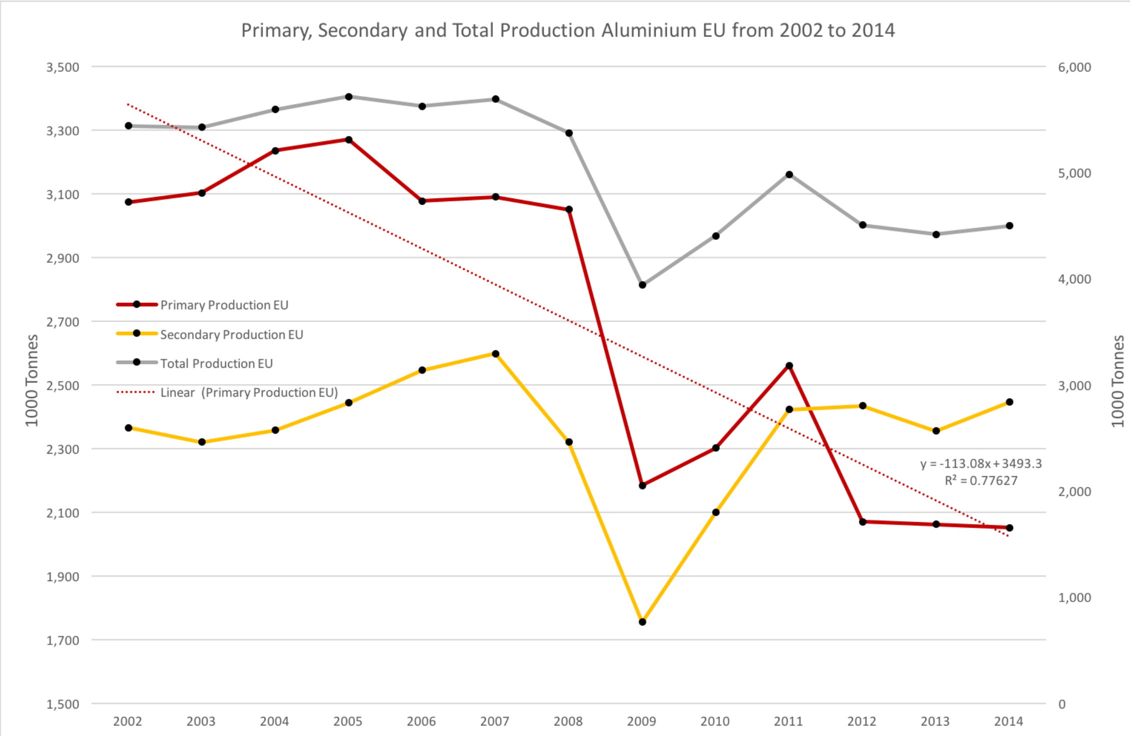


Figure 17: Primary, Secondary and Total Production Aluminium EU from 2002 to 2014, Data: European Aluminium.

Figure seventeen depicts the fabrication of aluminium in the EU from the year 2002 until 2014, differentiated by the production lane and additionally the total output of the sector related to the secondary axis. For the primary production a negative linear trend can be estimated. From the peak value in 2005, with a total primary aluminium fabrication of 3.3 million tonnes, the output level constantly dropped by a total of thirty-seven percent until it hit the two million tonnes mark in 2014. The result of a linear regression suggests that the interior manufacture of primary aluminium lowers by 113.000 tonnes per anno. This result can be supported if a closer look on the development of primary aluminium smelters is made. In 2002, twenty-six facilities for primary aluminium production were running business in the EU. Until the year 2010 this number fell to nineteen and in 2014 only sixteen factories remained producing primary aluminium (European Aluminium, 2016a). However, the data series for the second route illustrates a different trend. If the years shortly after the financial crisis in 2007 until 2011 are excluded from the observation, it can be noted that the level of secondary aluminium fluctuated between 2.3

million tonnes and 2.6 million tonnes. Hence, and since the literature suggest that aluminium scrap is merely used in the secondary aluminium production, it can be assumed that the demand for recycled aluminium did neither decrease nor increase substantially, with the exemption of the excluded time span.
Import quantities of aluminium scrap showed a negative trend and at the same time export figures demonstrated an extremely positive tendency. Therefore, the conclusion that the interior supply of aluminium scrap in the EU-28 must have increased substantially can be drawn.

Two possible assumptions relating to an increase in scrap could support this finding, namely higher recycling rates or higher semi-fabrication of aluminium products and generated waste thereof. Since reliable data for new scrap is easier to obtain, no end-of-life product such as old beverage cans are considered further. Thus, the focus is on the fabrication of unwrought aluminium for semi-production and the incidental scrap. But, as the interior primary unwrought aluminium production declined constantly over the whole observed period, these decrease in domestic production must have been substituted by increasing net-imports of unwrought aluminium to justify the assumption of enlarged scrap supply triggered by the semi-fabrication industry.

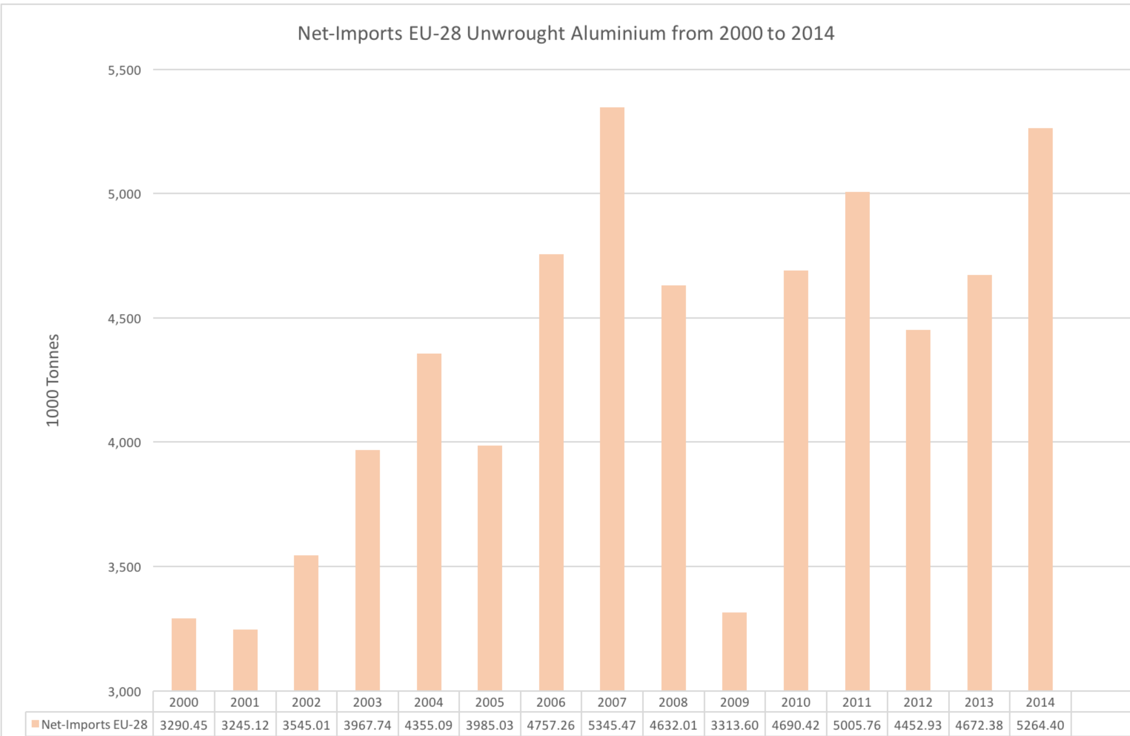
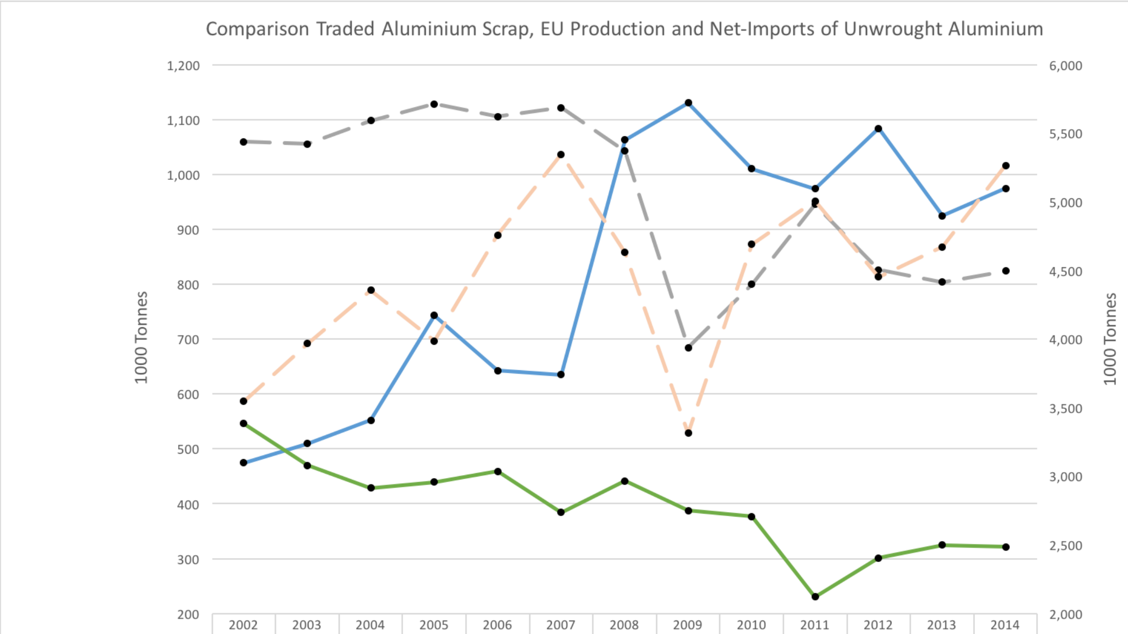


Figure 18: Net-Imports EU-28 Unwrought Aluminium from 2000 to 2014, Data: UN Comtrade.

Figure eighteen exemplifies the net-imports of unwrought aluminium from the year 2000 to 2014 between the EU-28 and the world. If the years between 2007 and 2011 are excluded in the reflection, as previously done in the course of the study of the secondary production of aluminium, a positive but not significant development can be noted. In 2014, net-imports of unwrought aluminium managed to approximate towards the all-time high of 2007 and only 1.5 percent were missing to surpass this peak. The next chart offers the opportunity to compare directly the net-imports of unwrought aluminium with the total production of the EU.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Export EU-28 Scrap	474	509	552	743	642	635	1,063	1,130	1,010	974	1,084	925	975
Import EU-28 Scrap	546	470	429	440	459	384	441	387	377	230	301	325	321
Total Production EU	5,438	5,422	5,592	5,712	5,622	5,687	5,370	3,938	4,400	4,982	4,504	4,416	4,496
Net-IM Unwrought AL	3,545	3,968	4,355	3,985	4,757	5,345	4,632	3,314	4,690	5,006	4,453	4,672	5,264

Figure 19: Comparison Traded Aluminium Scrap, EU Production and Net-Imports of Unwrought Aluminium, Data: Various Sources.

This line graph demonstrates the development of the combined EU production of aluminium, the net-imports of unwrought aluminium (both scaled at the secondary axis) and the material flows of scrap entering and leaving the EU-28 from the year 2002 and 2014. It has to be mentioned that from 2002 until 2007 the net-imports increased impressively from 3.5 million tonnes to 5.3 million tonnes while the local production of unwrought aluminium in the EU fluctuated around 5.5 million tonnes. Besides, the data series for the period between 2012 to 2014 supports the previously stated assumption of increased aluminium supply within the EU scrap market. While the domestic production of aluminium remained constant, the net-imports of unwrought aluminium managed to increase from 4.5 million tonnes to roughly 5.3 million tonnes. This positive trend suggests an increase of scrap due to semi-fabrication.

To sum up, the constant divergence of exported and imported aluminium scrap indicates a change in the domestic scrap market. First, a lower domestic demand could be responsible for this increase in net-exports. However, this assumption can be rejected since the secondary production of aluminium is the sole application for aluminium scrap and the output remained, with minor fluctuations, within the limits of 2.3 million to 2.6 million tonnes per year. Second, a change in the supply of scrap is a possible explanation for the surge in net-exports. Although the development of unwrought aluminium net-imports showed a gently positive trend and the related increase in scrap generation through semi-fabricated goods could be a relevant source for scrap, the illustrated data is a rather weak argument. However, if one considers the total production of the primary and secondary aluminium fabrication and the net-import of unwrought aluminium, the picture changes. Adding the mean value of 4.3 million tonnes of unwrought aluminium net-imports, calculated from the figures for the years 2000 to 2014, to the domestic production of combined five million tonnes on average, suggests that over 9.3 million tonnes of raw aluminium is processed in the EU-28 per year. If only ten percent of waste is produced by the different production techniques, already 930.000 tonnes of new scrap are created within one year. This figure would represent already roughly thirty-seven percent of the average scrap amount demanded by the secondary production of aluminium in the EU-28.

More likely though, is an increase in recycling rates or, more narrowly defined, a growth in old aluminium scrap availability. In Europe, for instance ninety percent of the used aluminium in the construction and automotive sector is recovered (European Aluminium, 2016a). If one considers the shift towards lightweight construction of cars in recent decades within the automotive industry, for example an increase of aluminium content for automobiles from fifty kilograms in 1990 to 140 kilograms in 2012 (Ducker Worldwide, 2016), the recent increase in aluminium scrap supply can be estimated. According to Eurostat (2017), approximately 6.2 million ELVs were officially registered within the EU-28 in 2014. If one assumes that this number is constant and the officially dismantle cars in 2014 had an average aluminium content of ninety kilograms, 0.55 million tonnes aluminium scrap were recovered. However, if the aluminium content is set to be 140 kilograms, this number rises up to 0.86 million tonnes. Therefore, this example is just one possibility which suggests that the stronger employment of aluminium in the automotive or construction sector impacts the scrap supply with a delay in time. Hence, the aluminium scrap stock will remain continuously increasing in near future.

3.2.4 Aluminium Scrap Flows

As mentioned in chapter 3.1.6, the material flow scheme of aluminium and aluminium scrap is closely related to the system of steel and steel scrap. Hence, no own illustration is provided but the material flow system in section 3.1.6 shows the complexity of the issue. However, to investigate the importance of exported scrap related to the interior production some data is discussed.

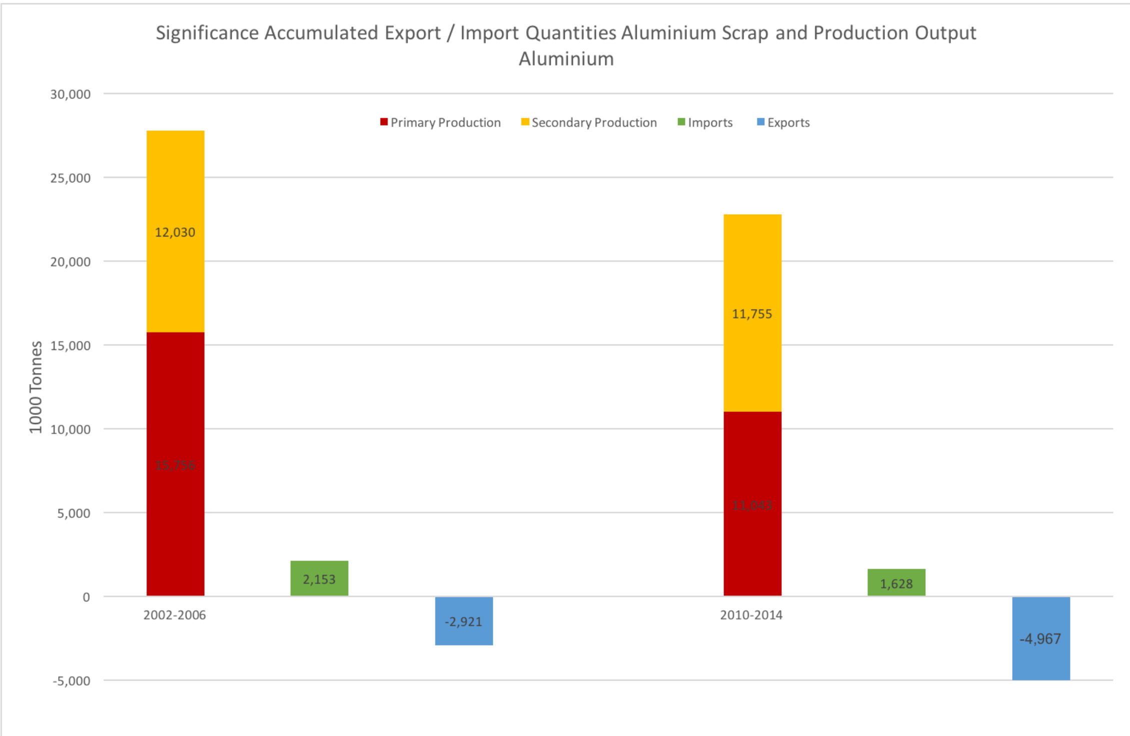


Figure 20: Significance Accumulated Export / Import Quantities Aluminium Scrap and Production Output Aluminium, Data: Various Sources.

Figure twenty explains the accumulated exports and imports of steel scrap between the EU-28 and the world and the total aluminium production of the EU-28. All flows and numbers from 2002 to 2006 and from 2010 to 2014 have been gathered while the years 2007-2009 were excluded since the market for aluminium and aluminium scrap did experience significant changes within this time range. The chart indicates that the exports of aluminium scrap developed extremely positive as they climbed by seventy percent while import flows were reduced by one fourth from the first to the second observed period. The records related to the production of aluminium suffered both a decline, primary production by almost thirty percent and secondary by two percent in the course of time. This evolution suggests that between 2010 and 2014 an oversupply of aluminium scrap did exist as the secondary production remained constant while the net exports quadrupled. Although the secondary route has substituted most probably some shares of the reduced primary production, aluminium scrap was still abandoned. However, it has to be noted that the specific export price for aluminium scrap suffered a massive drop within the years previous to this considered time range. Hence, some scrap dealers might have stocked their scrap and started selling again as soon as the price level recovered. But, as the accumulated exports have been compared to the summed flows of the years 2000 to 2006, during which the export prices skyrocketed by almost hundred percent, the four times higher net-export quantities are to high to be only the result of increased inventory destocking.

Besides, the ratio of net-exports of aluminium scrap related to the secondary production was six percent in period one and twenty-eight in period two. This finding is impressive and further supports the assumption stated in the previous chapter that a change in supply of the domestic scrap market occurred since the total output of the secondary production declined only slightly by two percent during the considered time ranges.

3.3 Copper Scrap Analysis

3.3.1 Development Export and Import Quantities

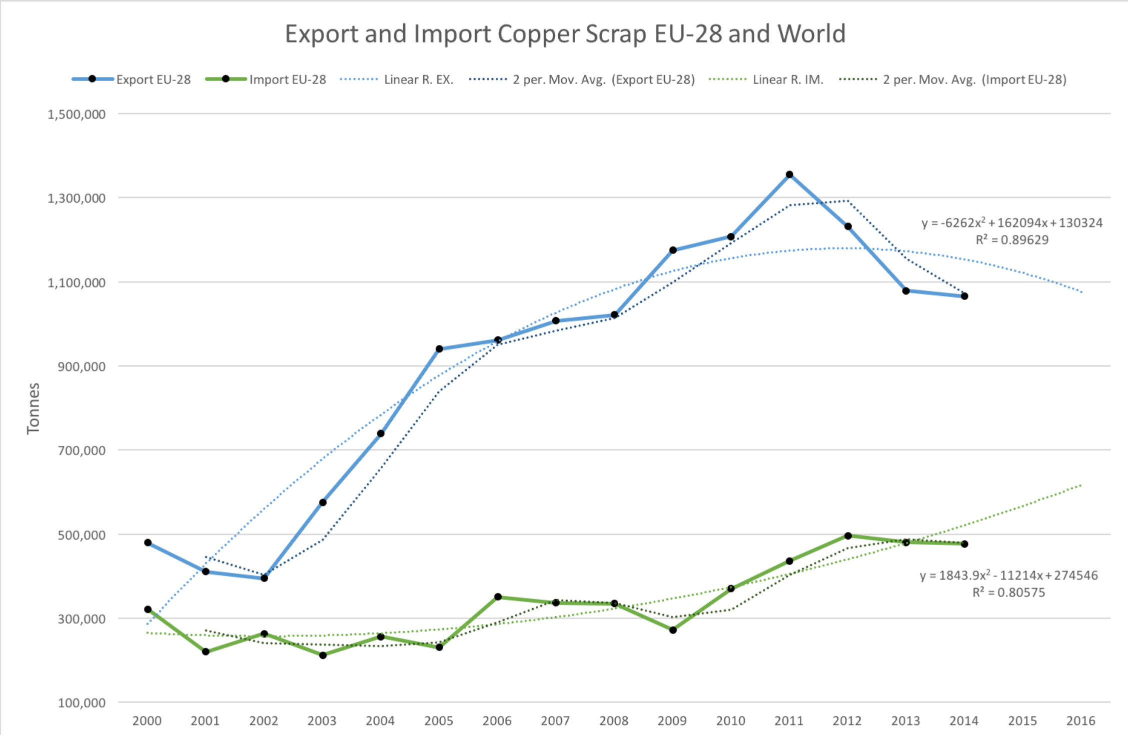


Figure 21: Export and Import Copper Scrap EU-28 and World, Data: UN Comtrade.

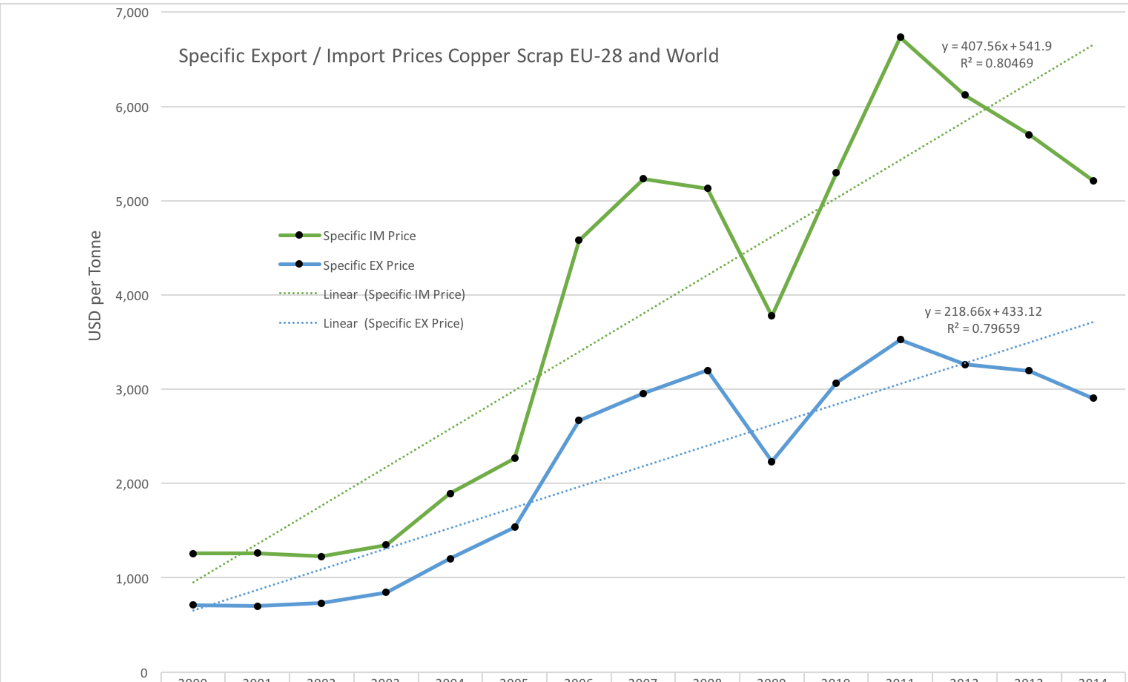
This chart demonstrates two main graph lines contrasting import and export quantities of copper scrap between the years 2000 and 2014 from the EU-28 to the world. Moreover, the result of the linear regression analysis on time dependency, $Yex = -6262X\text{^}2 + 162094x + 130324$ for the export data and $Yim = 1843.9X\text{^}2 - 11214X + 274546$ as function for imports, is depicted. In this case, the polynomial trend line offers significant results since the coefficient of determination is equal to ninety percent for exports and eighty-one percent for imports respectively.

Copper scrap exports started with a two-year decrease from 480.000 tonnes to approximately 390.000 tonnes in the observed period. In 2002 exports initiated to climb at a level of 390.000 tonnes until they reached a high of 940.000 million tonnes in 2005. During this time period the mean growth rate was close to thirty-tree percent. From this point, exports remained steadily increasing but at a slower rate and they peaked in 2012 with a total of 1,350.000 tonnes exported. This upsurge was followed by an impressive

downturn of roughly twenty percent within three years, or in quantities expressed, from 1,350.000 tonnes down to 1,070.000 million tonnes in 2014.
With regard to the development of the import figures, the graph indicates that the numbers oscillated from the year 2000 to 2009 between 350.000 tonnes maximum and 210.000 tonnes minimum. This stage of fluctuation was abolished in 2009 and three consecutive years of steady growth led to 500.000 tonnes of accumulated import of copper scrap in 2012. From this point, however, the development changed its direction again and a slight decrease in imports was experienced.

In summary, exports as well as imports of copper scrap increased from 2000 to 2012 but within different orders of magnitude. While import figures remained growing constant, exports suffered a substantial decline after the impressive surge from the year 2000 to 2011.

3.3.2 Change of Specific Import and Export Price



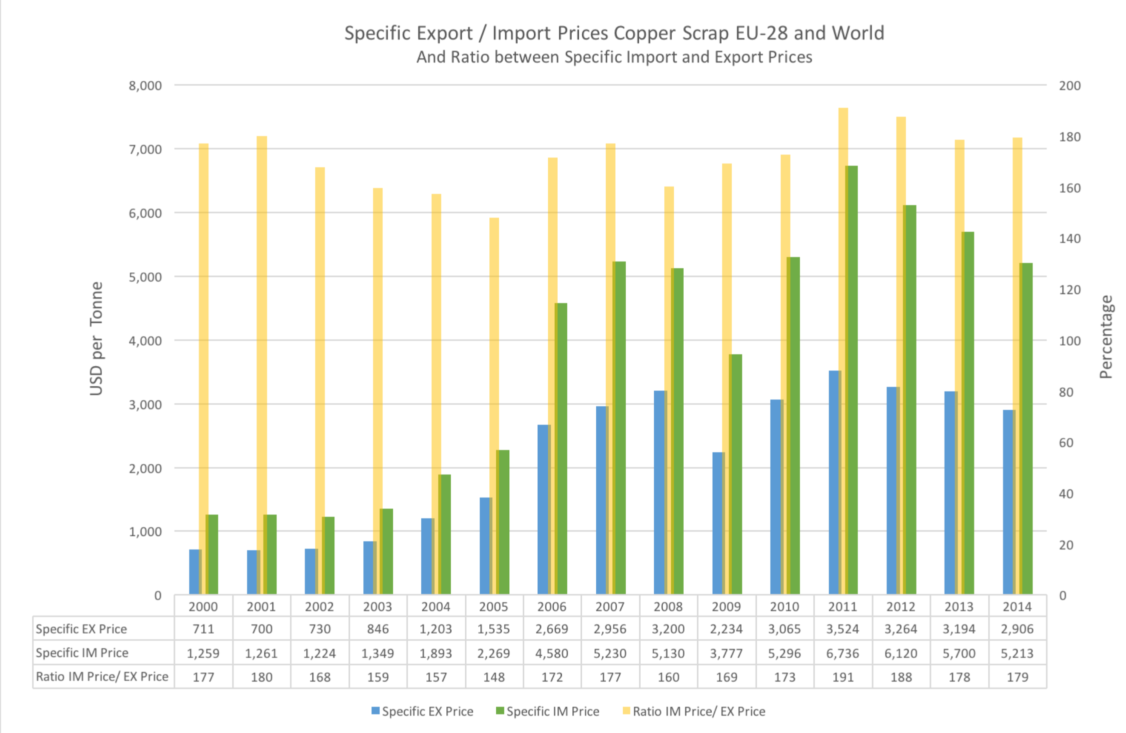
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Specific IM Price	1,259	1,261	1,224	1,349	1,893	2,269	4,580	5,230	5,130	3,777	5,296	6,736	6,120	5,700	5,213
Specific EX Price	711	700	730	846	1203	1535	2669	2956	3200	2234	3065	3524	3264	3194	2906

Figure 22: Specific Export / Import Prices Copper Scrap EU-28 and World, Data: UN Comtrade.

This line chart shows the development of the specific export and import price for copper scrap from the year 2000 to 2014 for the EU-28. Additionally, a linear trend is illustrated for both indices. The result of the linear regression on the course of time, $Yex = 218.66X + 433.12$ with an R^2 of roughly 0.8 and $Yim = 407.56X + 541.9$ and its corresponding R^2 of 0.8, proof a statistical linear relation between the price level and time. In this case, the coefficient of change for the import price suggests that it rises by almost hundred percent more as the export price per change of unit time.

Between the years 2000 to 2002 the import price and the export price remained on a constant level while former oscillated around USD 1.250 and latter nearby USD 710 per tonne. From this point they experienced a modest upturn until the import figure reached USD 2.269 per tonne and the export price USD 1.535 in 2005. Starting in 2005, the export indicator performed outstandingly and doubled to USD 3.200 in 2008. During the same period, the import price for copper scrap developed even more impressively and reached the USD 5.130 mark per tonne. Then, a setback during 2009 resulted in a decline of both prices until the import price endured at USD 3.777 per tonne and the export price at USD 2.234 per tonne. The following two years until the year 2011 the import figure surged remarkably by seventy-eight percent and it hit an all-time high of USD 6.736 per tonne. The price for copper scrap exported of the EU-28 increased too till 2011 and peaked at USD 3.524 per tonne. Then, both prices dropped again until the end of the considered period and in the year 2014 the prices level were at USD 5.213 per tonne for imports and at USD 2.906 per tonne for exports.

Overall, the specific price for trade in copper scrap increased dramatically until the year 2008. Next, a downturn was experienced by both indices lasting one year followed by a remarkable upsurge until 2011. From this point, a negative trend can be seen until the end of the examined time series.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Specific EX Price	711	700	730	846	1,203	1,535	2,669	2,956	3,200	2,234	3,065	3,524	3,264	3,194	2,906
Specific IM Price	1,259	1,261	1,224	1,349	1,893	2,269	4,580	5,230	5,130	3,777	5,296	6,736	6,120	5,700	5,213
Ratio IM Price/ EX Price	177	180	168	159	157	148	172	177	160	169	173	191	188	178	179

Figure 23: Specific Export / Import Prices Copper Scrap EU-28 and World and Ratio between Specific Import and Export Prices, Data: UN Comtrade.

Figure twenty-three illustrates the specific export and import price for copper scrap between the world and the EU-28 as well as the ratio between them from the year 2000 to 2014. Notable is, that the ratio has never fallen substantially below the 150 percent mark. This means that the price paid for imports is constantly 1.5 times higher than for exports. Besides, the all-time high of the ratio is in 2011 with 191 percent which is exactly the point where also the specific export and import price extended to their all-time high.

3.3.3 Discussion Traded Quantities and Related Prices

The phase from 2002 to 2005 shows a noteworthy development of the movements from copper scrap imports and exports and their related prices. The data series for the price levels show a similar increase of import and export values whereby former enlarged by eighty-five percent and latter ones could improve even better with a 110 percent upsurge compared to figures of 2002. The traded quantities, however, experienced a different progress. While imports of copper scrap fluctuated between 210.000 and 260.000 tonnes per year, exports increased steeply from 395.000 to 940.000 tonnes between 2002 and 2005. Under consideration of the supply and demand model, the extreme increase of the price indices must be triggered by a shortage of supply or an escalation in domestic or international demand for copper scrap during this period. Similar to the aluminum production two routes for raw copper production exist, whereby primary production is used for refining copper ore and the secondary production is feed with cooper scrap. However, it should be mentioned that in the cooper industry also semi-fabricators use new scrap for production. The data used for the figure twenty-four contain this aspect and for the data series of secondary production the output of copper from total scrap employment is applied. (ICSG, 2014) For further investigations, figures related to the European production are provided below. It has to be noted that the data for the copper production of the EU-28 was not available to the author. But, it is assumed that the industrial development within the European Union follows same movements as the whole of Europe. This assumption is supported by the fact that, according to the ICSG (2014), Poland, Germany, Bulgaria and Spain belonged to the the 20 top countries worldwide in terms of copper smelting but no other European country, except those mentioned Member States of the EU, were represented.

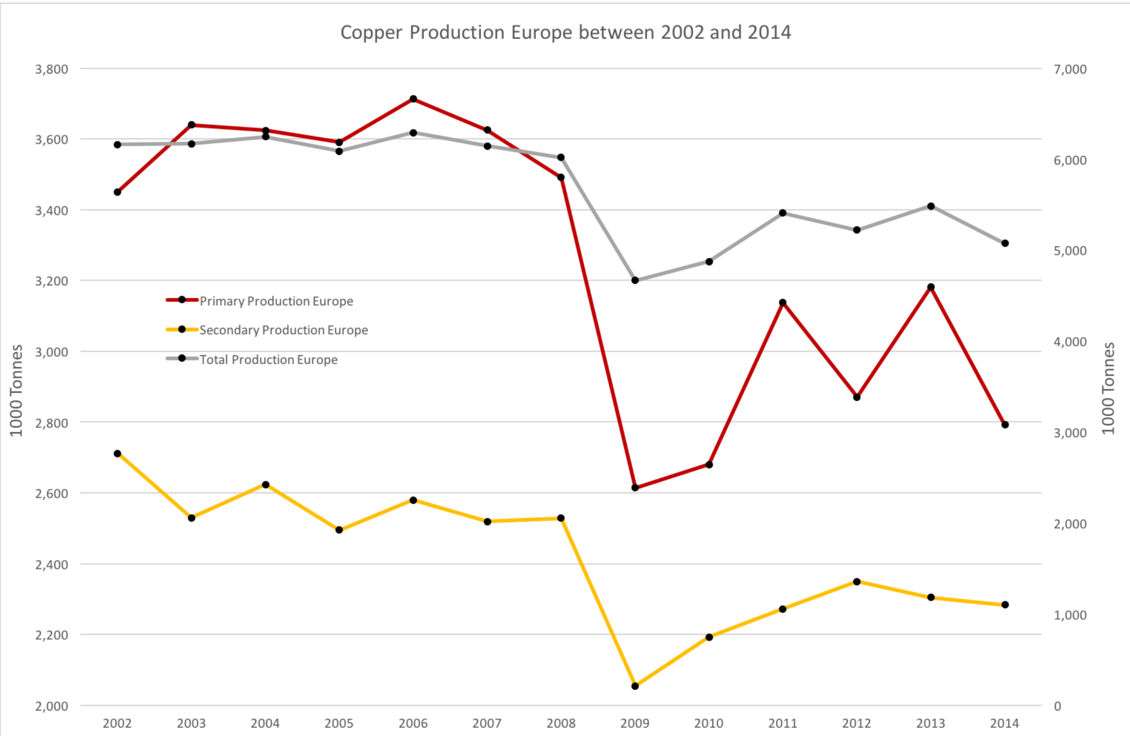


Figure 24: Copper Production Europe between 2002 and 2014, Data: International Copper Study Group.

This graph shows the output of the primary and secondary copper production industry in Europe between 2003 and 2013 and the total production related to the secondary axis. To analyze the points raised, particularly the yellowish colored data series, secondary copper production in Europe is of further interest. Between 2002 and 2005 the raw copper production via the secondary route decreased marginally by around eight percent. This is surprising, since during the same years the impressive growth in copper scrap export was experienced by the EU-28. Therefore, a relationship between scrap export and the internal demand for copper scrap seems to be not existent. Considering absolute terms, further support can be found. From the year 2002 to 2005 the output of the secondary copper production decreased from 2,700.000 tonnes to 2,500.000. Exports of copper scrap, however, doubled from 400.000 to 940.000 tonnes. So, if one would assume a relation amongst them, only 200.000 tonnes of increased exports can be explained, especially since the import figures remained on a constant level. Therefore, the assumption, established under the consideration of the demand and supply model, that domestic demand has risen from 2002 until 2005 and that this increase resulted in a surge of specific scrap prices can be rejected.

The domestic supply of copper scrap in this thesis is derived from the primary copper production and the semi-fabrication of copper. From 2002 until 2005 the primary copper production improved positively by four percent or from 3,450.000 to 3,590.000 tonnes. Therefore, the arising waste of copper might have improved too. This minor positive movement, however, is clearly not the origin for the massive increase in export of copper scrap. Even if one would combine the decline of demand related to the secondary manufacturing with the insignificant positive trend of the primary production and the resulting scrap generation, the numbers are not fitting. Hence, an insight to the trade in commodities for semi-fabrication of raw copper is provided to discuss further.

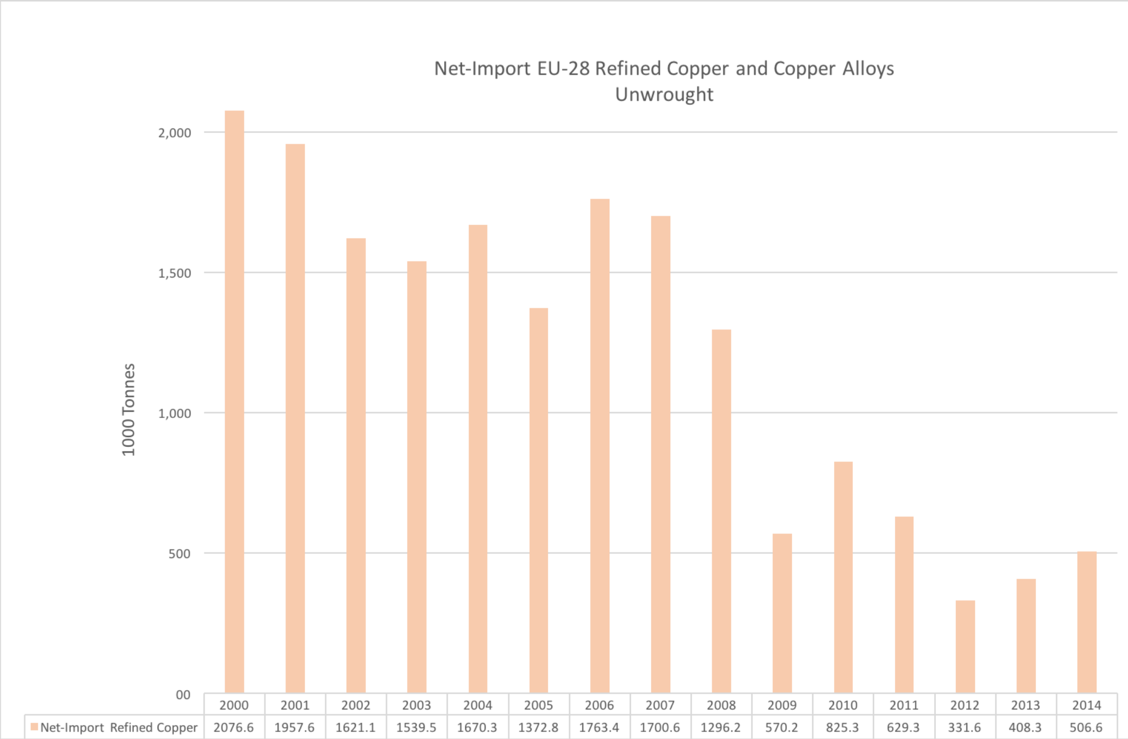
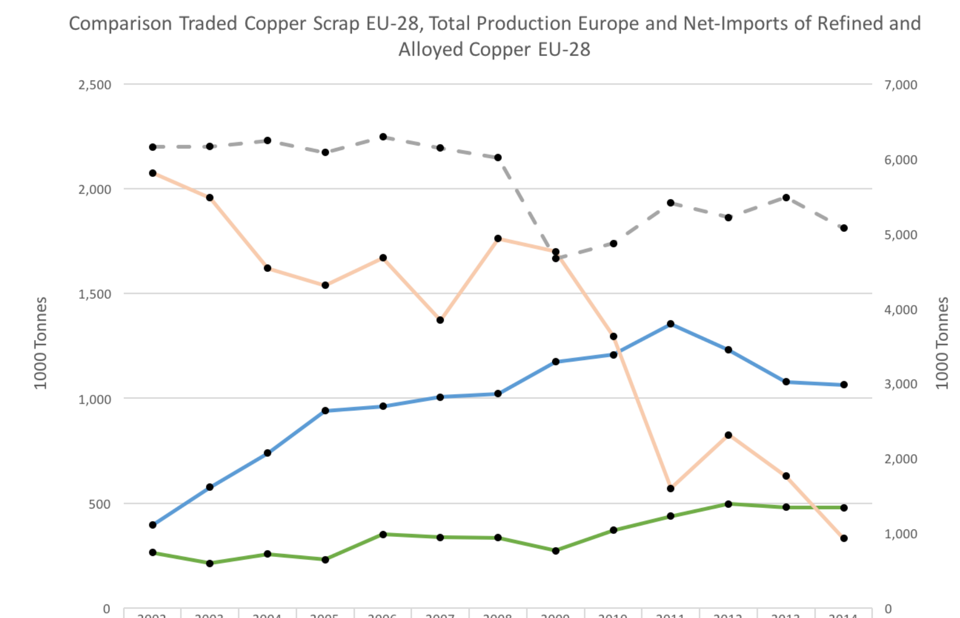


Figure 25: Net-Import EU-28 Refined Copper and Copper Alloys Unwrought, Data: UN Comtrade.

This illustration reviews the net-imports of refined and unwrought copper and copper alloys from the EU-28 between the year 2000 and 2014. Over the whole observed period the figures dropped dramatically to roughly one fourth of the levels of 2000. The relevant time range for the previous discussed issue, however, expresses a slight decrease with fluctuations from 1,620.000 tonnes to 1,370.000 tonnes. To sum up, there are no indications that the domestic supply of copper scrap has increased significantly from 2002 to 2005. Therefore the assumption that the change of domestic supply triggered the outstanding increase in scrap prices can be excluded.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Export EU-28 Scrap	395	576	739	940	961	1,007	1,021	1,175	1,208	1,355	1,231	1,078	1,065
Import EU-28 Scrap	263	212	257	230	351	337	335	272	370	437	496	480	477
Net-Imports EU-28 Refined Copper	2,077	1,958	1,621	1,539	1,670	1,373	1,763	1,701	1,296	570	825	629	332
Total Production Europe	6,161	6,168	6,248	6,085	6,293	6,144	6,019	4,668	4,873	5,410	5,220	5,486	5,076

Figure 26: Comparison Traded Copper Scrap EU-28, Total Production Europe and Net-Imports of Refined and Alloyed Copper EU-28, Data: Various Sources.

This line graph provides an overview of the traded copper scrap quantities between the EU-28 and the world combined with the net-imports of refined copper and alloyed copper as well as the total copper production of Europe related to the secondary axis. Remarkable is the negative trend of the net-imports of refined copper. The small increase from 2007 to 2008 excluded, this figure is declining over the whole observed period. Especially the years between 2009 to 2011 show a substantial drop from 1.7 million tonnes to 0.6 million tonnes only two years later. This evolution is an indicator that, next to the aluminum producing industry, also the copper-manufacturing sector is object to changes recently. However, within the discussed time range from 2002 to 2005 also the net-imports of refined copper dove by one quarter. Therefore, it can be implied that also the new scrap from the semi-fabrication has decreased.

As a result, the explanation left for the boost of the specific prices, under appliance of the supply and demand model, is that the external demand for copper scrap must have risen extremely. According to the ICSG (2010), the use of copper scrap within Europe decreased between the year 2002 and 2005 from 2,700.000 tonnes to roughly 2,500.000 million tonnes. In comparison, the world´s usage without Europe developed from

4,400.000 tonnes to 5,000.000 tonnes in 2005. These numbers support the assumption that the external demand for cooper scrap are the key factor for the increase in specific export and import price levels from 2002 to 2005.

For the sake of the completeness, it has to be mentioned that the different prices for copper scrap and copper is within different orders of magnitude than the figures for raw steel or aluminum. In the year 2008, before commodity price levels experienced a sharp drop, the world market price for aluminum was roughly USD 3300 per tonne and for copper USD 8700 per tonne. This circumstance, however, makes copper recycling very promising and it is an incentive to the secondary industry to use not just new scrap but also old scrap for the production of raw copper. Within the last decades, the End-Of-Live Recycling Rate which relates the actual recovered copper to the theoretical available amount, remained constant despite the increase in copper usage and the enhanced complexity of consumer goods which complicates recycling (International Copper Assosciation, 2014). This evolution suggests that the recycling industry is willing to invest a lot for the dismantling of these new and composite products to gain copper scrap.
Nevertheless, the available date does not explicitly mention the difference of old and new scrap employment. Moreover, the UN Comtrade Database is not offering any further classification of import and export flows that would allow a view on structural differences as it has been provided for steel scrap in section 3.1.5.

Besides, the extreme high copper scrap price might excite companies to stock copper scrap during periods of lower prices and dissolve them again as soon as the price has recovered. This circumstance could distort the assumptions made under consideration of the supply and demand model since in times of higher prices more scrap is made available. Nonetheless, a measurement of the impact of this stock piling is difficult to express. For instance, between the years of 2005 and 2008 the export quantities of copper scrap increased by around eight percent although the specific export prices boosted during this time range by 108 percent. This evolution would classify the previous mentioned impact as not significant. Another picture emerges if the time period from the year 2002 to 2005 is considered where both indices increased by over 110 percent. However, supporting evidence for this relationship comes from a linear regression analysis that explains the exported copper scrap quantities by the specific prices. The result of the regression with an R^2 value of 0.85 and a P-value of 0.000001 suggests that there is a significant bond between these figures. For import values, a conducted regression shows a slightly different result with an R^2 value of 0.70 and a *P*-value of 0.000085, but the relation is still statistically significant.

Another remarkable observation can be obtained if one has a closer look on the impacts of the financial crisis on the copper scrap market. Within the year 2008 the price of copper scrap imports and exports suffered a one-year decline of twenty-six and thirty percent respectively. The figures for related quantities, however, emerged differently. The exports of copper scrap experienced a steeper growth during this year compared to the years before. This observation contradicts the previously mentioned positive relation of availability of scrap and prices. However, it has to be considered that the financial crisis had a substantial impact on the global economy, what is perfectly expressed in the evolution for the figures of steel or aluminum scrap. Therefore, the noted companies, which stockpiled copper scrap, might have got alarmed of a possible further negative development of the price level and acted against the assumed pattern. On the other hand, imports of copper scrap dropped from the year 2008 to 2009 slightly, what is again against the implied relation between price levels and traded quantities. Overall, it can be said that the financial crisis has not affected the copper scrap market dramatically. The price levels recovered after this one-year decline very fast and the flows of scrap where more or less only minimally touched.

3.3.4 Copper Scrap Flows

The flow scheme of copper production and copper scrap is very similar to the steelmaking and related flows. Hence, a separate material flow system for copper is not within the scope of this work but to understand the complexity of the system one can look up the illustrations provided for steel and steel scrap in section 3.1.6.

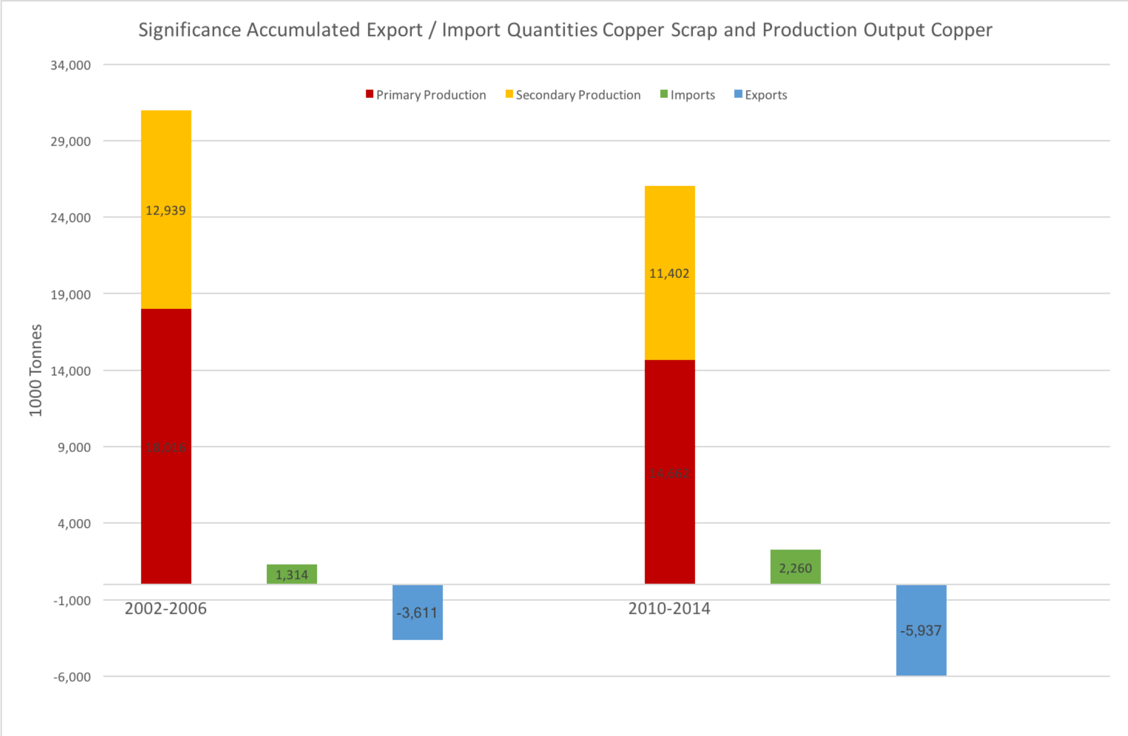


Figure 27: Significance Accumulated Export / Import Quantities Copper Scrap and Production Output Copper, Data: Various Sources.

Figure twenty-seven depicts the accumulated material flows of exports and imports of copper scrap between the world and the EU-28 for the years 2000 to 2006 and 2010 to 2014. In addition, the total production of copper within the EU-28 for the same time range is shown. From the first observed time period to the second, import quantities improved strongly positive by seventy-two percent and export figures by sixty-five percent respectively. The output levels for the copper production however, experienced a reverse trend. Secondary production declined by twelve percent between the first investigated period and the later one while the primary production level was reduced by nineteen percent. The ratio of net-exports of copper scrap related to the secondary production was during the first time range eighteen percent and during the latter one roughly thirty-two. This evolution is insofar remarkable since from 2002 to 2006 the secondary production declined, which explains the high percentage of net-exports. However, from the year 2010 to 2014 the secondary production increased and the net-export increased to the extend of almost one third of the output figures. This development suggests the obvious change of the copper manufacturing in the EU, especially of the semi-production sector.

4. Summary and Recommendations

The objective of this master thesis is to provide a contribution to the scientific discussion regarding the shift of Europe`s economy to a circular economy model, as promoted through the European Circular Economy Package implemented in 2014 by the European Commission. Since the success of a circular economy is highly dependent on the knowledge of the availability and distribution of commodities, especially for the recovery of potentially precious secondary raw materials, the focus of this work was directed towards the international trade with metal scrap and the European scrap market. The choice to investigate steel, aluminium and copper scrap flows entering and leaving the Single Market is easily explained by the strategic importance of these material for the economy, the almost perfect suitability for recycling and the intense energy and natural resource usage of the primary production industry.

Hence, four different research questions have been established and discussed in this work. In addition, and within the scope of question one, some specific developments, for instance the impact of the economic crisis in 2007 on the trade in scrap, have been elaborated. Moreover, illegal trade with End-of-Life Vehicles was investigated, as the loss in secondary raw material for the interior scrap market due to this illicit activity is substantial.

Q1: How was the dynamics of export and import of steel, copper and aluminum scrap between the EU-28 and the world from the year 2000 until the implementation of the European Circular Economy Package in 2014?

In connection with this research question, the elaborated data show dissimilar results for the different metals investigated. For steel scrap, a linear trend for export quantities and imports is shown and statistically proven whereby the export figures increased and import records decreased over the observed period (Chapter 3.1.1). Also the trade in aluminum scrap behaved similar to the data series for steel scrap but within different orders of magnitude (Chapter 3.2.1). Besides, the impact of the financial crisis resulting in an extreme increase of export quantities was reflected by aluminum scrap immediately and lasted only two years, while the boom in steel scrap export was delayed but continued over several years. Statistics related to the copper trade suggest a polynomial linear tendency and export quantities started to decline after peaking at the all-time high in the year 2011 while imports remain growing (Chapter 3.3.1).

Q2: How was the development of related specific prices and is there a difference in the structural composition of these material flows? Can mass flows be traced?

The specific prices for steel scrap have increased overall, however, with a one-year downturn in 2009 and a negative trend starting in 2011 until the end of the investigated time period. Furthermore, a correlation between them with a coefficient of 1.5 was found (Chapter 3.1.2). This difference in price of steel scrap could be proven to be mainly triggered by alterations in the structural composition of the scrap flows. While the imported steel scrap quantities show a stainless steel content between ten and twenty percent, the figures for their export counterparts are within the limits of one to five percent (Chapter 3.1.5). Nevertheless, for aluminum and copper scrap, the assumption that the structure of import flows contains high-graded scrap, which result in a higher price, cannot be proven. But it is strongly suggested by the constant higher level of the specific import price compared to the export price. The prices for aluminum scrap increased impressively and peaked in the year of the economic downturn in 2007. After this point specific prices plunged significantly within two years and managed to recover only 2011. Since then a constant decline can be seen (Chapter 3.2.2). Also the prices for copper scrap suffered a slight setback in the aftermath of the financial crisis after several consecutive years of growth. Specific copper scrap prices behaved similarly to the aluminum scrap prices and managed to even surpass their high of 2008 in the year 2011. However, from this point on they started weakening too (Chapter 3.3.2).

Furthermore, the tracking of the scrap flows is a highly complex and demanding task and therefore they cannot be traced easily. The material flow schemes in section 3.1.6 demonstrate these issues and illustrate why no satisfying solution is provided. Nevertheless, one of these material flows is investigated in this thesis, namely the dismantling and illegal trade of End-of Life Vehicles. Due to failure of tracing the deregistered cars within the EU-28 and different legislative regulations regarding the definition of ELVs, a huge amount of cars has unknown whereabouts. As a result, large quantities of various metal scraps are lost for the domestic scrap market. With the assumption, that thirty percent of the ELVs with unknown final destination, are neither dismantled by an authorized treatment facility nor legally exported, but exported illegally, the annual loss for the scrap market within the observed time frame is approximately USD 420 million per year. In tonnage, this number is equal to roughly 800.000 tonnes of steel and iron scrap, 90.000 tonnes of aluminum scrap and 17.000 of copper scrap (Chapter 3.1.6.1).

Q3: Is the order of magnitude of scrap export and import quantities significant for the production of unwrought steel, aluminum and copper within the EU-28?

To answer this question, two time frames within the whole observed period have been determined and figures accumulated. The first timeline was set between the years 2002 and 2006 and the second from 2010 to 2014. For steel scrap neither the former time range with a ratio of 2.5 percent amongst net-exports and production figures nor the latter one with a ratio close to 8.6 show a significance (Chapter 3.1.6). In order to make a statement on the impact of net-exports on the secondary aluminum fabricating industry, following numbers can be shown. In period I, the ratio between net-exports and secondary production were roughly six percent while these statistics climbed until period II up to twenty-six percent. Since this percentage is over one fourth of the total output of the secondary production, which is only run on aluminum scrap as input, one could assume that the traded material flows are significant (Chapter 3.2.4). For copper scrap the ratio between net-exports and the secondary production of period I was around eighteen percent and thirty-two percent for period II. However, within the observed time frame the net-exports seem to be not significant for the interior production of copper.

Q4: Which recommendations can be suggested considering the circular economy approach and the European Circular Economy Package?

The recycling industry is a crucial factor for the successful implementation of the circular economy in the Single Market. One key factor for the usage of scrap in the secondary production industry of raw metals is the grade of the scrap. The structural differences of the steel scrap exports and imports perfectly exemplify this issue. The percentages of higher graded steel scrap imported are much higher than their exported counterparts. Besides, a multiple price is paid for stainless steel than for usual steel scrap. Therefore, the European Union should promote the sorted disposal of scrap metals according to their special attributes to reduce the import of expensive high-graded scrap. Another key factor is the increase in recycling rates, one of the basic pillars of a circular economy approach. According to the rules of the demand and supply model, the domestic price of scrap will decrease if the recycling rates are surging and the demand remains constant. As a result, possibly, depending on development of the external market, prices paid abroad are much higher than within the European Union. Hence, scrap dealers might be tempted to export scrap to achieve higher revenues. This reaction to price differences, however, would clearly jeopardize the aim of a circular economy to keep the materials within the Single Market. Therefore, it is necessary to act on an intergovernmental level and impose some legislative measures. First, tariffs on export of scrap metal could counteract this evolution and keep the scrap within the domestic market. Second, the secondary production sector which uses scrap as their input could be subsidized. The final recommendation concerns the issue of unknown whereabouts of ELVs. Although, some legislative measures have been imposed on the European level, the subject of illicit trade and dismantling of ELVs has not been tackled successfully and substantial losses for the European scrap market are arising. One major step would be to eliminate national differences of classifications of used cars and ELVs.

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