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The Carbon Impact of Component Production in China: Investigating the Impact of Carbon Border Adjustment Policies for a Global Manufacturing Company

A case study

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Abstract

Title The Carbon Impact of Component Production in China: Investigating the Impact of Carbon Border Adjustment Policies for a Global Manufacturing Company?

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Contribution This thesis has been a complete elaboration between the two authors. Each author has been involved in every part of the process and contributed equally.

Background The thesis aimed to research the impact of the Carbon Border Adjustment Mechanism (CBAM) on Atlas Copco Industrial Technique's (ACIT) supply chain of components sourced from China. In addition, the aim was also to find accurate embedded emission data from the component manufacturing. ACIT is a multinational industrial company that provides industrial power tools and assembly solutions to various industries. The CBAM is a new legislation set to be implemented in 2023, obligating European companies within covered industrial sectors to pay for their emissions in third countries. By investigating this, the goal was to deliver a factual basis for strategic supply chain decisions based on the finding of the thesis.

Methodology Holistic single case study.

Purpose and Research questions This study aims to estimate embedded emissions in steel and aluminum components sourced from China and examine the impact of the CBAM on ACIT's upstream supply chain.

1. What is the weight of raw materials acquired by ACIT through component sourcing from China?
2. What are the embedded emissions of ACIT's sourced components from China?
3. Is ACIT in the scope of the CBAM, and what would be the impact of the legislation on the upstream supply chain?

Findings ACIT is not in the scope of CBAM and is not directly impacted by the legislation. If ACIT were to become part of the scope in the future, the monetary impact is deemed negligible and would not trigger any supply chain re-configurations as it stands. However, if the monetary impact would increase severely, ACIT needs to decide whether they should stay with the same suppliers and develop their manufacturing process into a less carbon-intensive process, or change to suppliers with less embedded emissions in their components. The author's recommendation in this case is to analyze which of the current suppliers is performing best in terms of carbon emissions and focus on extending the partnership with these suppliers. Thus, reducing the risk of new partnership creation in the supply chain, and minimizing the risk of disrupting the supply chain.

Keywords Carbon Border Adjustment Mechanism, CBAM, EU ETS, Embedded emissions, Steel and aluminum manufacturing in China, Sourcing.

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List of Abbreviations

ACIT Atlas Copco Industrial Technique

CBAM Carbon Border Adjustment Mechanism

ETS Emission Trading System

EU European Union

EGD European Green Deal

UoA Unit of Analysis

ASO Asian Sourcing Office's

WBS Work Breakdown Structure

SCM Supply Chain Management

SC Supply Chain

VMI Vendor Managed Inventory

MT-SSCM Multi-Tier Sustainable Supply Chain Management

ICT Information and Communication Technology

TCO Total Cost of Ownership

DRI Direct Reduction Iron

BF Blast Furnace

BOF Basic Oxygen Furnace

EAF Electric Arc Furnace

ISO International Organization for Standardization

GHG Greenhouse gas

CN Combined Nomenclature

WTO World Trade Organization

SMA Simple Moving Average

CNC Computer Numerical Control

SaaS Software as a Service

QDCPS Quality, Delivery, Cost, Product- and process development, and Sustainability

RFI Request for Information

RFQ Request for Quotation

KPIs Key Performance Indicators

1 Introduction

This section will present the background, the purpose of the study, and the chosen research questions. Additionally, it will describe the focus and delimitations to limit the scope of the study. The aim is to provide a comprehensive overview of the research topic.

1.1 Background

The climate crisis and its consequences are casting a shadow across the globe, darker by the day. Many countries, companies, and even industrial sectors are progressing toward minimizing their climate impact, however, the transition needs to be ramped up. Currently, there are several actions taken to rapidly mitigate the increasing carbon emissions, such as the implementation of legislative emission reduction targets and carbon pricing mechanisms. These regulations and legislations incentivize companies to get an understanding of their carbon footprint and how their supply chain is producing emissions.

The European Commission has decided to implement such legislation in 2023, making European companies within the covered industrial sectors obligated to pay for their emissions in third countries - and it's called the CBAM (European Commission 2021*b*). The aim of the CBAM is to encourage European Union (EU) importers to increase their supply chain transparency and to push for greener production in every tier of the supply chain, i.e. making every part of the supply chain, from raw material to finished goods, more sustainable.

Many speak of the new legislation in a restrictive manner, as it is still subject to changes. However, the possibility to assess the impact of the legislation in a practical setting is already possible. Trade legislation can significantly influence a company's global supply chain management as it governs all of the movement of goods and services across borders and between companies. The CBAM could have several direct impacts on a global supply chain, including *increased costs*, new *compliance requirements*, *supplier selection* evaluation, and a *sustainability strategy.* These are all factors that a company would have to evaluate in order to maintain an effective supply chain (Xu et al. 2017).

This thesis is a case study, researching the legislation's impact on ACIT. The primary objective is to understand **if**, and **how**, the legislation will affect the company's supply chain of components from China and to deliver a factual basis from which strategic supply chain decisions can be taken (*The case is limited to China although ACIT sources from several more countries outside the EU, due to time constraint*). Moreover, the aim is also to find the emissions linked to ACIT's steel- and aluminum component sourcing from China. By upstream mapping the supply chain of components, the goal is to go beyond available emission averages and through synergies with ACIT's suppliers find accurate emission data. This will not only help ACIT become more aware of its situation but also be used to assess the impact of the CBAM if ACIT is, or were to be in the near future, in the scope of the legislation.

1.1.1 Atlas Copco AB

Atlas Copco is a multinational industrial company with an active presence in over 180 countries. It was founded in 1873 in Stockholm, Sweden, and has since then grown steadily to an organization of over 40 000 employees. Atlas Copco AB is listed on the Stockholm Stock Exchange, currently having the 4th highest market value of all listed Swedish companies at 608B SEK.

An innovative mindset has driven the company throughout its history, resulting in several active business areas. These business areas have grown and are now their own entities within the Atlas Copco conglomerate. The business areas are; **Compressor Technique**, **Vacuum Technique**, **Power Technique**, and **Industrial Technique**. As previously stated, this thesis is written for *Atlas Copco Industrial Technique* ACIT.

ACIT is specialized in providing industrial power tools, maintenance software, and assembly solutions for manufacturing industries. ACIT offers several product categories, for example electric-, battery-powered, and pneumatic tools, and assembly solutions such as connected nut runners and adhesive dispensers. Historically, advanced hardware technologies have been the unique selling point of ACIT, however, the upcoming software and service solutions providing optimized efficiency, fault-proof production, and improved production processes are on the rise. The customer base is wide, with industries such as automotive, aerospace, energy, and other general industries all in need of these tools and assembly solutions. With a focus on innovation and sustainability, ACIT is a leader in the industrial tools and assembly solutions market.

1.1.2 CBAM - Carbon Border Adjustment Mechanism

In 2003 the European Parliament and the Council of the European Union presented directives regarding the establishment of an Emission Trading System (ETS) (European Commission 2003). It was launched in 2005 with the aim to reduce emissions to meet the targets of the Paris Agreement.

Since then, the European ETS has developed significantly, and in 2019 the European Commission introduced the European Green Deal (EGD) to further tackle the climate challenges. The goal of the new strategy was to reduce greenhouse emissions by 55% (compared to 1990) as well as be completely climate neutral by 2050 (European Commision 2019).

To meet the targets, one of the first propositions by the European EGD was the introduction of a Carbon Border Adjustment Mechanism (CBAM) to create an additional toolbox for the EU to meet the set targets (European Commission 2021*b*).

The main objective of the mechanism is to mitigate carbon leakage, which occurs when companies relocate their production to third countries with weaker climate policies to avoid carbon pricing or emissions regulations. CBAM works by applying a carbon price connected to the imported goods, and the size of this tariff is based on the emissions embodied in the production of those goods. EU is confident that this mechanism will prevent domestic industries from being at a disadvantage compared to foreign competitors that do not face similar carbon pricing or emissions regulations. In other words, it will reduce the inequality in CO_2e costs between the European actors and actors in third countries (Korpar et al. 2022). The following goods are currently in the scope of the CBAM: iron and steel, cement, fertilizers, aluminum, electricity, and hydrogen.

As Korpar et al. (2022) also explains that an additional objective of the mechanism is to level the playing field for producers within the EU by enhancing their competitiveness.

1.2 Problem formulation

Even though sustainability and supply chain transparency has been on the radar for a long time at ACIT, the EU decision of enforcing the CBAM pushed the interest of a thorough investigation of the sourcing of affected components.

This thesis is an investigation of the steel- and aluminum components sourced from China, and how they have been affected by the new carbon-related border adjustment mechanism.

However, this is not only viewed as a financial case but rather a strategic business and information case. ACIT sees this as an opportunity to map their supply chain upstream and the information connected to each component of each tier of the supply chain to get a better understanding of the embedded emissions in their outsourced production, as well as a chance to make strategic choices based on more accurate data than before. As the industry leader, they believe this will push both the company and its partners forward toward a more sustainable industrial production technique.

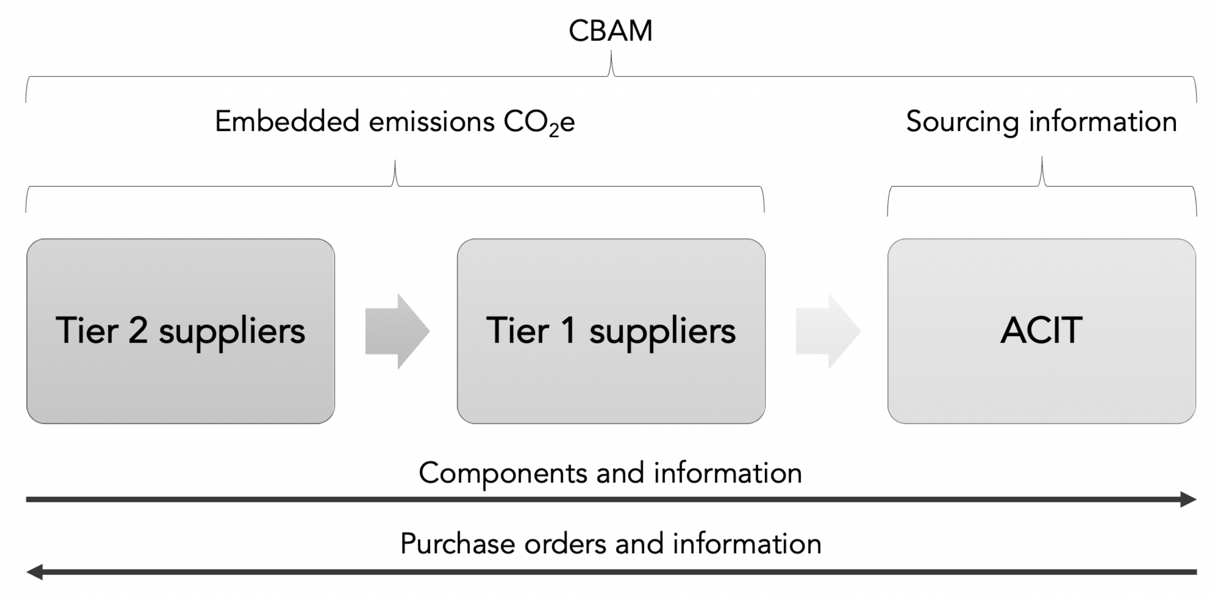


Figure 1.1: Overview of the thesis' investigated areas (*Source:* authors).

1.3 Purpose

This study's purpose is to estimate embedded emissions in steel and aluminum components sourced from China and examine the impact of the proposed Carbon Border Adjustment Mechanism (CBAM) on ACIT's upstream supply chain.

1.4 Research questions

In order to fulfill the purpose of the thesis, several research questions need to be answered. First, the total amount, or weight, of each raw material in ACIT's components sourced from China is needed. This information will enable a calculation of the emissions based on weight, which in turn can answer the impact of CBAM. Second, the embedded emissions in the raw materials used by ACIT's suppliers are needed. This will be based both on accurate emission data from suppliers and through research of the most common steel- or aluminum production methods of the area and the emissions linked to that production method. Third, an investigation of whether or not ACIT fits into the scope of the legislation. If ACIT is **not** currently in the scope, a theoretical analysis of the impact of the legislation would be will be conducted, as the European Commission has stated that more companies and industrial sectors will be included in the legislation in the future.

Concatenating the three steps above resulted in the following three research questions:

1. What is the weight of raw materials acquired by ACIT through component sourcing in China?
2. What are the embedded emissions of ACIT's sourced components from China?
3. Is ACIT in the scope of CBAM, and what would be the impact of the legislation on the upstream supply chain?

1.5 Focus and delimitations

The following sections illustrate boundaries and focus points in the thesis which might not be obvious. Focus areas are subjects or parts of the research that are crucial or of extra interest, and delimitations are boundaries of the research that ensures the research's timeline and conciseness.

1.5.1 Focus areas

1. Steel- and aluminum components sourced from China.
2. The emissions (Scope 1) linked to the production of steel or aluminum components in China.
3. Current suppliers (Tier 1 and Tier 2) of Atlas Copco Industrial Technique (ACIT).
4. The new CBAM legislation introduced by the EU.
5. How trade regulations impact supply chain decision-making.

1.5.2 Delimitations

1. We will not consider scope 2 or scope 3 (indirect) emissions as they are not covered by the CBAM.
2. As of a certain date (**05-04-2023**) we will not take any further updates of the CBAM legislation into account to ensure the thesis deadline.
3. The focus of the thesis is to gather as much information as possible and present it rather than reaching a strategy for the company going forward.
4. A theoretical analysis of the impact of CBAM will be made if ACIT is not yet in the scope of CBAM.
5. The thesis will only evaluate key suppliers, i.e. spot-market purchases or small businesses will not be dealt with.
6. The thesis will only take the direct impact of CBAM into account i.e. overhead costs and increased indirect costs from suppliers will not be investigated.

1.6 Target audience

There are two different target audiences for this master thesis. The first target audience is ACIT's operations and sustainability department. The operation and sustainability department covers several affected entities such as sourcing, supply chain management, trade compliance, etc. As all of these areas might be affected by the legislation, the result of the research will be of interest to them and will be shared both via the thesis and via a presentation of the study. The second target audience is members of the Division of Engineering Logistics at The Faculty of Engineering at Lund University. The research is based on a supply chain management perspective and is ultimately the author's final part of their master studies within engineering logistics and supply chain management.

1.7 Outline of the thesis

The thesis is structured into several different parts, each contributing differently. The different parts are presented below with brief explanations of each segment's contribution.

1. **Introduction** - Introducing the subject of research and the case company. Research questions, purpose, and focus and delimitations are presented to frame the thesis. The targeted audience and an outline of the thesis are also presented.

2. **Methodology** - Portrays how the study was conducted, from conceptualizing to finished analysis.

3. **Literature Review** - Creating a frame of reference based on previous knowledge that is available. As this thesis investigates a new legislation, this part is extensive to make sure that no part of the information is lost.

4. **Empirical study** - Information and data gathered from the case company needed to execute the analysis. Gaps found in the literature review will hopefully be filled in this chapter.

5. **Analysis** - Using the knowledge found in the literature review and empiricism chapters, an analysis of the case was conducted.

6. **Conclusion** - Conclusions based on the result of the analysis.

7. **Discussion** - Discussing the final result and its validity, and the contribution of this thesis and the opportunities that lie in this field.

2 Methodology

The following chapter will introduce the chosen type of study and how each step was conducted. The aim is to ensure that any researcher following the methodology would reach the same conclusion as the thesis'.

2.1 Systematically choosing the type of study

Based on our purpose and research questions, the research onion (Saunders et al. 2007) was chosen to systematically identify the type of study. The researched subject in this thesis can be studied from various angles, thus, a framework for finding the correct approach, study method, and techniques was needed. Saunders et al. (2007) mentions the *"research onion"*, a framework that systematically guides the user towards the correct form of study based on the different layers in the "*onion*". In other words, the idea of the onion is that by peeling off the layers, i.e. answering sub-questions regarding the phenomenon of study, one will slowly reach the core of the research methodology. The journey to the core acted as the guide for the research method.

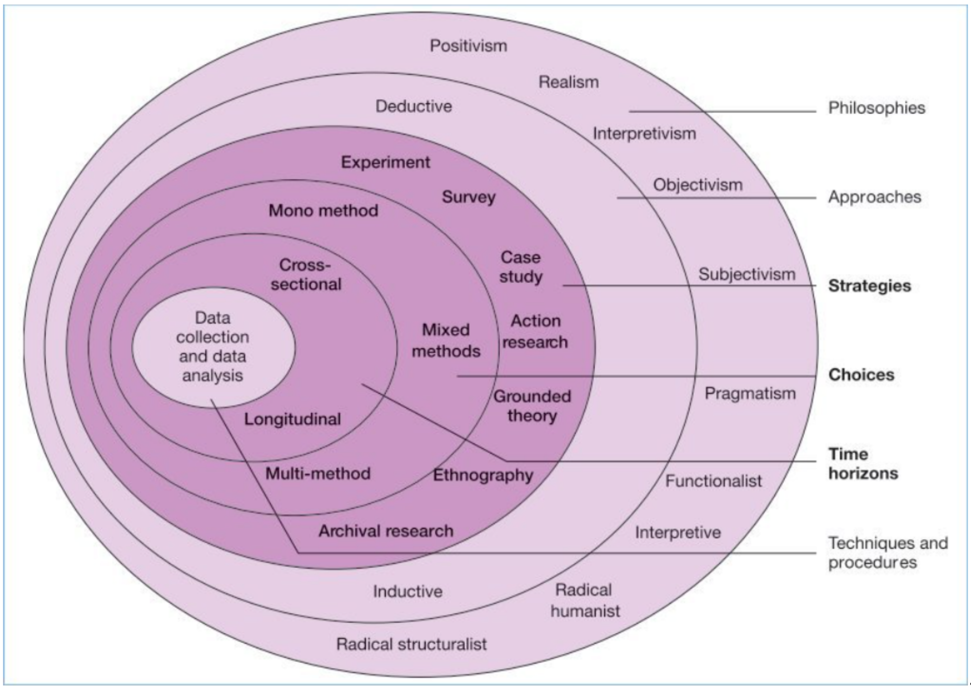


Figure 2.1: The research onion (Saunders et al. 2007).

As seen in Figure 2.1 the framework covers several aspects of scientific research. It takes the research's philosophy, approach, strategy, method choice, time horizon, and techniques into account, logically aiding the researcher when constructing a methodology. Therefore, the framework presented by Saunders et al. (2007) laid the foundation of this thesis methodology, and each layer of the "*research onion*" is covered in the first part of the methodology chapter.

2.1.1 Research philosophy

Research philosophy refers to the overarching mindset of the researchers and how knowledge - especially the development of new knowledge - is conveyed. When embarking on a research journey, no matter the size of the project, the aim is to develop new knowledge within a certain field. The adopted philosophy contains assumptions and information on how the researchers view the world, impacting the newly formed knowledge. Thus, it is important that the philosophy is acknowledged to mitigate the biases and increase the legitimacy of the outcome.

There are three major schools of thought when it comes to the philosophy of research: epistemology, ontology, and axiology (Saunders et al. 2007). All three have subcategories, however, this thesis is of **epistemological** nature. There are three kinds of philosophies under the epistemology umbrella: positivism, realism, and interpretism. As this thesis relies on information that is both qualitative and quantitative, i.e. data that is both of positivistic- and interpretistic character, it will follow a **realistic philosophy**. More specifically, the thesis will follow a **critical realist's** philosophy. A critical realist acknowledges that there are deceptions in data, i.e. that we as human researchers can interpret something in one way while its actual state is something different. This is the preferred philosophy for managerial cases as it leaves room for the possibility that things can, and will, change.

2.1.2 Research approach

During the initial stages of the research project, one must decide on a path toward theory development. There are two main approaches used in scientific research today, the **deductive** approach and the **inductive** approach, see Figure 2.2 (Saunders et al. 2007).

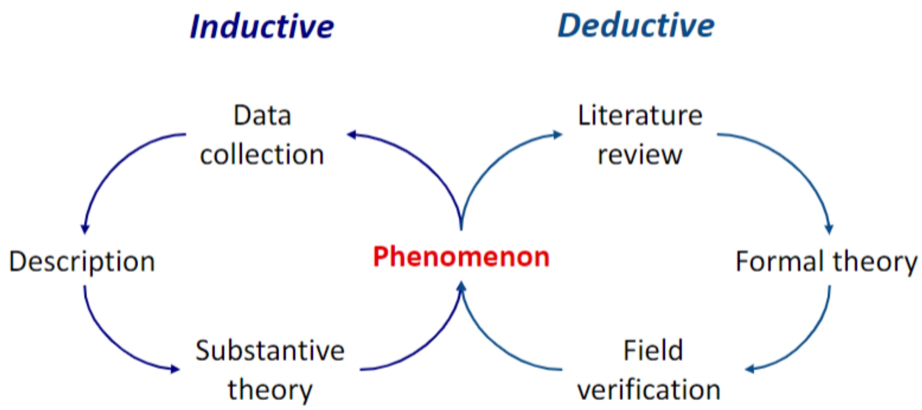


Figure 2.2: The processes of different approaches (Woodruff 2003).

However, there is a possibility of combining the two approaches, using a balanced approach, i.e. **abductive** approach. The abductive approach goes through both loops displayed in Figure 2.2 and according to Saunders et al. (2007) it is often the most advantageous approach. This thesis will follow an *abductive* approach as the gathering of quantitative and qualitative data will transpire simultaneously to the theory building - based on previous studies and literature. Using this approach will hopefully result in a theory that has a foundation in the data collection of the phenomenon and is backed by previous research. Moreover, the approach also goes in line with the *realistic* philosophy of the study.

2.1.3 Research strategy

After deciding on a philosophy and an approach for the research, the next step was to design a research strategy that transformed the research question into a research project. Saunders et al. (2007) states several different types of research strategies such as experimental, survey, case study action research grounded theory, ethnography, and archival research - all displayed in layer three of the "*research onion*" (Figure 2.1).

To decide research strategy, a framework from Yin (2018) was used (*see Table 2.1*). The framework has its starting point in the research questions and the purpose of the thesis but also takes the data handling and collection method into consideration.

Method	Form of Research Question	Requires Control Over Behavioral Events	Focuses on Contemporary Events
Experiment	how, why?	yes	yes
Survey	who, what, where, how many, how much?	no	yes
Archival Analysis	who, what, where, how many, how much?	no	yes/no
History	how, why?	no	no
Case Study	how, why?	no	yes

Table 2.1: Relevant situations for different research methods (Yin 2018).

Applying the framework to this thesis and making an analysis of the different strategies, it was concluded that a **case study** fits this thesis best. A case study's primary objective is to answer the "how?" and "why?" questions, and does so by dissolving the borders between the studied phenomenon/process and the environment in which it is being studied (Yin 2018). The research questions of this thesis are how- and why questions (1.4) asked about a contemporary set of events over which the researchers have little control - fully matching with the definition of a *case study research strategy* (Yin 2018).

Furthermore, a combination of data collection methods was used, aligning with the characteristics of a case study. A rich understanding of the context and the processes within it was gained by triangulating the data from different sources, ensuring that the conclusion was aligned both quantitatively and qualitatively (Yin 2018, Saunders et al. 2007)

Multiple-case versus single-case

When pursuing a case study the researchers had to distinguish the type of case study that the thesis will follow. As Yin (2018) stated, both multiple-case and single-case studies are research strategies, designed differently, but with the same methodology framework.

Since this case will revolve around one organization, ACIT, a single-case study is the chosen approach for this thesis. The single-case study is characterized by focusing on the details of a researched subject concerning a single group, organization, or event. In comparison to multiple-case studies, a single-case study provides a more in-depth analysis of the phenomenon which allows us to examine more complex cases in a specific setting (Yin 2018).

Unit of Analysis

There are two types of single-case studies according to Yin (2018): *holistic* and *embedded*, depending on the **unit of analysis**. The difference between the two types is that the holistic approach investigates a single unit of analysis, while the embedded approach investigates multiple units of analysis within a single case. The holistic single case study aligned with the research purpose and questions best as the research only analyzed a single unit, and was, therefore, the chosen study type.(Yin 2018).

The chosen unit of analysis Unit of Analysis (UoA) for the holistic single case study was:

> ***The Carbon Border Adjustment Mechanism's impact on ACIT's upstream supply chain of steel- and aluminum components from China.***

To clarify the UoA, the graphic showing the problem formulation (1.1) was extended to show the UoA.

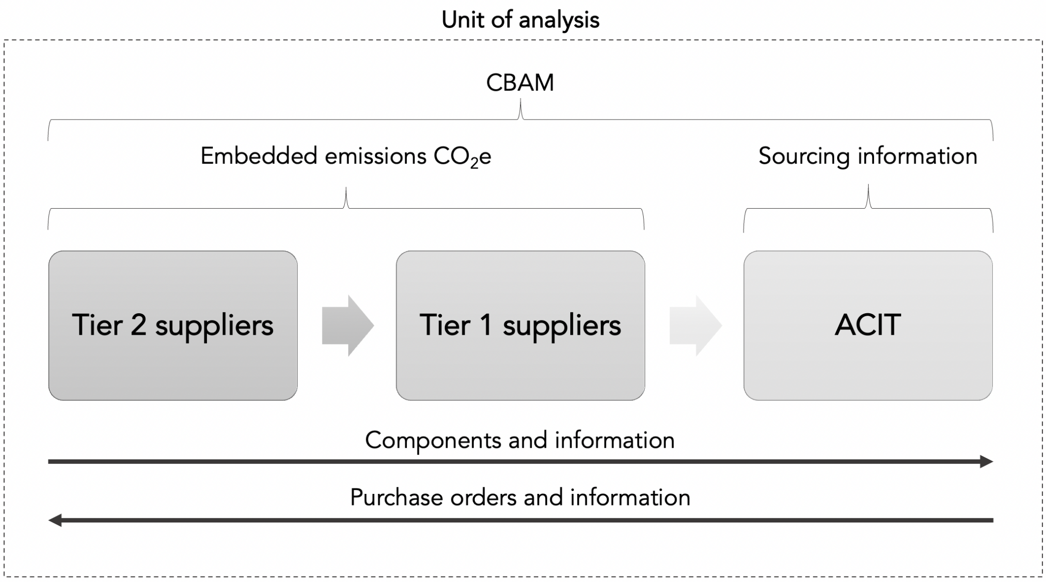


Figure 2.3: The unit of analysis (*Source:* authors).

The UoA (Figure 2.3) covers the research questions (1.4) and will ultimately work as a guide toward a conclusion for the thesis.

2.1.4 Research choice

Previously in the thesis, quantitative and qualitative data have been discussed as research choices to conduct data. Due to this, a **mixed methods** will be used as described by Saunders et al. (2007). This research choice is further divided into two subcategories, **mixed-model research** and **mixed-method research**, depending on how the methods will be used.

The subcategory that this thesis will follow, is the **mixed-method research**. This method uses both quantitative and qualitative data collection to conduct the necessary data. This can be done either *parallel* or *sequential*. In contrast to **mixed-model research**, this method does not combine the different methods (Creswell & Creswell 2023). In other words, both methods will be conducted and analyzed according to their type. This approach and choice of research will be the most suitable when analyzing the UoA as well as coming up with concrete answers to the research questions.

2.1.5 Time Horizon

When developing a **research design**, the timing of the study needs to be clarified. A study made at a specific time is referred to as *cross-sectional* and a study made over a time period is *longitudinal* (Saunders et al. 2007).

This thesis will follow a *cross-sectional* time horizon due to the analysis being made at a given point in time and not over an extended time period.

2.2 Executing the holistic single-case study

To find enough data on the UoA and to be able to answer the research questions, the research process had to be iterative and divided. There were three different data collection methods; a **literature review**, **interviews** with stakeholders and individuals from outside the case with expert knowledge, and **quantitative data** collected from various viable data sources and questionnaires. How each of these methods was conducted is displayed in the following sections. The methodology of the analysis is presented in section 2.2.4.

2.2.1 Literature Review

A literature review supports the thesis by creating a foundation of professional scientific knowledge (Höst et al. 2006). Carrying out a rigorous literature review allowed the researchers to constructively build upon the already existing knowledge, mitigating the risk of repeating already published information. Thus, the literature review justified the research project and alleviated any worries that the research project would not fill gaps in the knowledge base (Jesson et al. 2011).

Höst et al. (2006) mentions three points that are crucial to know before performing a literature review:

1. How does one find literature that is relevant?
2. How trustworthy are the different sources?
3. How to concatenate the results of the literature review?

To answer the questions, the following iterative framework for the literature review, based on information from Höst et al. (2006), was composed.

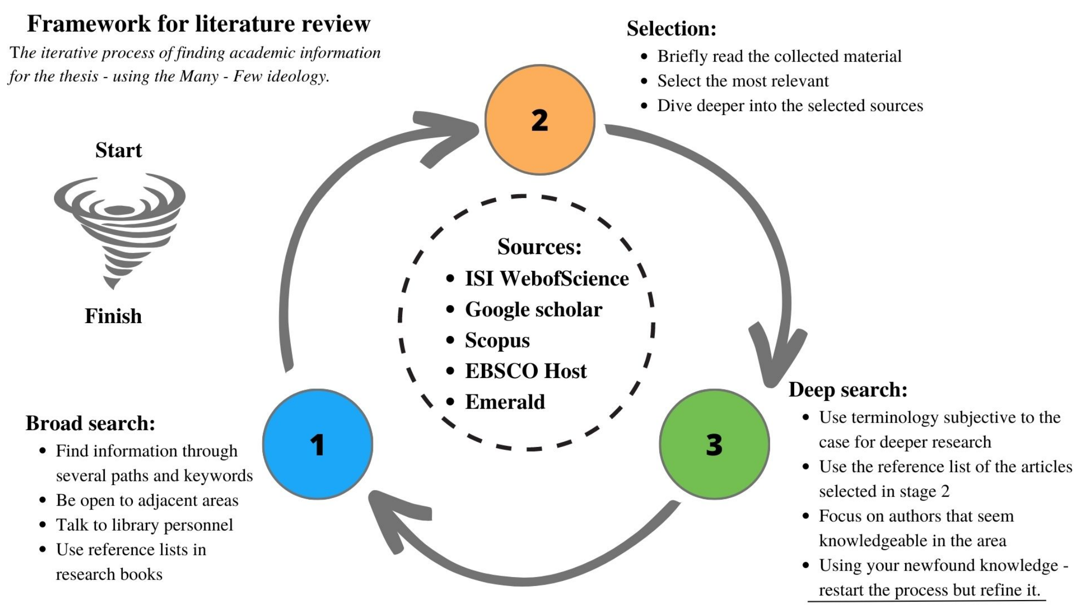


Figure 2.4: Literature review process. (*Source:* authors), *Inspired by Höst et al. (2006).*

To make sure question 2 posed by Höst et al. (2006) was answered, the thesis focused on scientific research. For a submitted paper to be acknowledged as scientific research, it has to go through tests, i.e. *scientific peer reviewing* (Höst et al. 2006). The program committee in charge of reviewing the paper makes sure that it fulfills certain criteria. The criteria are, and are not limited to, the topic's and result's *news value*, the *relevancy* of the research questions, and the *trustworthiness* of the research method (Höst et al. 2006).

There are several sources of text that have been scientifically peer-reviewed, such as *journals*, *conference proceedings*, *posters*, etc. (Jesson et al. 2011). Other sources of information such as books, web pages, and articles have also offered great value for the thesis work, however, these were scrutinized to minimize the risk of hidden agendas or biases in the materials.

Finally, a literature review process must concatenate the results of its findings (Höst et al. 2006). In this thesis, the concatenation of the findings transpired as iteratively as the review itself. This means, after every iteration in the literature review the researchers compiled the most interesting findings and mapped out a path going forward. This ensured that the next iteration was built upon the previous, thus, maximizing the yield of the research.

An illustration of the keywords used to find the best literature for the case can be seen in Table 2.2. The table consists of the key sources, accompanied by the keyword search that was made, as well as the fields of interest. The sources presented were the 10 most impactful to this thesis, meaning that they had high relevance as well as being a reference point for deep diving (Step 3 in Figure 2.4) and for snowballing other relevant sources.

Key source	**Keyword search**	**Field of interest**
(Yin 2018)	"Case study"	Case study design
(Saunders et al. 2007)	"Research strategy"	Research design
(European Commission 2021*b*)	"CBAM"	CBAM legislation
(Eicke et al. 2021)	"Constraints with CBAM"	Risk and constraints with CBAM
(Mentzer et al. 2001)	"Supply chain management"	Defining supply chain management
(Weele 2014)	"Procurement strategies for supply chains"	Procurement process
(Gardner & Cooper 2003)	"Mapping supply chains"	Strategic supply chain map
(Chopra & Meindl 2013)	"Supply chain strategies"	Designing a supply chain
(Fischer 1997)	"Designing an effective supply chain"	Designing a supply chain
(Xu et al. 2017)	"Governance regulations impact on supply chains"	Impact of carbon regulations on global supply chain

Table 2.2: The 10 most impactful sources.

2.2.2 Interviews

To broaden the understanding, interviews were conducted with stakeholders at the case company ACIT, suppliers of ACIT, and experts within the area. According to Yin (2018), case study interviews provide several strengths. They allow for targeted topics, i.e. the researchers are able to get specific information surrounding an area of importance. Moreover, the researcher gets insightful comments, meaning that the interviewee provides explanations that are rich in information as well as their personal opinions and perceptions.

There are three main types of interviews, **open-ended** interviews, **semi-structured** interviews, and **structured** interviews (Höst et al. 2006). The interviews conducted in this thesis were mainly semi-structured interviews and open-ended interviews.

- *Open-ended interview*

  The aim of an open-ended interview is to qualitatively explore the phenomenon. The questions are not tailored for a specific purpose and the interviewee will most likely talk more about the subjects they are comfortable with.

- *Semi-structured interview*

  A semi-structured interview will mix open-ended questions with questions that require specific answers. The aim is to find the interviewee's experience of the phenomenon both quantitatively and qualitatively in a descriptive manner. For these interviews, it is crucial that the specific questions are asked the same way each time to minimize the risk of biases in the answers.

The open-ended interviews laid a foundation for the semi-structured interviews later in the research process - especially when more quantitative data needed a qualitative explanation, aligned with what is stated by Höst et al. (2006). The interviews followed the interview guides provided in section A1.

In Table 2.3, the conducted interviews are presented by the role of the interviewed person in combination with the desired information that was obtained, as well as which research question it is answering.

Interviewee	**Information that should be obtained**	**RQ**
External		
Policy officer for trade policy (Svenskt Näringsliv)	Insights regarding CBAM and its functions	3
KREAB Consulting	Scope of CBAM	3
Internal		
Tactical buyer	Chinese suppliers	1 2
Strategic sourcing team manager	Chinese sourcing	1 2
Supplier value engineering manager	ACIT sourcing department	1 2
Technical cost engineer	Material specifications	1 2
Eco-design engineer	Sustainability compliance at ACIT	2 3
President MVI	ACIT's general strategy	3
Trade compliance lead	CN codes	3
VP Holding Nordic	Declaration of EU ETS connected to CBAM	3
Group Sustainability Manager	Sustainability strategy and EU ETS	2 3

Table 2.3: Conducted interviews.

Worth noting is the risk of biases, inaccuracy, and reflexivity in interviews (Yin 2018). To mitigate these risks several interviews were conducted on similar areas of the case study, and the use of control questions throughout the semi-structured interviews tested the interviewees' biases.

2.2.3 Quantitative data

The quantitative data used in this thesis was gathered from various data sources provided by ACIT, such as the analytics solution system and ERP. These data sources contained information regarding ACIT's sourcing activities in China. More specifically, data such as suppliers, order quantities, order spend, the weight of components, etc. However, the thesis required additional quantitative data to finish the analysis, such as the pricing of emission certificates, default emission values, etc. Such data was retrieved from various trustworthy sources outside the company and the validity of both the data and the source was checked by both the authors and a third party from the company before use.

Some quantitative data was also gathered from key suppliers using a questionnaire. A questionnaire is a research instrument used to conduct data based on pre-configured questions targeting a specific target population (Floyd 2009). The need for this data became evident after some initial analysis, hence, further explanation of how, and why, this data was gathered will be presented in the analysis methodology, section 2.2.4.

2.2.4 Analysis

The data collection methods and literature review collectively produced holistic, yet thorough, material from which the researchers could draw accurate analyses and trustworthy deductions.

The first step of the analysis was to map out, understand and quantify the upstream supply chain of components from China. Based on the interview information provided by the Asian Sourcing Office's (ASO) employees as well as the quantitative data, it was possible to map out the most impactful suppliers of steel- and aluminum components from China. Seven identified suppliers were responsible for 95% of the sourced goods in these categories in 2022, making them the key suppliers for the analysis and the focus group. The key suppliers were met with a questionnaire to help determine the mix of materials that were sourced from each, i.e. how much steel and how much aluminum ACIT sources from each supplier. The data from the questionnaire was added to the extracted dataset containing information from the analytics solution system and ERP, thus enabling a calculation of the summarized weight of steel and aluminum that the sourced components amount to.

The second step was to identify the embedded emissions linked to steel and aluminum component production. The literature review as well as some data collected through interviews resulted in default values that could be used for calculating the emissions based on the weight of the raw materials. However, as the aim was to find accurate emission data - the questionnaire sent out to the suppliers asked them to fill out the embedded emissions as well as their suppliers of raw material (ACIT's Tier 2 suppliers). This enabled a calculation of the embedded emissions based on both the default values of the specific region in which the Tier 2 suppliers were located, as well as a calculation based on the Tier 1 suppliers reported data. The different results were then compared and contrasted.

Finally, the third step was to identify whether ACIT fit into the scope of the CBAM legislation, and if so, what the impact of the legislation would be on their supply chain. Through several internal and external interviews with experts within the area, it could be concluded that ACIT does not fit into the scope of the legislation as of now. However, as the legislation is due to grow into more industrial sectors and companies, a "what-if" analysis of the impact was run. The analysis resulted in a financial model that takes the current price of an emission certificate, the expected amount of sourced goods, and the emissions linked to those goods, into account. This tool could then be used to compare the impact when using different suppliers, to analyze whether the supply chain, or the supply chain management, should change due to reasons such as increased administrative complexity and increased costs, and so on. These analyses were also made with input from buyers within ACIT to further solidify the drawn conclusions.

2.2.5 Summary

To get an overview of the research process, a WBS (Figure 2.5) was created, showing the initial process flow in a diagram.

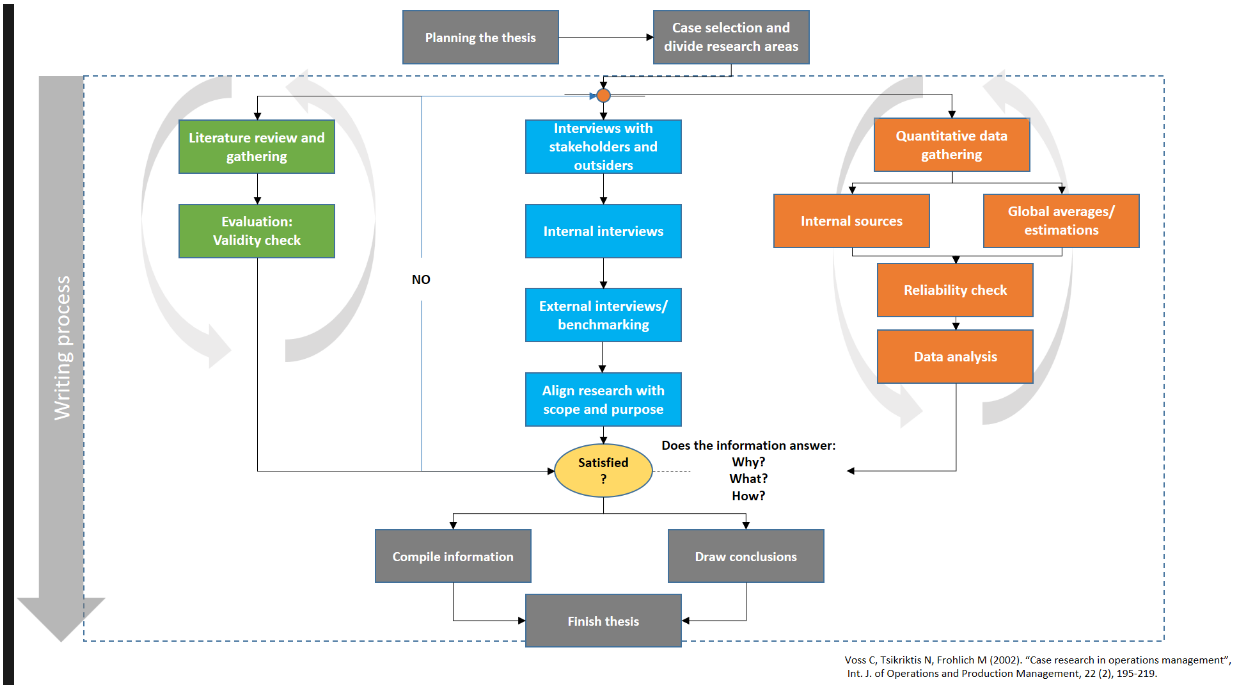


Figure 2.5: WBS of the project. (*Source:* authors).

Figure 2.5 displays the iterative process of the different data collection methods from a holistic point of view. However, to summarize the connection between the different chapters of the thesis and to get a better understanding of the outline, another image was created. The image is an analogy to a manufacturing company, such as ACIT, showing how the research process - from methodology to finished analysis - resembles a manufacturing process of goods - from raw material to finished goods.

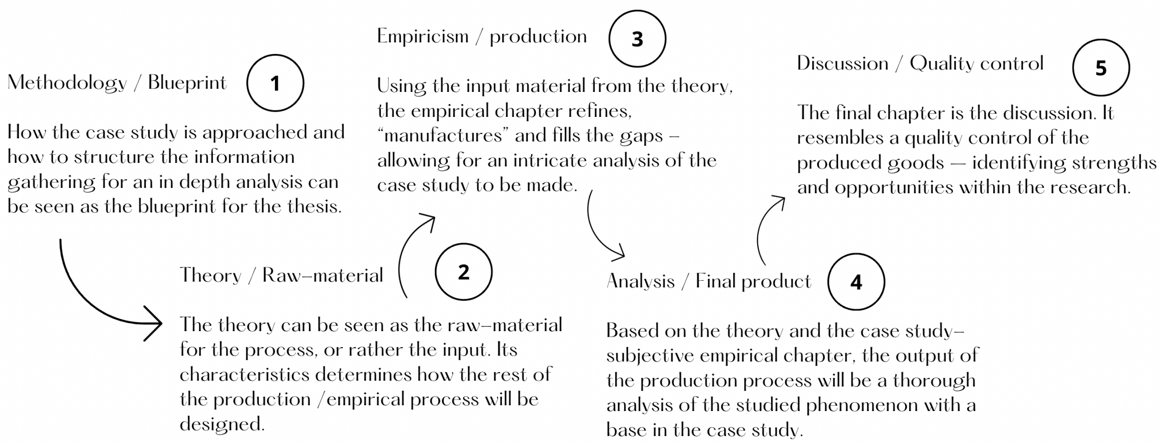


Figure 2.6: Outline of the thesis and how the chapters connect. (*Source:* authors).

2.3 Case study tactics

The following section refers to the case study tactics used in the thesis to increase the reliability and validity of the study based on the suggestions from Yin (2018).

- **Construct validity**

  It is a test that refers to the extent that the chosen method investigates the chosen phenomenon that is being studied. By using applicable measurements to capture the relevant information within the scope of the study, a more accurate observation of the phenomenon can be done (Gibbert et al. 2008).

  As further described by Yin (2018), construct validity is enhanced by triangulation, meaning to investigate the same phenomenon from different viewpoints, both when collecting data and when analyzing and comparing the findings.

  This thesis will use multiple sources, both when conducting interviews and when creating the literature review to increase the construct validity of the study. Additionally, key informants will sporadically review drafts of the thesis to observe how well the thesis is aligned with the purpose of the case study something that Yin (2018) stated as a tactic for increased construct validity.

- **Internal validity**

  Internal validity relates to the causal relationship between variables within the study when analyzing the conducted data. The test addresses how well the research conclusion can be defended by logical reasoning and causal arguments Gibbert et al. (2008).

  The tactics to increase the internal validity of the thesis are the use of valid and reliable measures to ensure that the collected data represent the variables being investigated and analysed.

- **External validity**

  The external validity concerns the generalizability of the findings in all types of settings, and not only the studied setting (Gibbert et al. 2008). However, Yin (2018) stated that it is difficult to generalize a single-case study, and the crucial factor when wanting to increase the external validity is the use of theory in order to enhance generalizability. Therefore, this thesis will investigate different theories and models done previously to increase external validity. In other words, an essential part of the thesis will be to build a rigorous literature review to enhance the external validity.

- **Reliability**
  Reliability refers to what extent the findings can be repeated, by another investigator, without any errors. The important factor when creating a reliable study is the documentation of the research procedures which leads to enhanced transparency (Gibbert et al. 2008). This thesis will as explicit as possible, describe the different models and procedures done to enhance the transparency and reliability of the thesis as well as maintain a chain of evidence throughout the thesis.

2.4 Ethical aspects of the study

The methodology used in the study as well as the display of results, information and knowledge, was all done with grave attention to the different stakeholders, keeping ethical aspects of the study in mind. The interviewees and sources of data were handled with anonymity as a protective measure, also setting up a zone of trust that aid towards more truthful answers. All data gathering was made in collaboration with the case company and in accordance with the predetermined requirements. The handling and analysis of said data was also conducted with care, not displaying any explicit information without consent.

These actions have been taken to ensure a more transparent, ethical and professional report. The gathered data, in raw or analyzed form, has not been shared with anyone without consent throughout the research process, and data will only be shared to the public in this report as per previous agreements with the case company.

3 Literature Review

In this section the literature review described in section 2 is presented. The section covers relevant academic journals to build a knowledgeable foundation for further investigation. Furthermore, the subjects presented are linked to the research questions presented in section 1 and will give a holistic understanding of the fundamentals revolving around this case.

3.1 Supply chain management

The following sections present different areas within Supply Chain Management (SCM) that are relevant to this case. The definition of a Supply Chain (SC) can be described as (Mentzer et al. 2001):

> *"A supply chain is the network of organizations that are involved through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer."*

According to Mentzer et al. (2001) it is important to distinguish the terms **supply chain** and **supply chain management**. The supply chain as a phenomenon exists even if it is managed or not, and supply chain management refers to the managerial efforts by the actors within the supply chain (Mentzer et al. 2001).

The definition of supply chain management has been described by Monczka et al. (2001) as:

> *"The primary objective with SCM is to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers."*

Additionally, Mentzer et al. (2001) states that the overall philosophy of supply chain management includes more than just logistics and that the boundaries go further to other functions within a supply chain with the aim to create customer value as well as customer satisfaction.

3.1.1 Designing a supply chain

The design of a supply chain is the result of several strategic decisions made by an organization. Matters such as whether or not a supply chain function shall be outsourced or produced in-house, the size and location of a warehouse, and even what system support is most favorable, are all choices that inevitably have an effect on the design of the supply chain. (Chopra & Meindl 2013)

According to Fischer (1997) and Chopra & Meindl (2013), the first step of action when designing an effective supply chain is to find a strategic fit. A strategic fit is when the company's competitive strategy aligns with the supply chain strategy, basically saying that the customer requirements that the competitive strategy is trying to fulfill are supported by the capabilities of the supply chain (Lee 2002). Fischer (1997) provides a framework that can be used to match a company's products to the supply chain it needs:

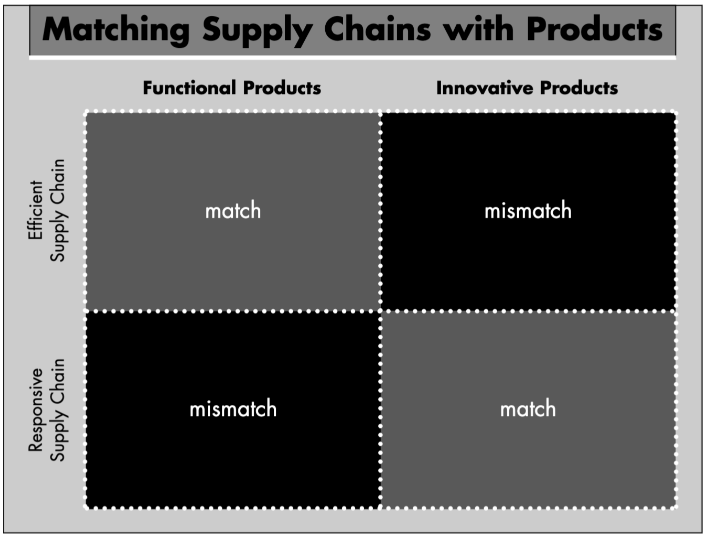


Figure 3.1: Matching products and supply chain for a strategic fit (Fischer 1997).

What Figure 3.1 tells us is that functional products, e.g. products that are mass-produced with very little variation, need an effective supply chain, whereas innovative products need a responsive supply chain that can quickly adjust to market changes (Fischer 1997, Lee 2002). However, using this framework requires an understanding of the competitive strategy of the company and its products, i.e. the unique selling point that differentiates the company from its competitors (Fischer 1997). Chopra & Meindl (2013) provides a concise list that guides toward which supply chain strategy is most beneficial based on the current competitive strategy.

	Efficient Supply Chains	**Responsive Supply Chains**
Primary goal	Supply demand at the lowest cost	Respond quickly to demand
Product design strategy	Maximize performance at a minimum product cost	Create modularity to allow postponement of product differentiation
Pricing strategy	Lower margins because price is a prime customer driver	Higher margins because price is not a prime customer driver
Manufacturing strategy	Lower costs through high utilization	Maintain capacity flexibility to buffer against demand/supply uncertainty
Inventory strategy	Minimize inventory to lower cost	Maintain buffer inventory to deal with demand/supply uncertainty
Lead-time strategy	Reduce, but not at the expense of costs	Reduce aggressively, even if the costs are significant
Supplier strategy	Select based on cost and quality	Select based on speed, flexibility, reliability, and quality

Table 3.1: Chopra & Meindl (2013)'s guide for aligning the competitive strategy to one of the supply chain strategies. *Based on Fischer (1997).*

To state that every existing supply chain is binary and either falls under the "Efficient supply chain" category or the "Responsive Supply Chain" category would be overarching, and simply not true Chopra & Meindl (2013). This is also displayed in Figure 3.2, showing that the strategic fit for your supply chain changes as a function of how uncertain the demand for the product is. Lee (2002) also portrays some examples of supply chains that are in the "gray area", e.g. innovative products with stable supply processes, etc., showing that each supply chain is different and although these mappings are great tools for understanding how to efficiently design your supply chain, it still needs to align with the market strategy of the company.

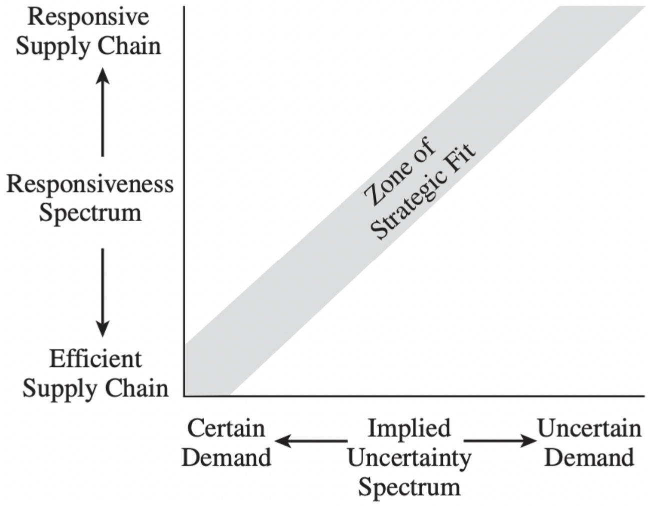


Figure 3.2: Graph showing the strategic fit as a function of demand certainty (Chopra & Meindl 2013).

After the overall strategy and design of the supply chain have been set, several actions can be taken to fine-tune the supply chain for optimal performance in a dynamic reality (Perea-López et al. 2003). For example, Cetinkaya & Lee (2000) researched the effects of a Vendor Managed Inventory (VMI), which allows suppliers to make decisions on when replenishment of goods shall occur based on an agreed-upon stock level between the purchaser and supplier. Perea et al. (2000) created a hybrid dynamic supply chain simulation model that can be used in decision-making to reduce the risk of bullwhip effects and other demand amplification issues. These are just examples of processes and tools that can be used to optimize the design of the supply chain after the rough "sketch" has been laid out.

3.2 Sustainability in a supply chain

Fraser et al. (2020) states that mapping with a Multi-Tier Sustainable Supply Chain Management (MT-SSCM) mindset is needed to cover the entire scope and to become truly transparent. Fraser et al. (2020) also states that through the use of a comprehensive MT-SSCM framework, which relies heavily on mapping, transparency, and traceability can be achieved. In addition, Kembro et al. (2017) asserts that although difficult to achieve full transparency, i.e. "open books", with all suppliers, new Information and Communication Technology (ICT) and strategic moves allow for information to be passed on more easily throughout SCs - ultimately progressing toward a more detailed and aware MT-SSCM and information sharing.

Direct- and indirect emissions

Direct emissions, also referred to as Scope 1 emissions, concern the emissions caused by a company from activities and operations that it owns and controls Read (2022), Wei et al. (2019), e.g. the emissions from running machinery for the production of goods or emissions from burning fuel for vehicles.

Indirect emissions can be categorized in Scope 2- and Scope 3 emissions. Scope 2 emissions are emissions caused by the production of the energy that a specific company buys from an energy supplier (Read 2022, Wei et al. 2019). Scope 3 emissions are emissions that are not controlled by a company, hence emissions caused by customers using the products produced by a company, or the emissions created by a supplier in their production (Read 2022, Wei et al. 2019).

3.2.1 The impact of carbon regulations on global supply chains

With different governance regulations being introduced toward corporations' environmental responsibility, it has forced industries to seek new ways to organize their supply chain design (Xu et al. 2017). In addition to Xu et al. (2017), Turki et al. (2018) states that the impact of a carbon trading price will trigger producers to invest in re-manufacturing processes to mitigate their carbon emissions which ultimately leads to reduced costs. The authors continues by mentioning that an increase in re-manufacturing production sets high demand on the quality of the products since manufactured (new) products usually have higher quality (Turki et al. 2018). The redesign of the supply chain with the aim to accommodate re-manufacturing and returned products could be a sound investment since it may lead to higher profitability (Srivastava 2007). The author continues by mentioning that decisions regarding the location of facilities must be considered to transfer used products from old users to a producer and ultimately to future markets (Srivastava 2007).

Furthermore, Mollenkopf et al. (2010) mentions that companies with operations in multiple countries may face varied environmental regulations and levels of implementation of green operations which make global sourcing more difficult.

A study presented in Wang et al. (2017) showed that with applied carbon tax regulations, a centralized supply chain is the more beneficial managerial strategy compared to a decentralized supply chain. The authors continue by motivating that in a decentralized supply chain companies throughout the supply chain prioritize their own profitability over reducing their carbon emissions. Hence, governments need to raise carbon taxes in order to enhance social welfare and mitigate carbon emissions. In comparison, a centralized supply chain proved to increase the supply chain profit as well as the social welfare of the government and contribute more to lowering carbon emissions. (Wang et al. 2017)

3.2.2 Supply chain mapping

Supply chain mapping has several benefits, not only for this thesis in particular but for all companies seeking strategic supply chain management. A map graphically portrays the current flow of goods and can help in planning processes, understanding the information flow parallel to the goods, finding weak links and ultimately displaying the dynamics of your supply chain in a way that is easy to grasp and analyze. (Gardner & Cooper 2003)

Moreover, Gardner & Cooper (2003) states that a strategic supply chain map allows the company to fictively redesign and modify its supply chain, enabling simulations or analyses of a "what-if" case. In the case of new regulations, such as CBAM, these simulations, or analyses, can identify the suppliers that offer more competitiveness and resilience.

To accomplish a strategic supply chain mapping it is important that companies extend their scope of interest beyond Tier 1 suppliers and customers (Theodore Farris 2010). The author states that relationships such as supplier's supplier (Type 1) and supplier's other customers (Type 2) are essential to understand potential shortages of material as well as general competition on the market that could impact purchasing (Theodore Farris 2010). Moreover, relationships between the customer's customer (Type 3) and the customer's suppliers (Type 4) are important parameters to combine when doing competitive analysis and seeking potential business opportunities (Theodore Farris 2010).

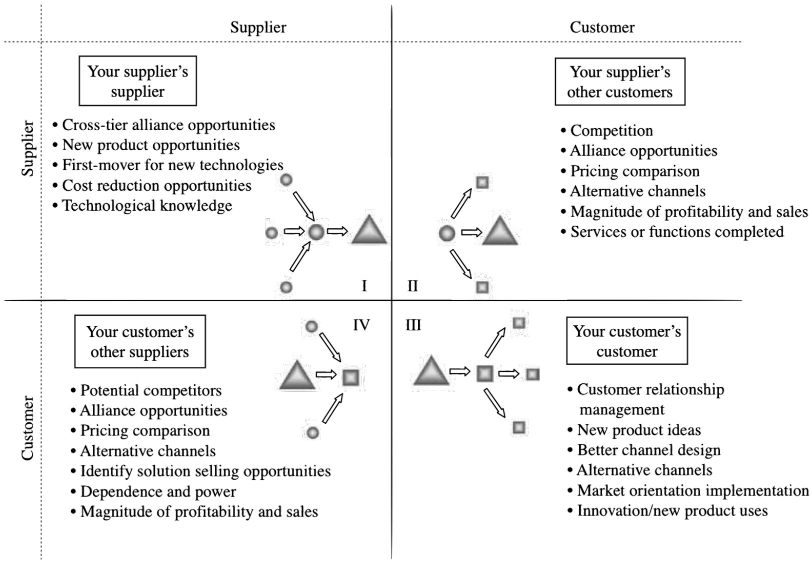


Figure 3.3: Relationships of interest within a supply chain (Theodore Farris 2010).

3.2.3 Procurement

Procurement is an umbrella term for the function of purchasing goods or services that are used as input in a company's value chain (Weele 2014). It is a broad term, covering both the purchasing of goods that are used directly in products and support activities, hence, it is labeled a support activity within an organization by Porter (1985). To minimize confusion between the terms *procurement* and *purchasing*, Weele (2014) summarized purchasing as follows:

> *"The management of the company's external resources in such a way that the supply of all goods, services, capabilities, and knowledge that are necessary for running, maintaining, and managing the company's primary and support activities is secured at the most favorable conditions."*

This section will investigate purchasing- frameworks, activities, and processes within the supply chain.

The Purchasing Process

Most purchasing activities follow a similar process, with the overall goal of reducing the Total Cost of Ownership (TCO) (Weele 2014, Ellram & Siferd 1993). The process can be divided into two parts, tactical purchasing (*information gathering, negotiation,* *and contract writing*) and order function (*ordering, expediting and evaluation*), and is graphically displayed in Weele (2014):

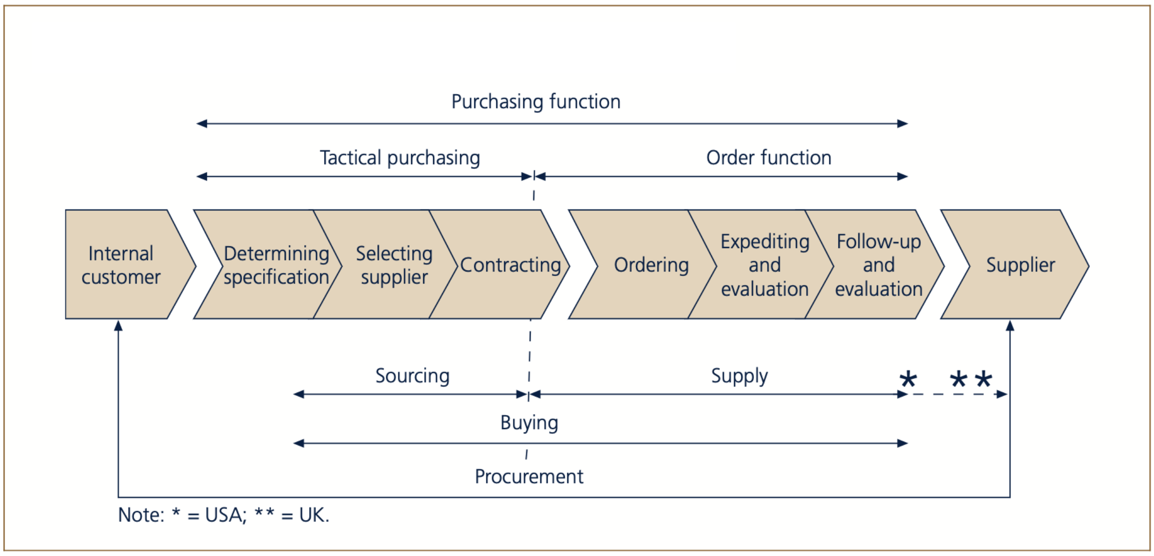


Figure 3.4: The purchasing process by Weele (2014).

This is an iterative process where well-functioning procurement/sourcing organizations use the acquired score in the supplier evaluation as a basis when selecting suppliers for new projects. Following the purchasing process displayed in Figure 3.4, it is easy to reach TCO-thinking in your purchasing organization (Weele 2014). This has several benefits such as; better supplier selection as the total cost of a product is examined rather than the price of the item, information gathering that enables improved data analysis, and consequentially improved material for strategic decisions (Ellram & Siferd 1993).

Purchasing maturity - The development model

To understand an organization's maturity and professionalism within purchasing, Weele (2014) produced a "**purchasing development model**". According to this model, purchasing and supply within an organization can progress through six stages of professional development over time. These six steps include *transaction orientation, commercial orientation, coordinated purchasing, internal integration, external integration, and value-chain integration.*

Stage	Focus	Activities
Transaction orientation	Serve the factory	*Clerical, order processing*
Commercial orientation	Reduce costs	*Commercial, tendering, negotiating, approved supplier lists*
Purchasing co-ordination	Savings through synergy	*Commercial, contracting, global sourcing*
Internal integration	Total cost of ownership	*Cross-functional buying teams, systems integration, vendor rating*
External integration	Supply Chain optimization	*Outsourcing, EDI/Internet, e-commerce, cost models*
Value-chain integration	Total customer satisfaction	*Customer driven activities, contract manufacturing, supplier development*

Table 3.2: The focus and activities linked to each step of the purchasing development model (Weele 2014).

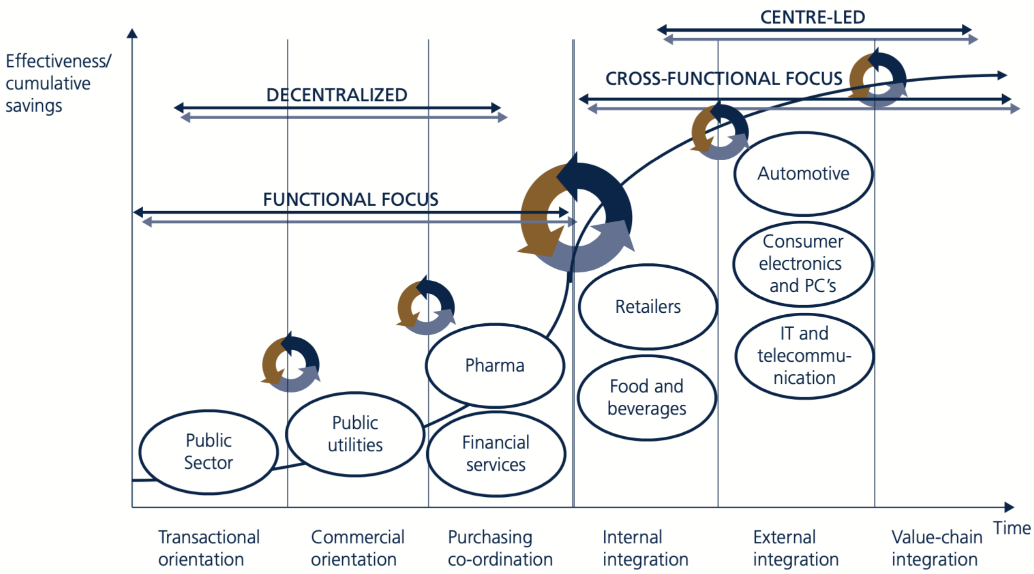


Figure 3.5: The purchasing development model Weele (2014).

Each step in the model represents a new focus and new activities for the purchasing organization, and these are summarized in Table 3.2 inspired by Weele (2014).

Although each step represents a more professional purchasing organization, it is not necessary for every company to reach step six in the model as it often requires heavy investments into the purchasing organization. Weele (2014) also denotes that the model may not be completely accurate for all types of industries and should only be used as guidelines when profiling a purchasing organization.

Purchasing strategies

Dissimilar from many other operations within a company, the strategy of the purchasing management often varies as the strategy needs to be product- or category-specific (Kraljic 1983, Porter 1985, Weele 2014). The purchasing strategy of global companies is often linked with the term sourcing, i.e. the purchasing of goods from the best possible supplier on a global scale, hence why companies often have a **sourcing strategy** for their goods (Weele 2014). The sourcing strategy defines how much of the commodity or category the company shall buy, from which suppliers or partners (long-term suppliers), which contracts the company shall strive for, etc. (Weele 2014). However, to aid in the setup of this strategy Kraljic (1983) put forward the *"Purchasing Portfolio Matrix"*, displayed in Figure 3.6. The idea of the matrix is to help companies identify which supplier management strategy the company shall follow based on two dimensions: the impact it has on the company profits, as well as the supply risk embodied in the purchased commodity.

Kraljic (1983) disclosed four different categories, and the idea was that by categorizing an organization's purchasing, customized strategies for managing each category and optimizing their overall purchasing performance could be developed. The categories identified in Kraljic (1983) was:

1. **Non-critical items** - Items that have a low level of profit impact for the organization, and a low level of supply market complexity. They can often be purchased in an unequivocal manner.

2. **Leverage items** - These are items that have a high level of profit impact, but a low level of supply market complexity. The abundant supply means that they can often be sourced from multiple suppliers and should be managed through negotiation, competition, and pricing.

3. **Strategic items** - These items have both a high level of profit impact on the organization and a high level of supply market complexity. The goods require careful management and a long-term approach to supplier relationships due to natural

scarcity.

4. **Bottleneck items** - These are items that are of low importance to the organization's profits, but have a high level of supply market complexity. The goods shall be under scrutiny, and management of the supply chain is needed to avoid disruption.

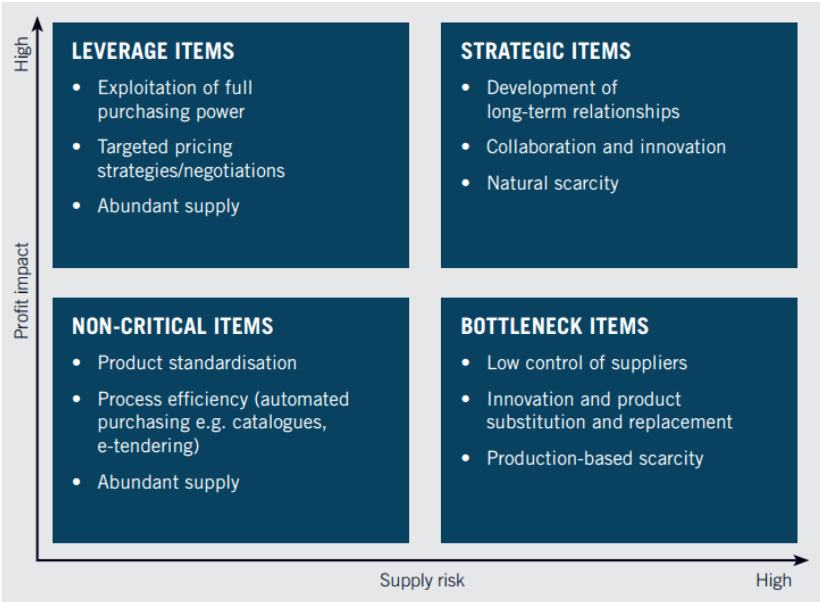


Figure 3.6: A simple version of the purchasing portfolio matrix submitted in Kraljic (1983).

3.2.4 Supply chain information systems

In today's business environment, access to information is crucial for the survival and growth of companies. Companies must tackle the challenge of integrating information from various sources, including upstream and downstream partners, internal departments, and macro-level data. An effective transmission and sharing of information are vital for coordinating economic and functional behaviors across the entire supply chain. Unlike individual companies, supply chains operate as an extended enterprise and have their unique characteristics, particularly in the way information flows is acquired. Therefore, managing supply chains requires specialized strategies to optimize the flow of information and ensure coordination among all stakeholders. (Jiang & Yang 2007)

3.2.5 Supplier requirements in supply chains

Supply chain requirements have become more and more stringent primarily since sustainability has become a critical issue for companies to address. Buyers are often held responsible for their suppliers' actions and practices. Hence, the buyers set their own requirements for their suppliers, based on their strategies as well as local and global regulations that may impact their organization (Shumon et al. 2019). As Shumon et al. (2019) further describes, requirements are often implemented through different standards such as the International Organization for Standardization (ISO), targeting requirements such as emissions reductions and re-manufacturing.

As described, the issues tend to transfer to upstream suppliers which can be challenging from their perspective (Shumon et al. 2019). More specifically, requirements imposed by buyers could create operational complexity that is difficult to handle for the suppliers. Suppliers may struggle to meet these requirements as they often involve adopting new methods and implementing additional processes, which can be time-consuming and challenging (Michelin et al. 2015). Moreover, suppliers may lack the necessary expertise or workforce to meet these requirements effectively. (Shumon et al. 2019, Michelin et al. 2015)

3.3 Production process of steel and aluminum

An explanation of how the two materials in focus are produced provides some background and areas of reference. Thus, the following subsections will discern steel and aluminum production, from raw materials to industry-ready products, generating a better understanding of the different processes and the embedded emissions within.

3.3.1 Steel

Steel is the most used material in infrastructure and industrial applications globally, and the demand is continuously growing (Wente et al. 2022). From needles to oil tankers, the applications of different types of steel are endless. The mechanical properties of steel make it one of the most versatile materials on the planet, it is relatively low cost and there is an abundance of material available - each parameter contributing to the current production of almost two billion tonnes of crude steel yearly (Wente et al. 2022).

Before moving on to the different alloys of steel and their respective production method, it is important to distinguish the two main types of steel that will be of relevance to this thesis. The types are **crude steel** and **scrap steel** (Wente et al. 2022). *Crude steel* is produced from mined iron ore, i.e. steel that uses "new" resources from the earth. *Scrap steel* is produced from the recycling of already processed steel. Consequently, crude steel requires certain production steps that scrap steel does not. More intricate explanations and differentiation will follow in the paragraphs surrounding the production process of steel.

Looking at the most recent yearly summary of global steel production, there is a clear leader in the yearly output of steel.

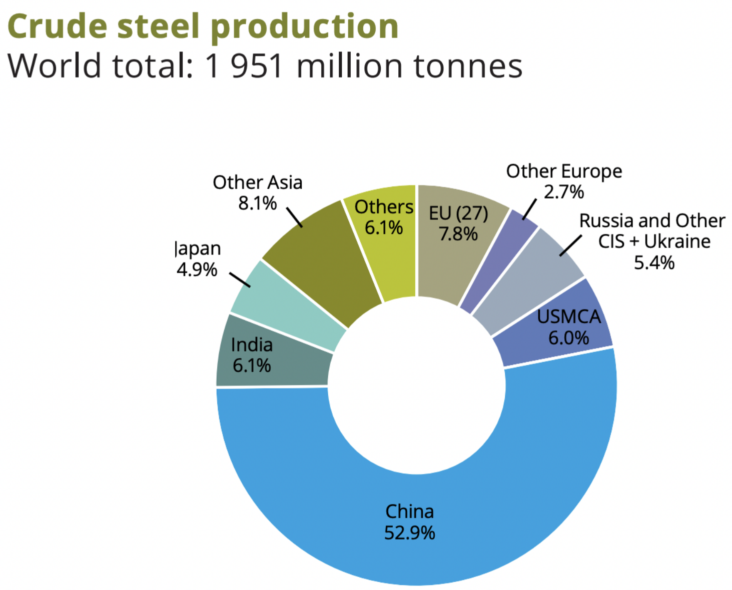


Figure 3.7: Yearly output of crude steel 2021 (World Steel Association 2022).

As seen in Figure 3.7, China is responsible for over 50% of the global output of crude steel. This is an astonishing number and to put it into perspective, China's population in 2021 was 1 444M people (United Nations 2021). Thus, China produced approximately 700kg of steel per capita in 2021.

Before investigating the Chinese production of steel and its global impact further, one must understand the production process behind steel. By understanding the process it becomes easier to single out areas of the process that are for example more costly, require more energy, or are especially complicated. The production process can be divided into a few significant steps and these will be presented chronologically.

Mining of raw materials

The first step of producing steel only concerns **crude steel** as it is the mining of iron ore from the earth. Arcelor Mittal, the second largest steel producer globally (World Steel Association 2022) has created a graphic view over the entire production process of steel, from ore to bars.

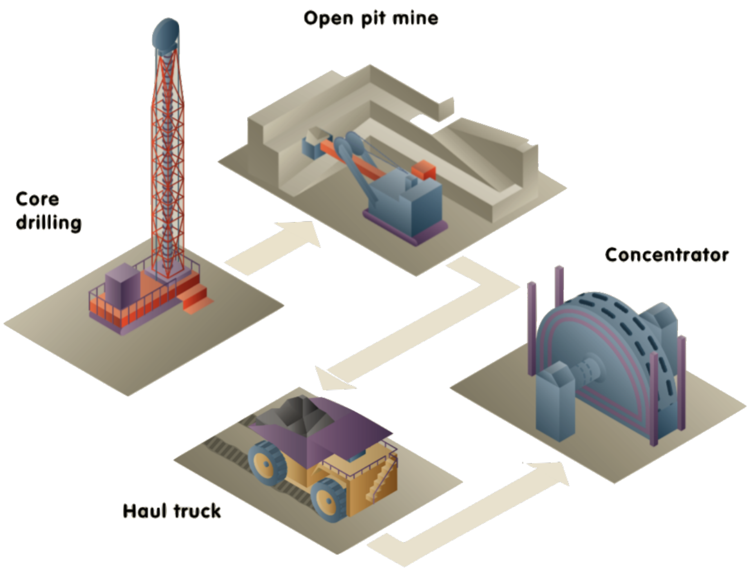


Figure 3.8: Production process from exploration to concentration (Arcelor Mittal 2023).

1. **Core drilling**

   The process begins with geological prospecting and exploration of land by drill tests (Arcelor Mittal 2023). When a site shows potential, planning to ensure optimal extraction of the material is commenced.

2. **Open pit mining**

   If the prospecting shows positive results, the next step is to mine the iron ore. This is most commonly done in open pits, called open-pit mining (Arcelor Mittal 2023). The excavation process begins by drilling holes into the ore which in turn are filled with explosives. The explosives blast the iron ore lose, making it possible to transport to the next steps via a **haul truck**. However, If the aim is to mine metallurgical coal that will later be transformed into **coke**, the process is different. In this case, you will need to mine in vertical shafts as the coal is deposited in layers underground.

3. **Concentrator**

   The concentrator transforms mined material into usable raw material by crushing and refining the iron ore. There are several ways to extract iron from the crushed material, the most commonly used are magnets, large millings or flotation processes (Arcelor Mittal 2023). The concentrated raw material is then sent to the next step of the production process (Wente et al. 2022).

Producing iron and steel

The concentrated iron ore and metallurgical coal have now been shipped to a steel plant that will transform it into steel, Figure 3.9. However, before the transformation begins, the raw material must be processed further.

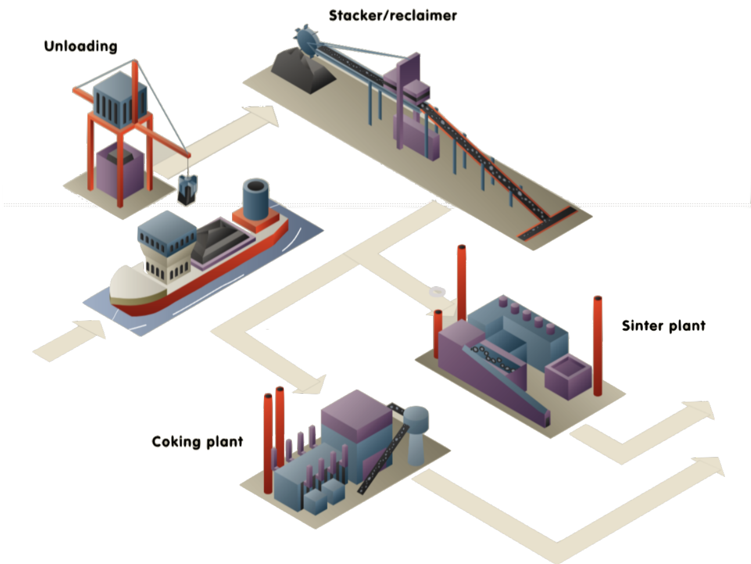


Figure 3.9: Transforming raw material into sinter or coke (Arcelor Mittal 2023).

The stacker/reclaimer divides the raw material into different buckets depending on the grade of the raw material. The metallurgical coal is sent to a *coking plant* where it will be anaerobically burnt into coke. The iron ore will enter a *sinter plant* with an output of sinter, or in common words, iron dust - consisting of crushed, refined, iron ore, fluxes, and recycled substances from the steel plant (Arcelor Mittal 2023). Worth noting is that the iron ore can be supplied to the steel plant in the form of iron pellets. In these cases, there is no need for the sintering process and the pellets can be used directly in the Direct Reduction Iron (DRI) steelmaking method. More on this in the following steps.

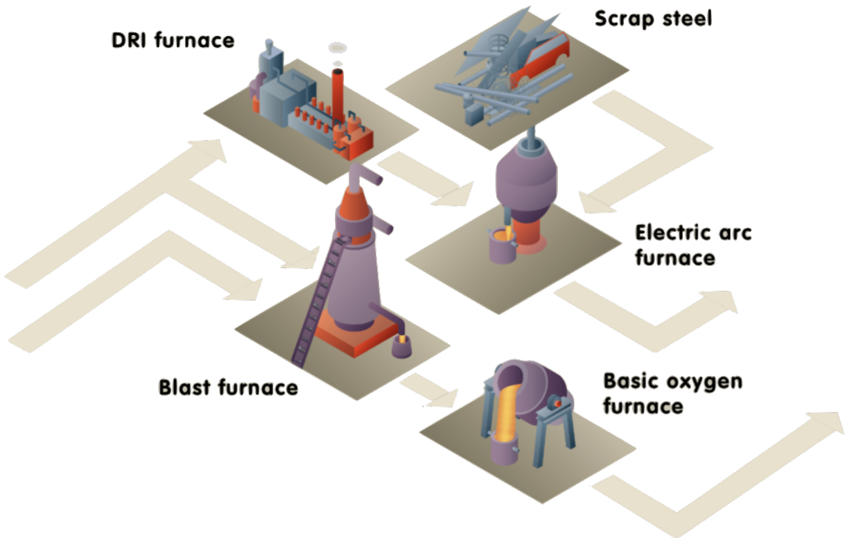


Figure 3.10: Transforming raw material to steel and iron (Arcelor Mittal 2023).

As seen in Figure 3.11, there are **two** types of input into this process, raw material as in *coke* and processed *iron ore* (either sinter or pellets), but also recycled *scrap steel*. The raw material sourced from the previous process goes into either the DRI furnace or the blast furnace. The output from this process will be **crude steel**. The scrap steel goes directly into the electric arc furnace. The output from this process is also called **scrap steel**. The process of these two types of steel will now be more intricately explained.

1. **Crude steel production**

   Firstly, there is the Blast Furnace (BF) to Basic Oxygen Furnace (BOF). The BF removes oxygen from the steel by blasting the continuous feed of coke and sinter with hot air, creating a temperature of 1800-2500℃ (Metallkompetens 2023). The output of the blast furnace is liquid iron which is sent to the BOF, but also $\mathbf{CO_2}$, CO, and a mixture of minerals called slag (Arcelor Mittal 2023). The BOF then reduces the carbon content of the iron, making it ready for casting (Metallkompetens 2023).

   Secondly, there is the DRI method of steelmaking (DRI-EAF route). The process is very similar to the process of sinter as the iron pellets also need a reduction of oxygen. However, instead of coke as fuel, the DRI method uses natural gas as the main fuel for the reduction phase. After the pellets have been reduced, it is then sent to the Electric Arc Furnace (EAF) where it often complements the scrap steel production (Metallkompetens 2023).

2. **Scrap steel production**

   Scrap steel production utilizes scrapped parts from the steel plant, from customers, or other steel products that have been recycled such as cars and home appliances (Metallkompetens 2023). As different types of steel have different grades and chemical compositions, the material is sorted accordingly. The EAF then melts the steel into liquid iron, consequently, making it ready for the following treatment steps. This is one of the many benefits of steel, it is infinitely recyclable (Arcelor Mittal 2023).

Finishing and forming

The final step of the steel-making process is to finish the steel, i.e. prepare it for its end purpose, and form it accordingly. There are several types of steel products produced from a steel plant and the possibilities are "endless".

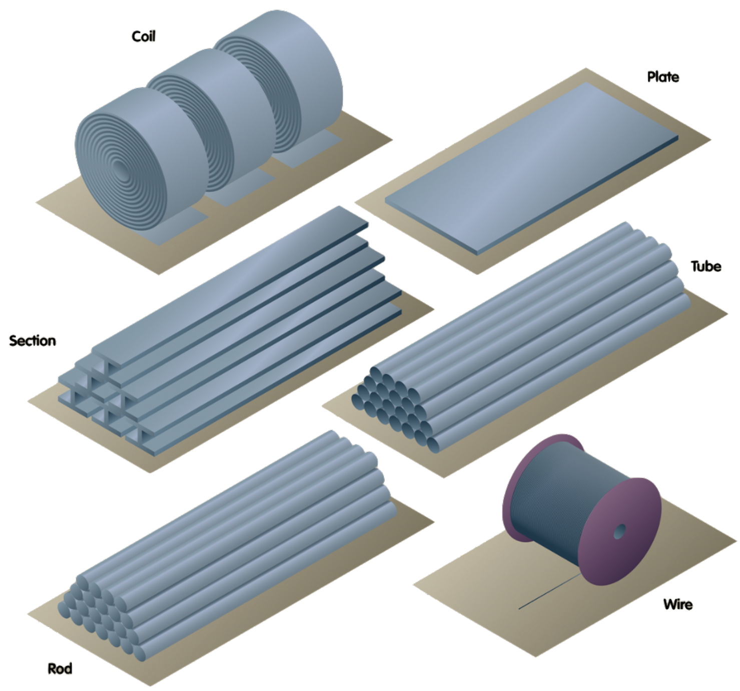


Figure 3.11: Example products from a steel plant (Arcelor Mittal 2023).

3.3.2 Aluminum

The use of aluminum alloys has in recent years increased mainly due to their desired properties. aluminum alloy is characterized by a high strength-to-weight ratio, thermal conductivity as well as ductility. This versatility is the main reason why global aluminum production stands for 25% of the material used in today's constructions (Georgantzia et al. 2021)

The general production process of aluminum can be generalized in two steps. The first one refers to the refining of the bauxite to alumina and the second is about smelting the alumina to create aluminum (Bridenbaugh et al. 2018, Metallkompetens 2023). The different steps will be further discussed below.

The global production of aluminum is shown in Figure 3.12.

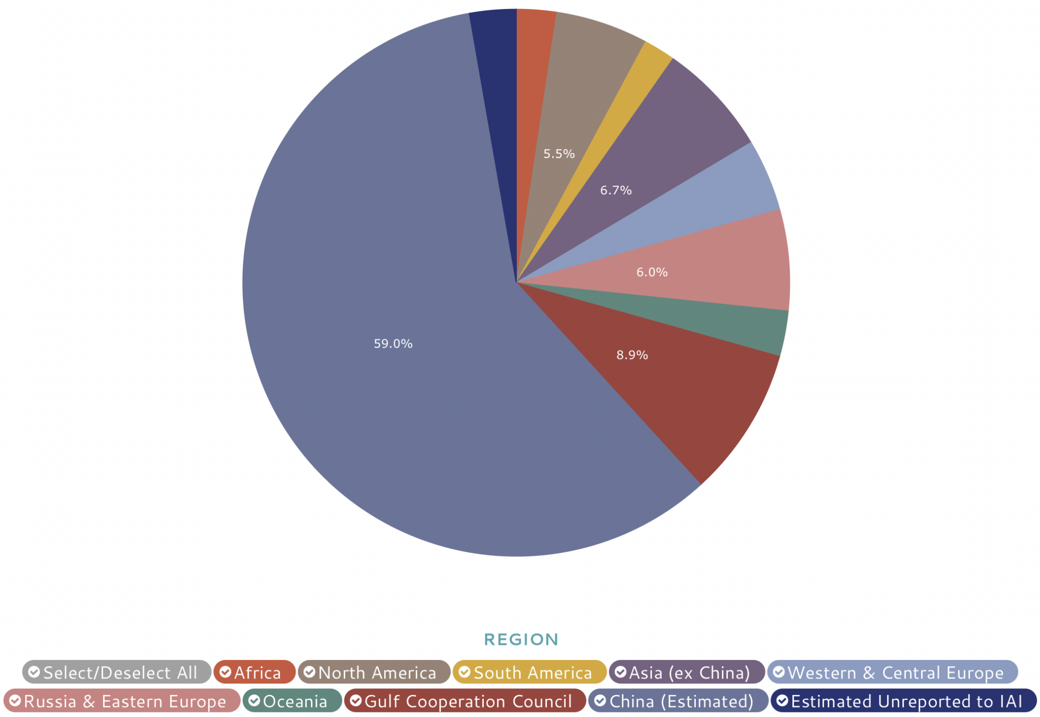


Figure 3.12: Yearly output of aluminum 2022 (The International Aluminium Institute 2022*b*).

As Figure 3.12 illustrates, China alone represents 59% of the total aluminum produced globally which represents 40 387 thousand tonnes for 2022.

Mining of bauxite

The aluminum production process starts with the mining of bauxite, found near the earth's surface. The ore from the mining is then transported to a process plant where it is crushed to further refine the ore as well as facilitate easier handling.

According to Bridenbaugh et al. (2018), nearly 90% of the mined bauxite creates alumina, while the rest 10% can be utilized in other operations, e.g. refractories and abrasives.

Alumina refining

To extract the alumina from the bauxite The Bayer process is used. The process includes *digestion, clarification, precipitation*, and *calcination* (Bridenbaugh et al. 2018).

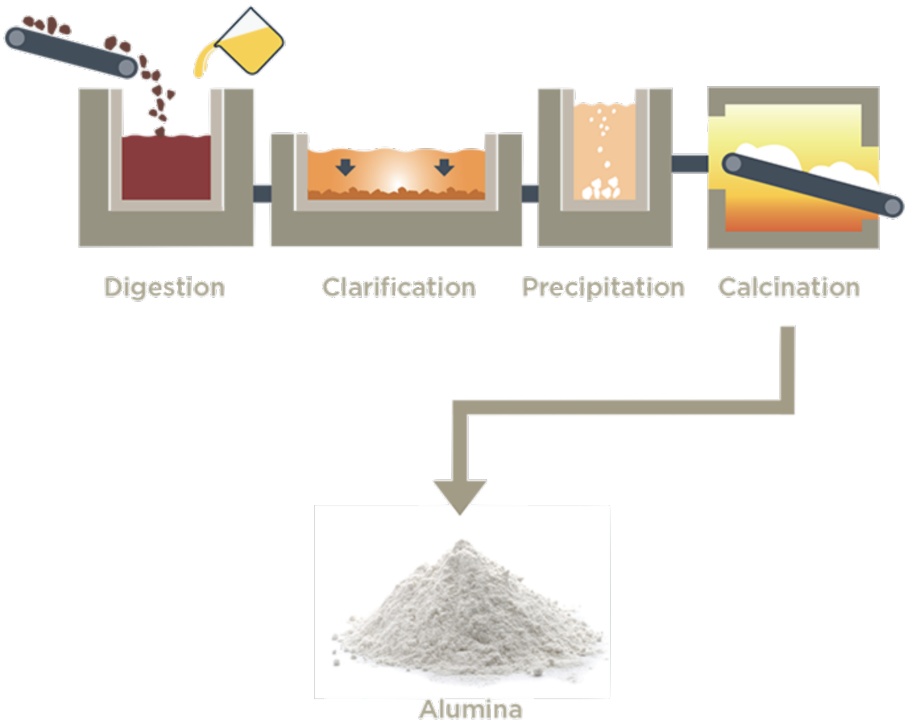


Figure 3.13: The Bayer process (Emirates Global Aluminium 2023).

1. **Digestion**
   To separate the aluminous minerals in bauxite from the rest, a mix of bauxite and sodium hydroxide is pumped into big tanks i.e. *digesters* where steam and pressure are added, causing the aluminous minerals and the sodium hydroxide to react. This creates a liquid supersaturated sodium aluminate solution.

2. **Clarification**

   Here the residue created in the digestion phase is separated from the sodium aluminate. This is done by several techniques and procedures depending on the residue. Crude cyclones, also called sand traps, are used for coarse material. For finer residue, raking thickeners are used with the addition of synthetic flocculants. This creates solid clumps which are removed by cloth filters.

   To further increase the degree of saturation in the alumina solution, the liquid transfers through heat exchangers which cools down the liquid and afterwards it is pumped into precipitators.

3. **Precipitation**

   In this phase, aluminum hydroxide crystals are added to hasten crystal separation. When added, it creates agglomerates with other crystals which separates the crystals from the sodium aluminate liquid.

4. **Calcination**

   The filtered crystals gained from the precipitation phase is calcined in rotary kilns at high temperature (approximately 960°C). Due to the rotation mechanism and the combination of high temperatures, water that is combined in the crystals is removed leaving only pure alumina left.

Aluminum smelting

To produce pure aluminum the alumina needs to be smelted which is accomplished through the Hall-Héroult process. The aim of the method is to break the bond and separate the aluminum from oxygen in the alumina by using electrolysis on the smelted substance. To accomplish this the smelted alumina is poured into special reduction cells accompanied by cryolite (molten salt) at temperatures around 960°C. By adding an electrical current to the solution, the bonds between aluminum and oxygen break resulting in liquid aluminum sitting at the bottom of the cell which then can be extracted for further handling (Emirates Global Aluminium 2023).

The chemical reaction created in the Hall-Héroult process can be seen below (Metallkompetens 2023):

$$2Al_2O_3 \rightarrow 4Al_{met} + 3O_2 \tag{3.1}$$

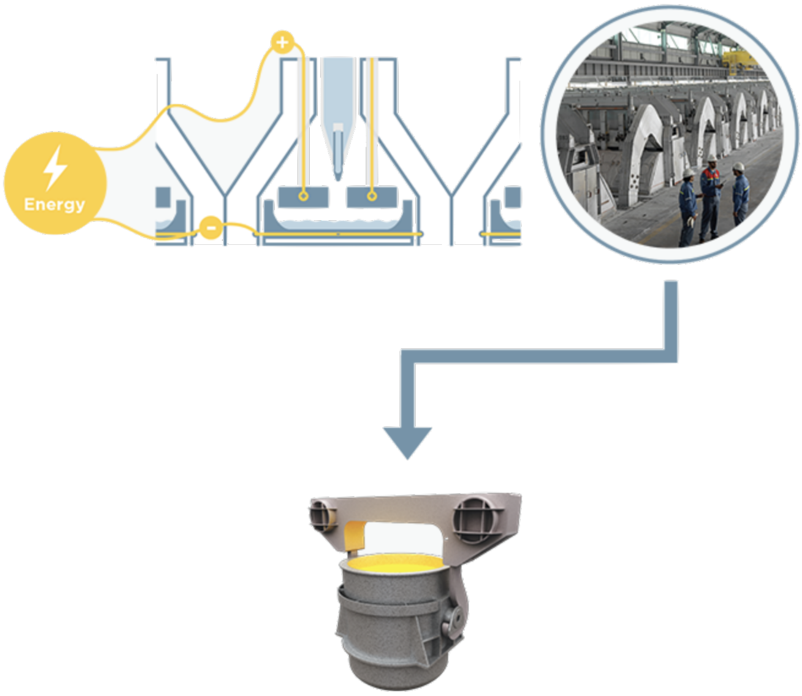


Figure 3.14: The Hall-Héroult process (Emirates Global Aluminium 2023).

Aluminum casting

The extracted pure aluminum is cast into products with several methods. The most common casting methods are die-casting, sand-casting, and permanent mould-casting. Additionally, it is in this step alloys can be added depending on the requested properties the product should have (Bridenbaugh et al. 2018, Emirates Global Aluminium 2023).

3.4 Carbon emissions linked to steel and aluminum production

This section is based on the carbon emissions related to steel and aluminum production globally addressing the carbon emissions related to the different production processes.

3.4.1 Steel

The carbon footprint of global steel production is extensive - accounting for 8% of the global energy demand and responsible for approximately 7% of the global Greenhouse gas (GHG), i.e. 2.6 gigatonnes of CO_2e, in 2022 (IEA 2022). The preeminent emissions factor of steelmaking is the burning of coal in the BF-BOF process (Figure 3.11), with IEA (2022) stating that 74% of the energy used in steelmaking globally comes from the burning of coal. This might seem like a low-hanging fruit in terms of reducing the emissions of CO_2e, however, it is more complicated than that. The burning of coal (*coke*) is a necessary step in the chemical process of steelmaking. The carbon in the coke reacts with the air that is blasted into the blast furnace, creating highly reactive and hot carbon monoxide. The carbon monoxide reacts with the sinter in the furnace, reducing the amount of oxygen in the steel and creating carbon dioxide. Thus, the BF-BOF route of producing steel that currently accounts for 90% of crude steel production is dependent on the emission-heavy incineration of coal (IEA 2022).

Comparing production methods based on carbon emission

As mentioned in section 3.4.1 - most crude steel production takes the BF-BOF pathway, but what is the impact of the other steelmaking processes currently used? The other production routes, natural-gas DRI-EAF and scrap-based EAF, also emit CO_2e when producing steel. However, as these processes use other sources of fuel, the emissions factor of each fuel has to be calculated. Moreover, as the electric arc furnace uses electricity as its fuel, one must take the Scope 2 emissions into account. This means allocating the emissions linked to producing the electricity to the final emissions of the process that utilizes it. Comparing the World Steel Association (2022)'s and IEA (2022)'s numbers we get Table 3.3:

Methodology	BF-BOF	Scrap-based EAF	DRI-EAF
IEA (direct)	1.2t CO_2/t	0.04t CO_2/t	1.0t CO_2/t
IEA (indirect+direct)	2.2t CO_2/t	0.3t CO_2/t	1.4t CO_2/t
Worldsteel Association	2.2t CO_2/t	0.3t CO_2/t	1.4t CO_2/t

Table 3.3: Carbon emissions of steel with different production methods (World Steel Association 2022, IEA 2022).

The indirect emissions (Scope 2) are seen in Table 3.3, hence, the scrap-based EAF route's 10x increase in emissions when including these. Moreover, the values presented in Table 3.3 are based on global averages. Although coke-burning emissions might be similar all over the globe as this process is necessary for the chemical transition from iron ore to steel, the EAF routes might be more or less emission-heavy based on the energy mix in the electricity. In other words, if a scrap-steel producer would maintain production with 100% renewable energy, the carbon footprint would decrease drastically.

Comparing different nation's steel production emissions

Previous paragraphs presented that most of the global steel production currently relies on coke burning. However, there are more factors that impact the final footprint of steel production. The amount of recycled steel in the steel mix, how well the factory preserves energy and material in production, and how the factory treats the emissions are all such factors. Hasanbeigi et al. (2016) stated that:

> *"The results of our analysis show that, for the entire iron and steel production process, the base-case (2010) CO2 emissions intensity was 2148 kg CO2/tonne crude steel in China, 1708 kg CO2/tonne crude steel in Germany, 1080 kg CO2/tonne crude steel in Mexico, and 1736 kg CO2/tonne crude steel in the U.S.."*

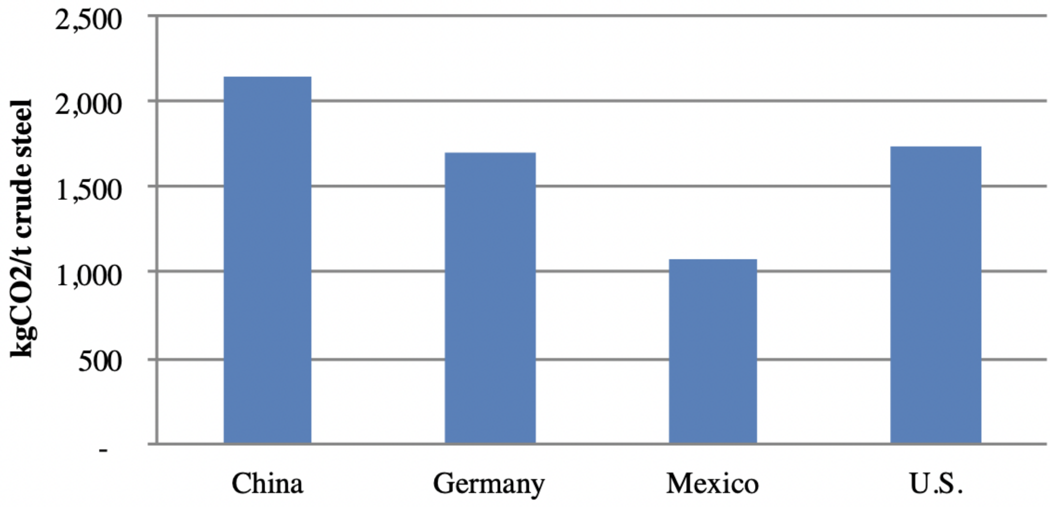


Figure 3.15: The CO_2 intensity of crude steel production, by country in 2010 (Hasanbeigi et al. 2016).

Keeping China's massive output of steel in mind, displayed in Figure 3.7, this shows that their crude steel production emits a lot of CO_2e. Moreover, Hasanbeigi et al. (2016) also investigated the amount of EAF steel production per country. EAF is a significantly more sustainable way of producing steel from a CO_2 emission perspective, as seen in Table 3.3. China had the smallest percentage of EAF production of all the case countries at only 9.68% (Hasanbeigi et al. 2016). Comparing the two production methods for an overall CO_2 emission intensity in steel production by country resulted in Figure 3.16. As displayed in the graph, China's EAF route emits 3x more CO_2 than Germany and Mexico, implicating that the electricity used to drive the EAF in China comes from dirtier energy sources.

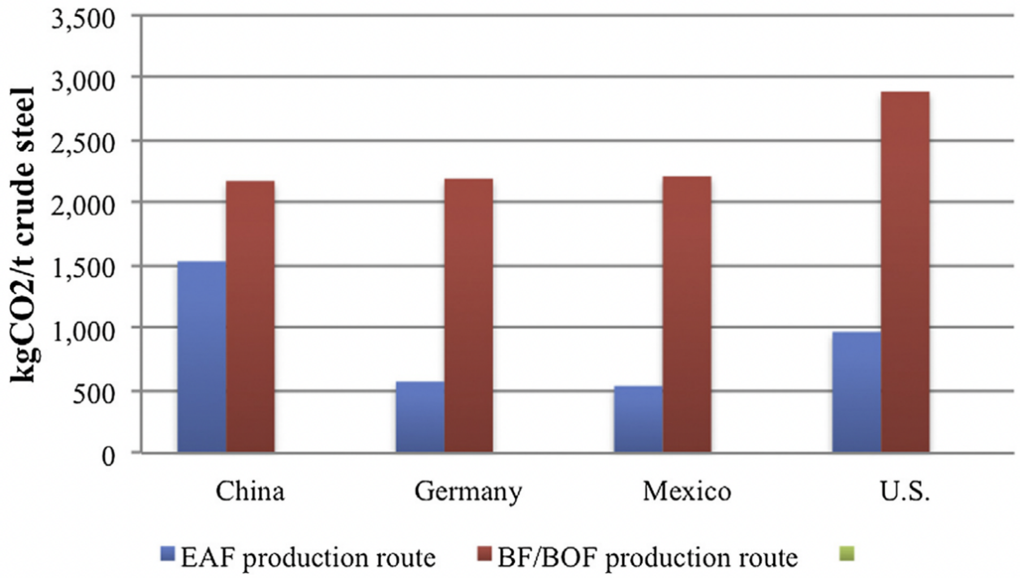


Figure 3.16: The CO_2 intensity of steel production, by country in 2010 (Hasanbeigi et al. 2016).

3.4.2 Aluminum

The production of aluminum with its corresponding processes stands for approximately 3% of the total global emissions. In 2021 the estimated direct carbon emissions (Scope 1) from the aluminum sector were 275 million tonnes CO_2e (International Energy Association 2022), and when including the indirect emissions (Scope 2), the amount of carbon emission reaches 1175 million tonnes CO_2e (International Energy Association 2022, The International Aluminium Institute 2022*a*). As Saevarsdottir et al. (2020) states, aluminum production will continue to see an increase in demand over the future years which will challenge the sector even more.

The relationship between the total production of primary aluminum and the total emitted CO_2e is illustrated in Figure 3.17. In total for 2021, 16.6 tonnes CO_2e per tonne of aluminum was emitted globally, where indirect emissions (Scope 2) accounted for approximately 75% of the total (The International Aluminium Institute 2022*a*). The direct emissions (Scope 1) from aluminum production stand for approximately 25% (4,3 tonnes CO_2e per tonnes aluminum) of the total emissions in the sector (The International Aluminium Institute 2022*a*, World Economic Forum 2020).

Period		Electricity-Indirect	Perfluorocarbon (PFC) - Direct	Process (CO2)-Direct	Ancillary Materials-Indirect	Thermal Energy-Direct/Indirect	Transport-Indirect	Total-Cradle to Gate
	tonnes of CO2e per tonne of primary aluminium							
2021	Mining	0.01	0.00	0.00	0.00	0.04	0.00	0.04
	Refining	0.4	0.0	0.0	0.4	1.6	0.2	2.7
	Anode Production	0.0	0.0	0.1	0.7	0.1	0.0	0.9
	Electrolysis	10.3	0.8	1.5	0.1	0.0	0.2	12.9
	Casting	0.0	0.0	0.0	0.0	0.1	0.0	0.1
	Primary Aluminium	10.7	0.8	1.7	1.2	1.8	0.4	16.6

Figure 3.17: Tonnes CO_2e emitted per tonne produced primary aluminum (The International Aluminium Institute 2022*a*).

As illustrated in Figure 3.17 and Figure 3.18, the process responsible for the most emissions is the smelting process, which accounts for 77% of the total emitted CO_2e globally. Additionally, the largest part of that number is connected to Scope 2 emissions and the electricity used to power the process (World Economic Forum 2020).

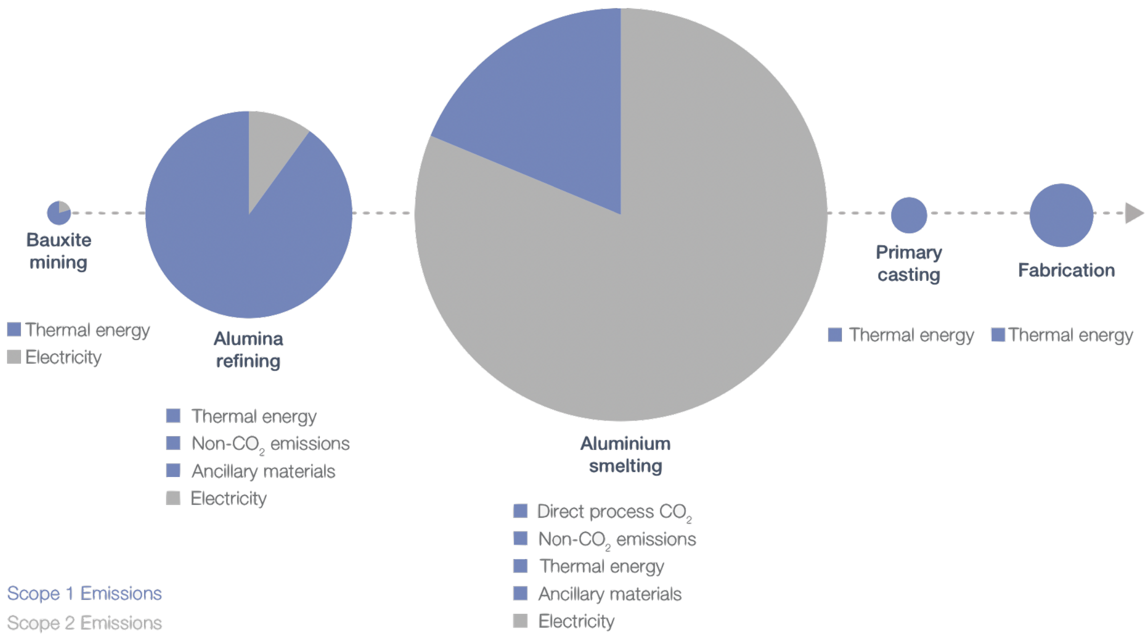


Figure 3.18: The CO_2e emissions in aluminum production (World Economic Forum 2020).

The reason for the big share of CO_2e in the smelting process is heavily connected to the large amount of aluminum production in countries reliant on fossil fuels (Saevarsdottir et al. 2020). With China producing 59% of the global primary aluminum, the emissions from the smelting process are weighted towards their procedures and techniques when extracting energy. By observing Figure 3.19, where the smelting power mix (GWh) is combined with the primary aluminum production for the year 2019, the biggest source of electricity is coal. When looking at electric power holistically i.e. the whole aluminum production sector in Table 3.4, coal accounted for 61% globally in 2018, while hydropower has decreased over the past few decades (Saevarsdottir et al. 2020). As Table 3.4 shows, the industry has seen a transformation regarding the choice of power supply. From using more renewable sources in the late 20th century to the non-renewable source being the vast majority today.

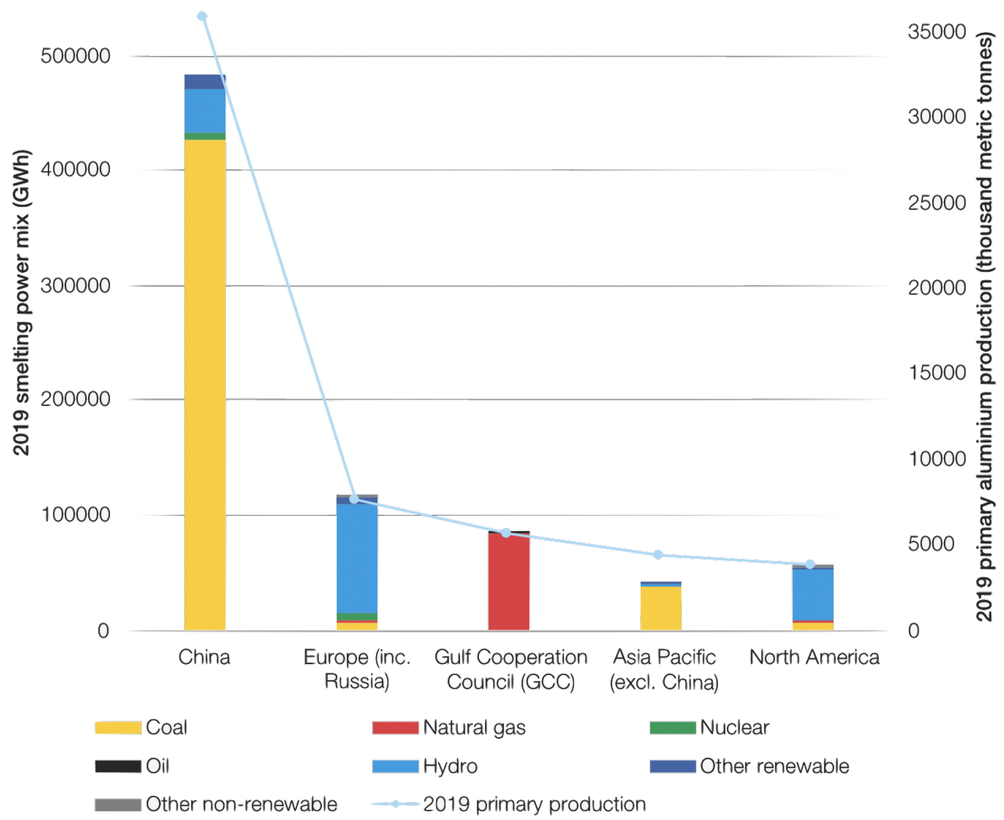


Figure 3.19: The global power mix in the smelting process and aluminum production (World Economic Forum 2020).

Sources of electric power in the global aluminum production						
	Fossil energy sources (%)			**Low emissions sources (%)**		
Year	**Coal (%)**	**Natural gas (%)**	**Oil (%)**	**Hydro (%)**	**Other renewable (%)**	**Nuclear (%)**
1980	25	8	10	51		6
1990	34	4	1	56		5
2000	40	8	0.7	46		5
2010	51	5	0.07	41		2
2014	58	10	0.14	31		1.2
2016	61	10	0.06	27	1.0	1.5
2018	61	10	0.02	26	0.9	1.3

Table 3.4: Sources of electric power in the global aluminum production (Saevarsdottir et al. 2020), *modified by the authors.*

When investigating the average emissions from aluminum production in China, a study made by Peng et al. (2022) presented that the average emissions in China corresponded to 15,9 tonnes CO_2e per tonne of aluminum produced in 2020. According to the study, recycled aluminum stood for 13,9% of the total aluminum production and the emissions of recycled aluminum accounted for 5,4% of those of primary aluminum (Peng et al. 2022).

Furthermore, the Peng et al. (2022) presented region-specific data regarding primary aluminum and recycled aluminum for the year 2019, Figure 3.20. The primary aluminum production was mainly concentrated around the northern and central west regions of China where the regions Shandong and Xinjiang accounted for 40% of the national production (Peng et al. 2022). The major production areas when observing the production of recycled aluminum are the southeastern regions where Jiangsu, Shandong, and Guangdong accounted for 35% of the national production.

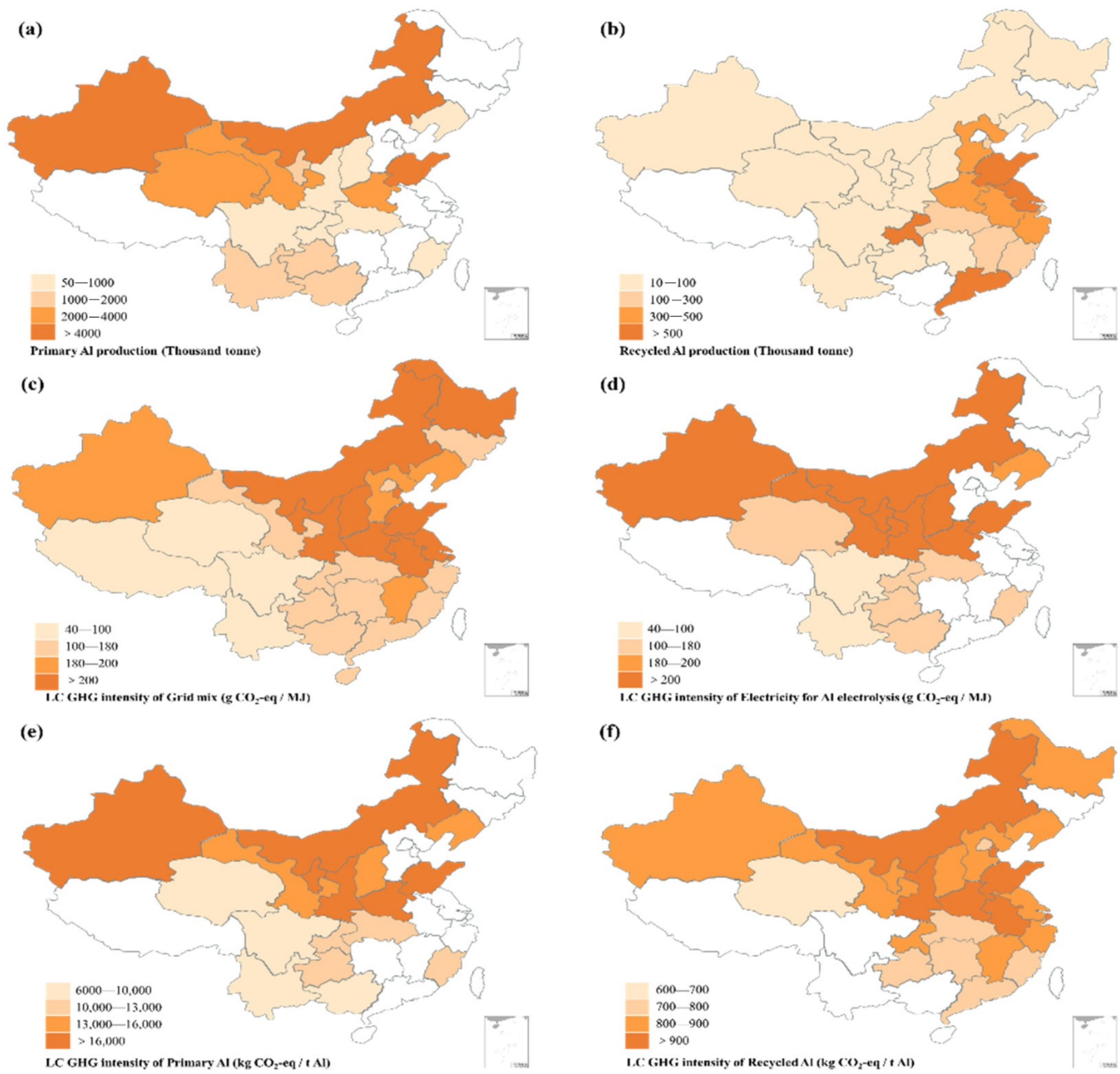


Figure 3.20: Aluminum sector in China (Peng et al. 2022).

3.5 Carbon Border Adjustment Mechanism - CBAM

The following sections are based on the legislation proposed by the European Commission in Brussels on 14 July 2021 regarding the implementation of a Carbon Border Adjustment Mechanism (CBAM) (European Commission 2021*b*) supplemented with several amendments adopted by the European Parliament (European Commission 2022).

3.5.1 Purpose of CBAM

When the European Union first launched EU ETS the aim was to address the climate challenges in the world. The system has a significant role in addressing and identifying the risk of carbon leakage but lacks in creating incentives for companies to invest in greener production both at home and abroad. This is where CBAM comes in, as a complement for ETS, to address these issues (European Commission 2021*a*).

As previously stated in section 1.1.2, the primary purpose of CBAM is to mitigate carbon leakage as well as level the playing field for producers within the EU. CBAM is an initiative, among 13 other EU proposals, introduced by the European Commission to meet the climate targets for 2030. The set of proposals is called the "Fit for 55 package" and refers to the EU's mission to decrease carbon emissions by 55% by 2030 (in comparison to 1990) and be completely carbon neutral by 2050 (European Commission 2021*b*, Sato 2022). The package covers different fields such as climate, transport, energy, as well as taxation (European Commission 2020).

3.5.2 The scope

The scope of CBAM is in principle related to imports of goods from non-EU countries with, as of today, a focus on five industrial sectors: aluminum, cement, fertilizers, iron and steel, and electricity. According to European Commission (2021*b*) it may apply to additional industries in the future, but the European Commission believes that these sectors have a high risk of carbon leakage and carbon emissions that needs to be mitigated (Schippers & De Wit 2022). To further specify the scope and decrease the administrative complexity, the European Commission has specified the targeted goods that will be affected by referring to their Combined Nomenclature (CN) codes in combination with a product specification

(European Commission 2021*b*). In general, these products are materials that have not yet been processed, in other words not finished products (Schippers & De Wit 2022).

Furthermore, the legislation states that the carbon emissions connected to CBAM will only be direct emissions (Scope 1) from the production of goods up until the import of the goods to the European Union (European Commission 2021*b*). Depending on the evaluation that will be made by the European Commission after the transition period, a decision will be made regarding the expansion of CBAM to also include indirect emissions (European Commission 2021*b*).

3.5.3 How it works

CBAM can be seen as an extension of the current EU ETS (Schippers & De Wit 2022). In short, European companies that source goods within the sectors that CBAM covers will have to give up climate credits (CBAM certificates) that cover the embedded emissions produced from the sourced goods (Schippers & De Wit 2022). These allowances/credits are bought from a national authority, creating a "CBAM-fund" used to support businesses and operations working towards mitigating the climate crisis. Moreover, the CBAM certificates can be traded on a weekly basis between companies and the national authority only, dissimilar to the ETS certificates that can also be traded between companies on an open market (European Commission 2021*b*). Additionally, on an annual basis, companies will have to disclose that the certificates that they have handed to the national authority stand accordingly to the emissions that their sourced goods account for (European Commission 2021*b*).

With that brief overview in mind, a deeper investigation of the areas of interest will be disclosed in the following sections. Please note that these sections will focus on how CBAM works for the import of steel and aluminum goods, and not all of the product categories affected by CBAM.

Calculating emissions in accordance with CBAM

The European Commission (2021*b*) stated three ways a company can determine its carbon emissions to stay in accordance with CBAM. As mentioned previously, **only** direct emissions (Scope 1) from production are covered by CBAM.

1. **Specific data on emissions**

   If the company in question is able to collect specific and correct data on the carbon emissions originating from the goods they have procured, they shall use the following equations to calculate the amount of CO_2e they need to account for with CBAM certificates.

   For **simple goods**, i.e. goods that only need raw material and fuel that has no embedded emissions, only the direct emissions (Scope 1) are calculated. This is done using the following formula:

   $$SEE_g = \frac{AttrEm_g}{AL_g} \tag{3.2}$$

   SEE_g = Embedded emission data for goods g, unit: CO_2e/tonne
   $AttrEm_g$ = The attributed emissions of goods g
   AL_g = The activity level of the good g

   For **complex goods**, i.e. goods that require the input of other simple goods in their production, another formula is used:

   $$SEE_g = \frac{AttrEm_g + EE_{InpMat}}{AL_g} \tag{3.3}$$

   EE_{InpMat} = The embedded emissions in the input material that is consumed in the production process of the complex good.

2. **Default values by country of origin**

   Default values must be applied when the authorized declarant is unable to accurately ascertain actual emissions. These values must be increased by a markup, which will be decided in the implementing legislation for this Regulation. The default values are set at the average emission intensity of each exporting nation, for each good specified by the European Commission (2021*b*), except for electricity.

   Only real values shall be used when establishing default values. It is possible to use literature values when actual data is lacking. Before gathering the necessary data to establish the pertinent default values for each category of goods affected by CBAM, the European Commission shall publish a method used to account for waste gases or greenhouse gases utilized as process inputs. The best data that is currently available will be used to determine default values, and the values must be updated on a regular basis and be based on the most recent and trustworthy information.

3. **Default values in lack of other data**
   If no other data is available, neither actual emission data nor country/region-specific emission data, default values based on the average emission intensity of the 10% worst-performing EU installations for that kind of commodities shall be applied. This is seen as the worst-case scenario and shall incentivize companies to start tracking their embedded emissions.

Pricing, penalties, and surplus

When the company has managed to identify and quantify its emissions, the act of purchasing and declaring CBAM certificates can start. The price of the certificates will fluctuate as it is mirroring the EU ETS certificate price. Currently, one ETS certificate covers one tonne of CO_2e, thus, the pricing is often referred to as "*the cost per tonne of CO_2 emissions*" As displayed in Figure 3.21 the price of the ETS certificates has steadily increased over the last few years, however, as with any open-market product - the past is not a guarantee for the future.

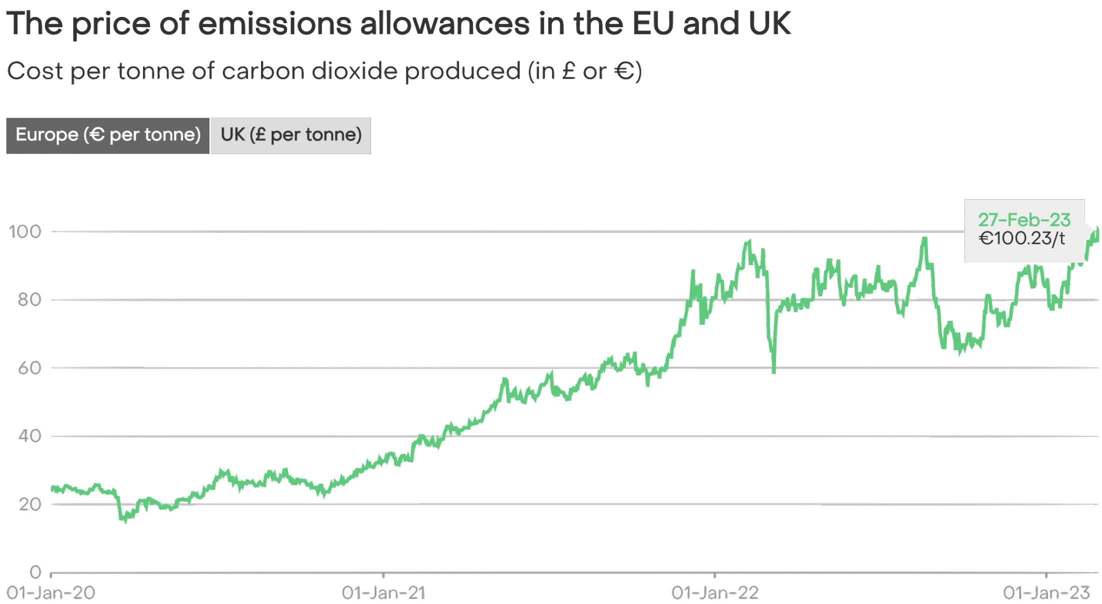


Figure 3.21: The EU ETS pricing from 2020 - 2023 (EMBER 2023).

The process of declaring emissions and CBAM certificates is rather straightforward. The declaration is due on the 31st of May for the previous calendar year and shall be handed to the responsible national authority (*not decided yet*). The declaration shall be comprised of the following:

1. The **total weight in tonnes** of each of the imported goods from the year preceding the declaration.

2. The **total embedded emissions** in each of the goods, expressed in tonnes CO_2e per tonne of good. These emissions shall be calculated in conformity with section 3.5.3.

3. The **total number of surrendered CBAM certificates**, which shall correspond to the total emissions expressed in point 2, after reduction based on paid carbon tax in the country of origin and free allowances issued during the transition period (further explained in the following section). If the company has paid carbon tax in the country of origin, documentation of said transaction must be demonstrated and certified by an independent third party.

If a company **fails** to surrender sufficient CBAM certificates, the remaining certificates, as well as an excess emissions penalty for the failure to correspond to the legislation, must be subsequently paid for (Schippers & De Wit 2022). The excess emissions penalty is currently stated as 100 per tonne of CO_2 not accounted for in the final declaration.

On the contrary, if a company has handed in a **surplus** of CBAM certificates, the responsible authority shall re-purchase the excess certificates if requested. These certificates shall be re-purchased at the same price as the company paid for them at the time of purchase. These certificates can also be saved up until one year before being canceled, meaning that the company can choose to save them and reduce their purchases of certificates for the following year. However, the company's ability to sell CBAM certificates back to the responsible authority is capped out at a third of the total number of certificates purchased during the preceding year, mitigating the risk of companies stocking up on CBAM certificates when cheap.

Moreover, to ensure a continuous market, each authorized declarant shall ensure that the amount of CBAM certificates in their account at the responsible authority covers at least 80% of the embedded emissions of each quarter.

Year	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Reduction rate	2.5%	5%	10%	22.5%	48.5%	61%	73.5%	86%	100%

Table 3.5: Phase-out of free EU ETS allowances.

Transition period

A simplified version of CBAM will be implemented in 2023, solely requiring reporting duties from companies but without any purchasing of CBAM certificates. This period of reporting duties will last until the 31st of December 2025. Furthermore, to enable implementation of the "real" CBAM that is both compliant with WTO regulations and grants companies time to adjust to the new legislation, a gradual phase-in will be put in place. The phasing-in period would start in 2026 and last, until 2034, working parallel to the phase-out of the current EU ETS system. During this time free EU ETS allocations would be granted to the affected companies, initially covering 100% of the emissions but incrementally decreasing per year. The rate of reduction of the free allowances will commence as follows:

3.5.4 Risks

Despite the obvious benefits regarding the decrease in carbon leakage and a leveled playing field among EU importers, the implementation of CBAM has its constraints and risks.

As previously stated, CBAM concerns the direct emissions (Scope 1) created at a production site outside the EU. The calculation of these emissions puts a high administrative burden and responsibility on actors upstream of the supply chain which in many cases may not be feasible (Sato 2022). The reason for this is that each stage of the process, with regard to carbon emissions, needs to be reported and linked to the specific product type. Due to that, the responsibility ultimately falls to the producers, to identify the emissions of the imported goods by obtaining data and relevant information from their suppliers (Sato 2022). Moreover, this might compel suppliers to provide information that otherwise would have been confidential for the downstream producers. According to Sato (2022), besides the actual carbon emissions, producers may be forced to share information on calculation procedures, vouchers, and other relevant information which will create confidentiality issues. Furthermore, Eicke et al. (2021) also assesses this, and states that companies in countries with effective analytical systems and publicly available data on emissions will have decreased administrative complexity and expenses in comparison to companies and countries who need to implement such systems from the ground up.

Additionally, it is not necessarily that countries with softer carbon emission policies emit more GHG than EU producers. The total GHG emissions do not only depend on the targets set by a specific government, but also on the input material, operating equipment and efficiency, and technology (Sato 2022). Moreover, Sato (2022) states that in practice this means that CBAM may levy products that do not have a significant role regarding carbon leakage.

An additional risk with CBAM concerns countries' vulnerability which may increase with the high carbon intensity of energy systems. According to Eicke et al. (2021) it will be expensive and difficult to break away from carbon-intensive systems. As stated by Åhman et al. (2017) this will ultimately lead to developing countries taking the main responsibility for the decarbonization of the concerned sectors by investing in technology to transform them. However, a way to avoid these expenses for developing countries would be to exclude some countries from CBAM which on the other hand may not be aligned with the regulations set by the World Trade Organization (WTO) (Eicke et al. 2021).

3.6 Investigation framework

The aim of this chapter was to find previous research that somehow connects to the presented UoA, provides guidance to the research questions and ultimately aids this study's progression toward understanding the research phenomenon. It did so by identifying gaps in the current research and laying a theoretical foundation on which the empirical chapter and the analysis can stand. The conclusion will summarize the most important points from each part of the theory chapter in a concise manner.

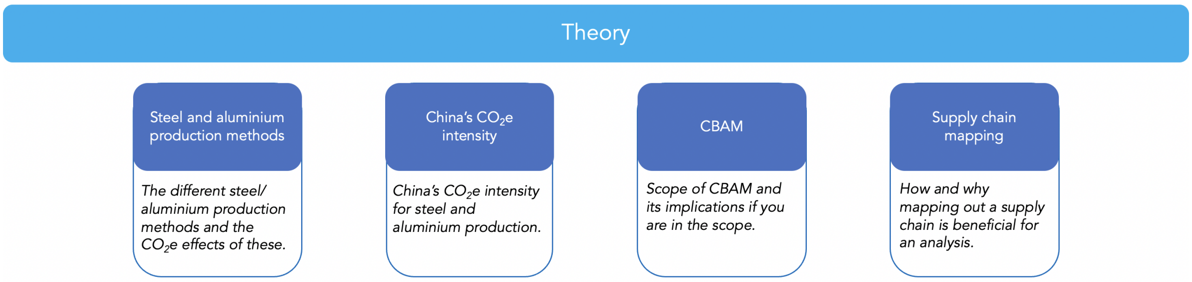


Figure 3.22: Summary of the relevant topics stated in the theory chapter (*Source:* authors).

The first section investigated how steel and aluminum are produced, how these processes can be differentiated, and what the environmental impact is. The section gave a better understanding of which processes are crucial for the production of the materials and where the emission-heavy sections of the production are located. The acquired knowledge in these areas will be crucial both when researching the phenomenon and when conducting the analysis.

As the thesis is targeting the aluminum and steel component production in China, the section concerning the CO_2e intensity of the production methods in China resulted in key insights. Both the current status of Chinese producers' emission intensity and the benchmark with other countries' intensity collectively contributes to an as-is analysis of the emissions linked to steel and aluminum production today. It shows that although the main production process of countries can be similar, factors such as energy- and material handling and recycling can dramatically impact the CO_2e intensity of the production.

The presented theory regarding the CBAM is mostly based on the legislation proposed by the EU Commission and the amendments of the legislation made in collaboration with the EU Parliament. The gathered information discerned the essence of the legislation, highlighting **why** it exists, the **scope**, **how** it works in practicality, and potential **risks** identified by previous researchers.

The section regarding impacted supply chain functions resulted in a core of SCM knowledge that will come in handy for the analysis. Several aspects of SCM were brought up, such as supply chain mapping for strategic actions, which factors impact the design of a supply chain, how trade regulations can imply constraints on a supply chain, etc. Moreover, the frameworks and knowledge gathered in this section identify what type of empirical data is needed to successfully and holistically analyze the phenomenon.

4 Empirical Study

This section will present the gathered data described in section 2. It revolves around the information and data findings from ACIT, needed to execute the analysis. The data collected are both quantitative and qualitative and are connected to the findings in the literature review.

4.1 Supply Chain Management at ACIT

Atlas Copco is in many aspects a decentralized company with several business areas and management teams. The decentralized approach funnels down throughout the company with the motto "*The one closest to the problem is closest to the solution*". However, for matters such as SCM and logistics, the ACIT business area has a centralized approach. For ACIT, the SCM activities are executed from the Atlas Copco headquarters. The activities are divided between a few teams, depending on the nature of the activity. For example, most parts of the upstream SCM are executed by the global sourcing team, whereas matters such as inbound logistics to the factories and inventory management are done by the logistics team. Upon further investigation, it could be concluded that the impacted activities linked to the research questions are handled by the *Strategic Global Sourcing* team.

4.1.1 ACIT Strategic Global Sourcing

The strategic global sourcing division is a category-driven division, i.e. the division is divided into subcategories with separate focuses, each contributing to the whole. The subcategories are *Strategic Buyers*, *Indirect materials and services*, and *Supplier value engineering team*, graphically presented in Figure 4.1.

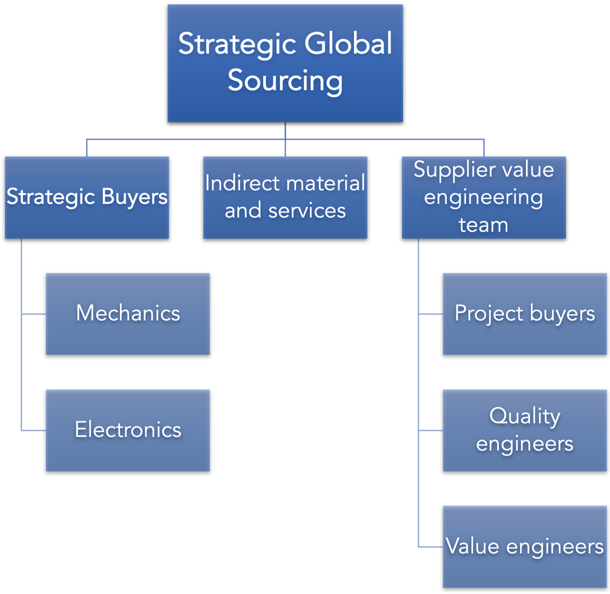


Figure 4.1: Strategic global sourcing's categories. *Source:* authors.

First, the strategic buyers are responsible for the "daily purchasing" activities, i.e. sourcing that feeds the factories with goods needed in the line production. The strategic buyers are divided into two subcategories. The mechanic's category is focused on sourcing components that go into the products, often consisting of one or few materials, such as casted components, Computer Numerical Control (CNC) components, raw materials, etc. The electronics category is responsible for sourcing materials and components with electrical attributes, e.g. cables, semiconductors, screens, sensors, etc. Second, the indirect sourcing of materials and services category is responsible for the sourcing of everything that **does not** go into the final products of ACIT. Examples of such goods or services are; machinery, Software as a Service (SaaS) platforms, consultancy services, etc. Third, the supplier value engineering team consists of project buyers, responsible for the sourcing of goods for projects such as start-up R&D projects, quality engineers that are responsible for the quality of the sourced goods and making audits at supplier sites, and value engineers that work closely with the R&D-team trying to cut costs by optimizing the sourcing.

The idea behind the category-driven sourcing structure is that each buyer shall become an expert in the category and the suppliers within that category, mitigating the risk of "losing" negotiations due to a poor understanding of the market they are trying to source in. In most cases, the different categories have divided the suppliers among themselves to further extend the professional knowledge of each buyer in each supplier's business area.

After conducting interviews with several employees within ACIT's sourcing division, the aim of making more sustainable decisions in all activities has become evident. There are teams actively working with sustainability, and the current focus is to better understand how to become more sustainable and transparent in the upstream supply chain. The focus on sustainability and transparency partially comes from the fact that the Atlas Copco group has committed to the Science Based Target initiative, meaning that they on an annual basis have to disclose carbon reduction targets and their progress, information which in turn is validated by a third party.

4.1.2 Requirements on suppliers

To uphold the high-quality standards of their products, ACIT sees choosing a supplier as a crucial activity in the sourcing process. Currently, the suppliers are evaluated based on five primary areas; *Quality, Delivery, Cost, Product- and process development, and Sustainability (QDCPS).* These areas are continuously evaluated throughout the partnership and the information put forward by the suppliers is validated through audits made by ACIT's quality engineers.

Moreover, ACIT puts requirements on suppliers to be ISO-9001 and ISO-14001 compliant. These ISO certificates ensure that the supplier has realized the necessary processes regarding quality and working environment respectively.

4.1.3 Atlas Copco Industrial Technique's purchasing process

The first step of ACIT's purchasing process is to locate the correct buyer to satisfy the internal demand for goods. As stated previously, the purchasing organization is category-driven, in addition, there are different types of purchasers for different types of purchasing activities.

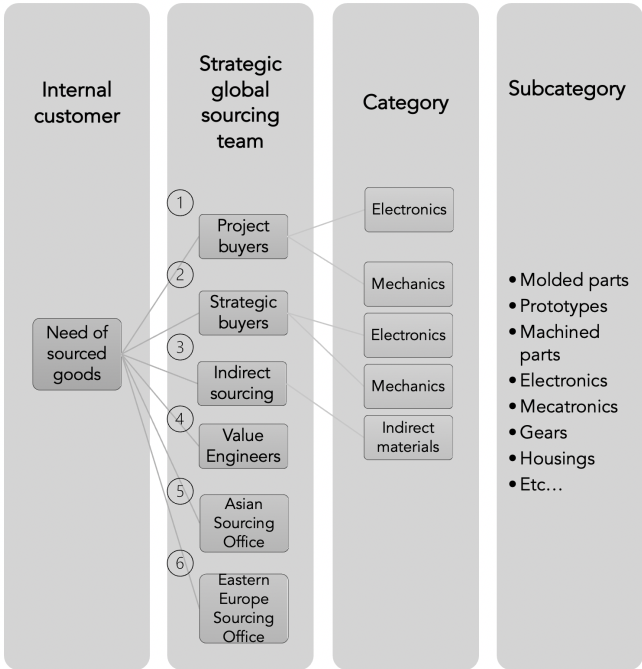


Figure 4.2: Finding the correct purchaser depending on the goods needed. (*Source:* authors)

Each of the numbered roles in the "Strategic global sourcing team"-column presented in Figure 4.2 can be explained as:

1. **Project buyers** - Buyers that source goods for projects such as R&D projects, testing a new supplier's quality, sourcing for low-running products, etc. These buyers often source low-quantity objects, such as prototypes.

2. **Strategic buyers** - Works with the daily need of goods for the factories and warehouses. Often buys large quantities and from preferred partners of the organization.

3. **Indirect sourcing** - Sources indirect material and services to the organization such as machines to the factory, consultancy services, software licenses, etc.

4. **Value engineers** - Executes value-adding activities for the sourcing team. An example of this can be changing a component design in collaboration with the R&D team to lower sourcing costs, but also helping suppliers become more sustainable by collaboration.

5. **Asian Sourcing Office / Eastern European Sourcing Office** - Satellite offices for the sourcing organization, aiding in purchasing processes with suppliers within

their geographical boundaries. An extension of the sourcing organization.

Although Figure 4.2 and the list above separate the different buyers into silos, this is not the case in reality. The sourcing team works cross-functionally between the categories, as components often fit into more than one category depending on their design.

The purchasing process of ACIT is similar to the one presented in Figure 3.4. The process begins with the responsible purchaser issuing a Request for Information (RFI) to relevant suppliers. The suppliers that provide information that meets the criteria of the project best are met with a Request for Quotation (RFQ). The supplier is then chosen based on the presented quotation, their previous partnerships with ACIT, and a revision of their current and previous performance. The revision is based on Key Performance Indicators (KPIs) that ACIT tracks continuously.

ACIT's aim with most suppliers is to develop a partnership where both parties grow and develop. Therefore, as soon as a contract has been signed between the purchaser and the supplier, continuous improvement projects commence. These are reliant on communication, cooperation, and mutual goals. In addition, ACIT's sourcing division carries out several TCO projects yearly. The idea behind these is to reduce costs through synergies with suppliers and cross-functional internal activities.

4.1.4 Product characteristics

The list of products sold by ACIT is vast. The business area provides hardware products such as industrial power tools for manufacturing, machine vision solutions, assembly solutions, and products for quality control, but also service solutions and software connectivity, pushing toward Industry 4.0. In addition, all products aim to create sustainable productivity for the customers.

The company's market vision is summarized in the words *"First in Mind - First in Choice"*. The first in mind statement refers to ACIT's vision of being the most recognizable company in its market segment and the first in choice statement implies that ACIT's products shall be the superior investment compared to competitors. The vision is deeply incorporated into ACIT's go-to-market plan, consequently affecting product characteristics. Currently, ACIT aims to become a reliant partner to their customers, tailoring the products to fit their specifications and making sure that matters such as service level, flexibility, ergonomics, quality, etc. are at the highest level. If interviewed employees at ACIT were to categorize their products in general, the products would be classified as **innovative**, pushing the market forward. Furthermore, interviews with members of the sourcing team stated that the varying demand is high for most products, making the sourcing of goods pressured and time-critical at times.

4.1.5 Steel and aluminum components sourced in China

The sourced goods that are in the scope of this thesis are steel and aluminum components that are sourced from companies in China. The components are purchased by category buyers from the Mechanics team seen in Figure 4.1. When asking employees within this team about the characteristics of these components they described them as:

> *"...relatively simple goods, being almost 100% single material components."*, *"...easily sourced components, in the sense that many suppliers can deliver them according to specification."* and *"...pretty linear pricing, size, and required machining (lead time) are the biggest cost drivers."*

4.2 Quantitative data on the upstream supply chain

Data pertaining to sourced goods from China has been extracted from the analytics solution system, a business intelligence (BI) system used for material resource planning (MRP). It is possible to retrieve various data and the status of performance indicators over time from the system, however, in this paper, the authors have limited the investigation to the sourced goods from the preceding year, i.e. 2022. The manager for the Asia Sourcing Office (ASO) stated that seven of ACIT's steel and aluminum component suppliers in China are responsible for at least 95% of the sourced components. This was also confirmed by looking at the sourcing data from analytics solution system shown in Figure 4.3. Therefore, these seven suppliers will be focused on in the analysis.

Figure 4.3: A piechart portraying how the identified suppliers each contribute to the total sourcing spend in their category. (*Source:* Analytics solution system)

After conducting interviews with several sourcing employees, sourcing managers, and ACIT's ASO, the upstream supply chain of Chinese aluminum and steel components could be unraveled. These are presented with relevant data in Figure 4.4, however, names of the companies will not be presented for either Tier 1 or Tier 2 suppliers due to agreements with ACIT.

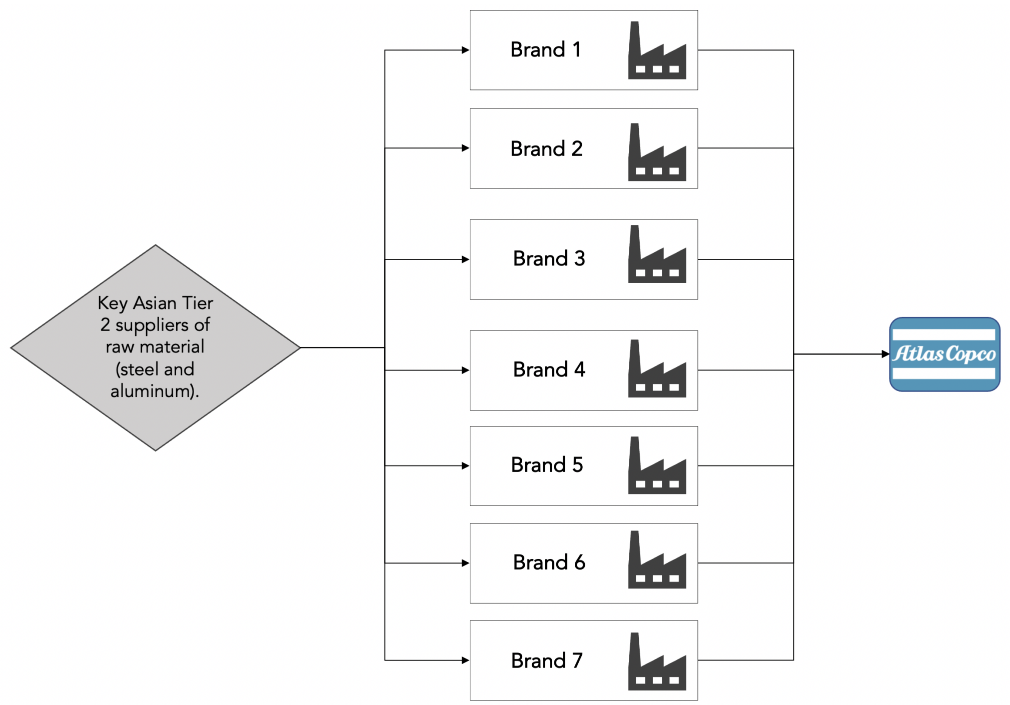


Figure 4.4: Basic data retrieved from suppliers and graphically portrayed flow of goods-which will be used in the analysis (*Source:* authors).

Moreover, to complement the findings from the analytics solution system and the interviews, a questionnaire was sent to the key suppliers which can be seen in A3.1. The creation of the questionnaire was connected to the research questions asking for specific information regarding, Tier 2 suppliers, embedded emissions, and raw material weight used in producing ACIT components. This data was not available in the information systems. A summary of the answers can be seen in Table 4.1.

	Brand 1	Brand 2	Brand 3	Brand 4	Brand 5	Brand 6	Brand 7
Amount of aluminum (kg)	8768	1030	4	8612	0	9525	8000
Amount of steel (kg)	0	37912	63	0	3156	11396	20000
Production yield (%)	85	40,8	20	40	22	11 & 19	39
Supplier of raw material	Conf.	Conf.	Conf.	Conf.	Conf.	Conf.	Conf.
CO_2e/kg raw material from suppliers	0,632	N/A	N/A	N/A	N/A	N/A	364 000

Table 4.1: Summary of the answers from the questionnaire sent to key suppliers (*Source:* questionnaire).

With the key suppliers identified, a graphically portrayed dataset combining the data from the analytics solution system, ERP, and the survey (shown in A2.1, A2.3, and Table 4.1 respectively). The dataset depicts the weight of each supplier's components by combining the material number for every component sourced from China and its corresponding net weight, resulting in Figure 4.5:

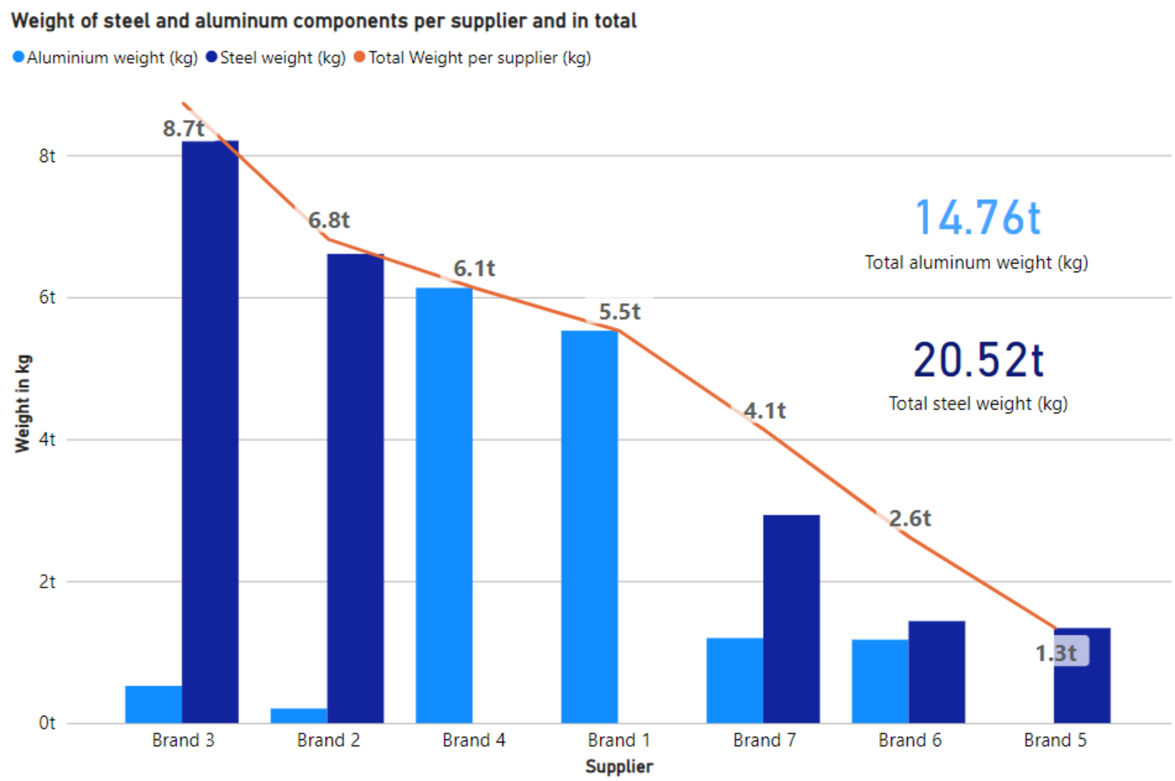


Figure 4.5: The weight of the sourced components from each supplier, presented in tkg. *Source:* authors).

As illustrated in Figure 4.5, the total weight of sourced aluminum from the seven biggest suppliers in China accounted for **20.52t kg** and respectively **14.76t kg** for steel.

Furthermore, using the findings regarding the suppliers from the questionnaire, a mapping could be done, locating all suppliers in China. The mapping is illustrated in Figure 4.6 and combines the geographical location of both Tier 1 and Tier 2 suppliers.

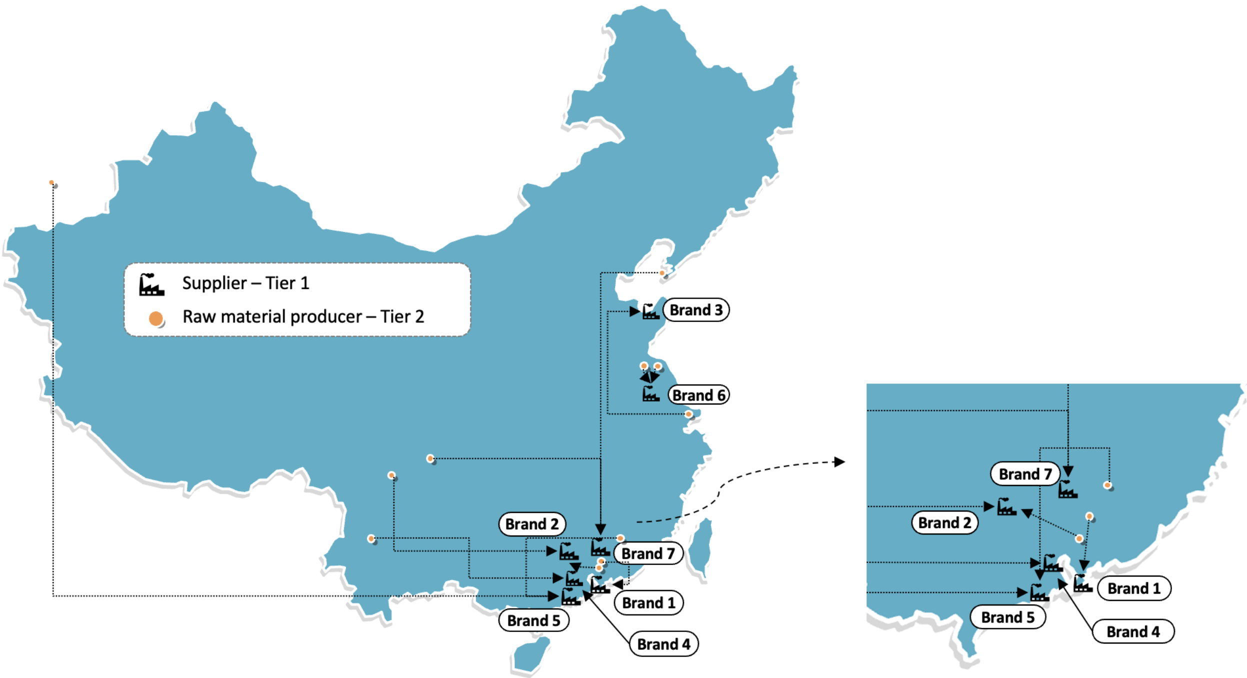


Figure 4.6: Mapping of the upstream supply chain in China (*Source:* Questionnaire).

4.3 Quantitative data on the embedded emissions

The second research question of this thesis concerns the embedded emissions of ACIT's steel- and aluminum component supply chain from China, and how these can be ascertained. The literature review resulted in averages that can be used for a theoretical analysis of the embedded emissions if the production route of the raw materials can be decided. Through interviews and data collection from the Tier 1 suppliers of ACIT, it could not be concluded that the Tier 2 suppliers use a certain production route, hence, an assumption was made in collaboration with ACIT. The assumption was that all Tier 2 suppliers produce solely crude steel and primary aluminum. Although this might not be accurate for all of the suppliers, this would generate the worst-case scenario regarding the embedded emissions, which is what ACIT is most interested in. Therefore, it is assumed that none of the Tier 2 suppliers are using recycled material in their production.

4.3.1 Carbon-tool

The previously mentioned questionnaire asked the suppliers to disclose the embedded emissions in their components. Most of the suppliers were not yet able to answer this as they do not have the tools adequate to measure or even estimate such emissions. However, ACIT's sustainability department was able to provide a newly developed tool that estimates the carbon impact of products sold by ACIT. This tool is known as the carbon-tool.

The carbon-tool is an ISO14067-certified tool that has data from the entire Atlas Copco group and will be used to measure the carbon footprint of ACIT's tools during their lifecycle. Although the main function of the tool is to provide a measure of the footprint in its entirety, it can also be used to see the carbon impact of the components that make up the products, i.e. its embedded emissions. This information will be used in the analysis to contrast the theoretical values found in the literature review to the values estimated by ACIT's carbon-tool, which is based on group-wide supplier information, and validity checked by a third party.

From the carbon-tool, embedded direct emission factors for steel and aluminum were retrieved. These emission factors are presented in Table 4.2.

Material	Direct emissions (kg CO_2e/kg)
Steel	**1.27**
Aluminum	**13.06**

Table 4.2: Steel and aluminum emission factors from ACIT's Product Carbon Footprint tool.

4.3.2 Total direct emissions from the sourcing of components

Using emission factors from both the literature review and the carbon-tool, a calculation of the total embedded emission of ACIT's sourcing of steel and aluminum components was calculated. The calculated emissions are complemented with the CBAM certificate price (as of 2023-06-04) per each supplier, as well as the total cost depending on the used emission factor.

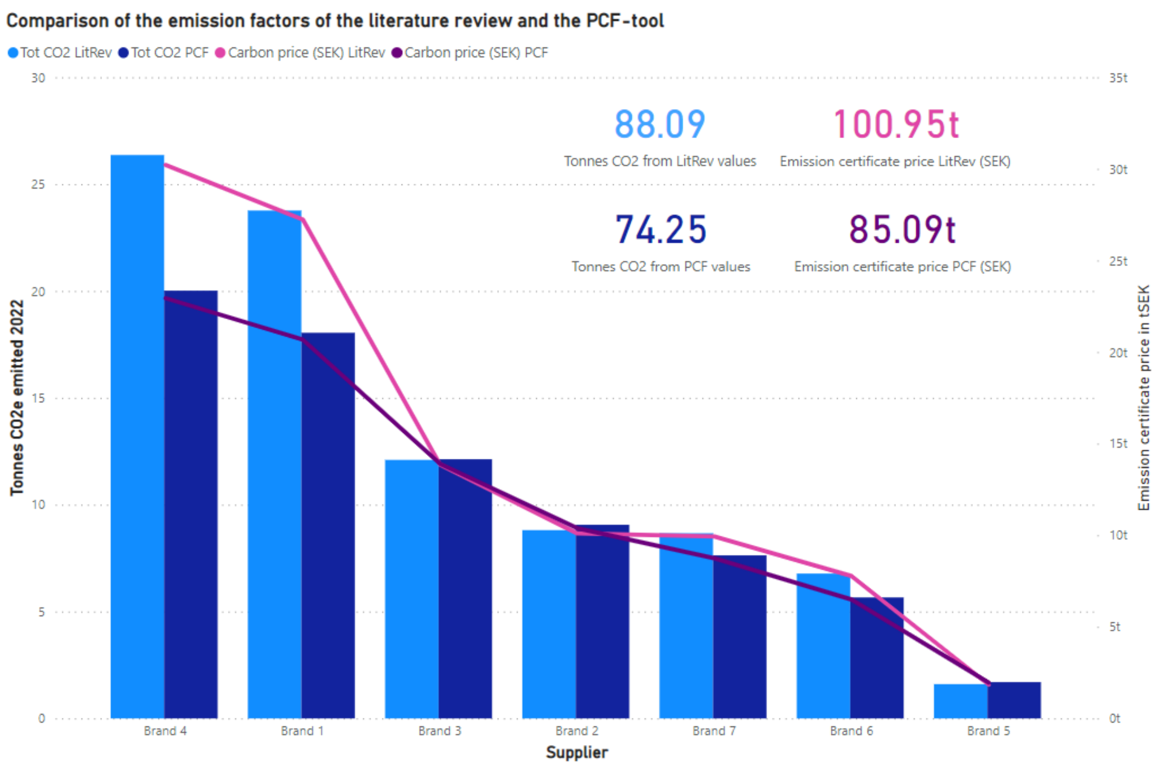


Figure 4.7: Comparison of the emission factors of the literature review and the carbon-tool. *Source:* authors).

The findings are not considered as having a high monetary impact on the sourcing of goods from China.

4.4 Findings on CBAM scope

The CBAM legislation has been thoroughly explained in section 3 giving an overview of the legislation. However, to address the third research question and fill the gap in the literature regarding whether or not ACIT is in the scope of the legislation interviews with external and internal actors were held.

Due to CBAM being a legislation that will be regulated on a national level by all members of the European Union, it was relevant to investigate which Swedish authority will be the regulating body. The regulating body will handle all matters regarding CBAM and the declaration of certificates. It is not yet decided which Swedish authority will be responsible, however, according to an expert in the area, two potential authorities were brought up, *Kommerskollegium* and *Tullverket*.

Furthermore, the EU will arrange guiding principles for how CBAM will be implemented during the transition period. The guiding principles will be more explanatory and go through what measures companies need to take to be fully compliant with the legislation in their daily operations. The guiding principles will also present the default values that should be used if companies do not have the ability to declare the actual embedded emissions in their imported goods.

The responsibility of declaring CBAM certificates will be a new challenge that importing companies will have to face. It has to be done in the right way and aligned with the directives set by the European Commission. The declaration of the CBAM certificates will therefore not necessarily be checked by a third-party actor on a regular basis. However, if the national authorities responsible for the declaration suspects that a company is not declaring the embedded emissions in the correct way, a third-party actor will investigate it which may lead to financial penalties depending on their evaluation of the situation.

The risk with CBAM according to an interview was primarily stated to be that some third countries will have difficulties in aligning their production with the standards set by the EU. This may result in third-country companies not being able to be competitive with EU companies. The administrative burden and complexity that increases with the introduction of CBAM could be too expensive for some companies to adjust to. However, the legislation could be seen as an incentive for suppliers in third countries to develop more green production and gain market shares in this transition.

Since the European Commission presented the product types that will be included in CBAM with CN codes, it was relevant to investigate the products that ACIT is currently sourcing. When investigating the product descriptions that ACIT is sourcing from China the authors found that there is no standardized way of declaring the specifications of the products. Thus, similar components can have different descriptions depending on, for example, the person responsible for the blueprint of the product. In other words, the authors found no system support for the classification of components at ACIT, making it challenging to connect the CN codes to the actual sourced components from China. At this stage of the investigation, it was found that ACIT *might* be impacted by the CBAM solely on the basis that the CN codes and the product descriptions could match ACIT's sourcing of components.

To reach a conclusion about whether or not ACIT is in the scope of CBAM, the authors triangulated the information gathered from interviews, with the data retrieved from a third-party consultancy firm, and the European Commission's publications. The conclusion was that the impact of CBAM is connected to the EU ETS and that a company **can not** be in the scope of CBAM if they are not currently included in the EU ETS. Since ACIT is not included in the EU ETS as of now, the direct impact of CBAM will be **zero**. It is important to understand that this is only a first draft of CBAM and that the legislation, as mentioned previously, may be developed and include more products and sectors in the future.

Summarizing the held interviews after this finding, it could be concluded that the reason for ACIT not being included in the EU ETS is that covers CO_2e-heavier industries/sectors. The companies included in the EU ETS, are mostly companies in the mining, energy, or other heavy industrial sectors.

5 Analysis

This section will compare the empirical findings of ACIT's supply chain structure, management, and setup, to the frameworks found in the literature. The aim is to find similarities, and discrepancies, between the theoretical frameworks of a supply chain, and ACIT's supply chain.

5.1 Analysis of ACIT's supply chain

This section will analyze ACIT's supply chain management to the frameworks found in the literature. The conclusions drawn from this section will be used later in the thesis to show potential areas of improvement and parts of the supply chain management that needs extra attention if the impact of CBAM would be great. Therefore, it can be seen as the foundation which later analysis and discussion will build upon.

5.1.1 Designing ACIT's supply chain for strategic fit

Fischer (1997) stated that finding a strategic fit is a fundamental part of a company's supply chain design. By working cross-functionally between the supply chain managers and the marketing responsible, it is possible to identify how the supply chain strategy should be formed to reach the most effective competitive market strategy (Lee 2002).

Analyzing the data gathered from interviews, it was deduced that ACIT's market strategy is to have the best and most innovative products on the market. The vision of ACIT is to have superior quality, service level, and innovativeness in their products, thus making them more attractive on the market. Combining this information with the "Matching supply chains with products" matrix in Fischer (1997), it was possible to identify that the theoretically aligned supply chain strategy is a **responsive** supply chain strategy, as seen in Figure 5.1. A responsive supply chain strategy characterized by its agility and ability to adapt quickly to the changes in ACIT's customers demands and the market trends.

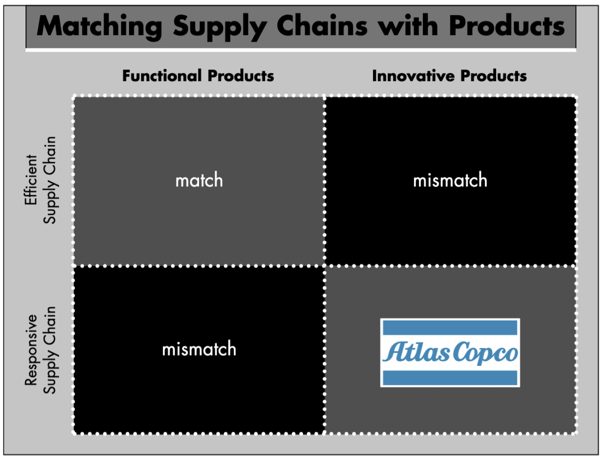


Figure 5.1: Matching ACIT's product characteristics to the appropriate supply chain strategy. (*Source:* Fischer (1997)).

Gardner & Cooper (2003) developed a framework containing different characteristics of a responsive supply chain in different parts of supply chain management, shown in Table 3.1. Using this framework, in combination with the interview answers regarding ACIT's current supply chain strategy, it could be concluded that ACIT's current supply chain already **is responsive**. Moreover, their work within *demand forecasting*, *flexibility in production*, *supplier partnerships*, *IT systems*, and *continuous improvement and innovation* are all characteristics of a company working in line with a responsive supply chain strategy. Furthermore, combining this with the analysis of the interview answers from both employees with market outlook knowledge and sourcing managers (who are active in the supply chain management decisions within the company), ACIT could be situated on the graph developed by Chopra & Meindl (2013).

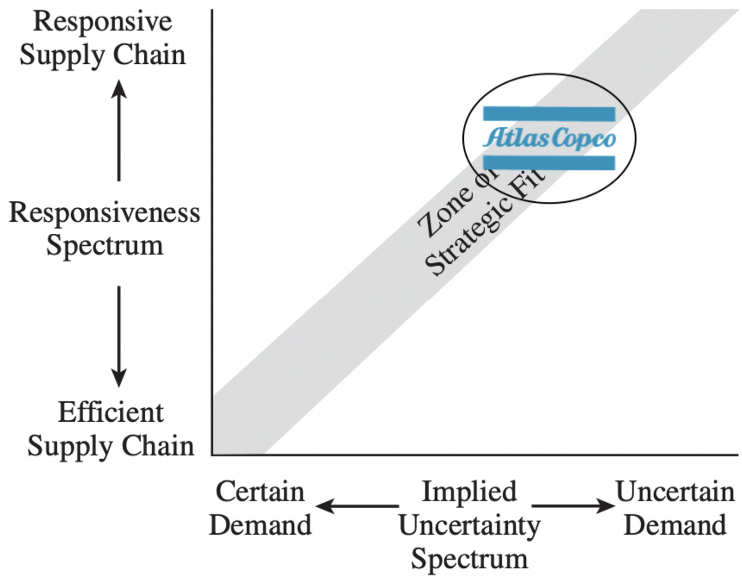


Figure 5.2: Matching ACIT's supply chain strategy with the demand uncertainty, showing that ACIT has achieved strategic fit. (*Source:* Chopra & Meindl (2013)).

In summary, ACIT's focus on offering the best and most innovative products, along with their emphasis on quality, service, and innovation, has over the years led them to adopt a responsive supply chain strategy, without necessarily following these theoretical frameworks but rather through following their identified best-practice. This strategy has allowed them to effectively respond to changing customer demands and market dynamics while maintaining their competitive strategy. (Chopra & Meindl 2013, Lee 2002, Fischer 1997)

5.1.2 Analyzing ACIT's purchasing

The purchased goods in the scope of this thesis are steel and aluminum components from China. The components are seen as low supply-risk goods, based on the data from interviews. Due to the number of available suppliers that can produce the components according to specification, as stated in interviews, and the impact these components have on the final cost of the product, it is determined that these components are categorized as "leverage items" in the "Purchasing Portfolio Matrix" from Kraljic (1983). (Weele 2014).

Categorizing these components as "leverage items" implies many things. These products are of high importance for ACIT's operations, and disruptions in the supply chain should be avoided to minimize the risk of downtime in the factory (Kraljic 1983). However, due to the many proficient suppliers in this category of products, ACIT possesses a lot of purchasing power, meaning they have the possibility to negotiate favorable terms (Kraljic 1983, Porter 1985).

Knowing this, ACIT should focus on continuing to build strong partnerships with its suppliers in this area, based on terms that are beneficial for ACIT. Moreover, monitoring of the market is needed to mitigate any risks that can impact the supply chain of these components, as they are crucial for manufacturing.

ACIT's purchasing maturity

In order to better understand the maturity of ACIT's purchasing activities, an analysis using the "development model" in Weele (2014) was made. Using this framework, it was possible to identify that ACIT 's sourcing division is currently at step 4, i.e. internally integrated as shown in Figure 5.3.

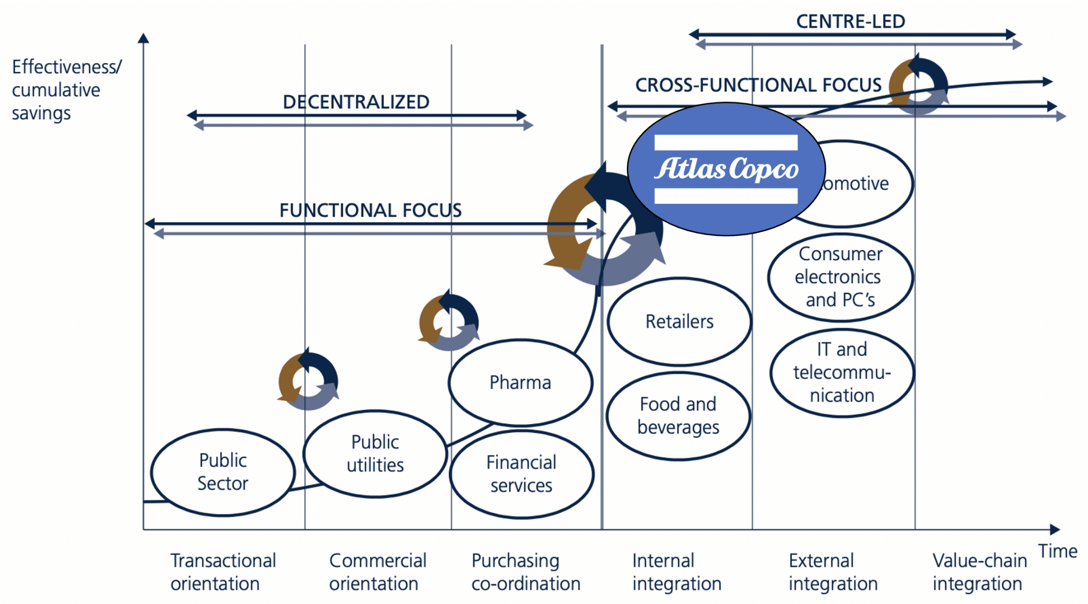


Figure 5.3: The purchasing development model with ACIT's location identified Weele (2014).

The sourcing division is no longer a "serve-the-factory" function of the company, but a crucial part of its supply chain and operations. Interviews have shown that internal integration runs deep in ACIT, and strategies are set cross-functionally with other functions in the company, such as R&D, logistics, and manufacturing. With a TCO mindset, sourcing is often included in the early stages of product development projects, ensuring that the suppliers are capable of providing components that reach the necessary QDCPS. (Weele 2014)

Analyzing the purchasing process

When comparing the purchasing process presented in Weele (2014) to ACIT's purchasing process, there are a lot of similarities. The main difference, a process not specified in Weele (2014) purchasing process, is the identification of the correct category buyer at ACIT. The category-driven strategy of ACIT's sourcing division implies that there is a correct buyer for each component, depending on its characteristics and attributes. This process is often autonomous and does not require much work after the internal customer has displayed their need, however, for new articles/components, this process is needed (Weele 2014).

As declared in interviews, ACIT is constantly striving for a more sustainable and transparent way of managing its upstream supply chain. Although the current purchasing process of ACIT is very similar to the process in Weele (2014), there are steps that can be taken in it which can increase the transparency. Fraser et al. (2020) stated that information sharing between suppliers and buyers is needed to reach a more sustainable supply chain management, information sharing that could be included in the current purchasing process. By measuring factors such as how sustainable a supplier is, and how transparent they can be with their sustainability data, already in the purchasing process, ACIT would be able to get a better overview of the carbon impact of their supply chain (Fraser et al. 2020, Kembro et al. 2017). Information such as this could be gathered in the initial RFI steps and evaluated together with other KPIs at the end of the process (Weele 2014).

5.2 Quantitative analysis

From the interviews with employees at ACIT's strategic sourcing division and through analysis of the order spend data - it could be concluded that over 95% of the sourced steel and aluminum components from China come from seven suppliers spread out in the country. However, it is important to have in mind ACIT also source components from other countries. Furthermore, it could be concluded that out of these seven suppliers in China, two solely produce aluminum components for ACIT, one solely produces steel components, and the remaining four produce a mix of steel and aluminum components (a mix being a production of separate components of both materials, **not** a mix of the materials in one component).

As of today, there is no way to easily fetch data stating the weight of the components sourced from suppliers of ACIT, hence, the cross-referenced dataset had to be created when gathering empirical data. The dataset contained order information, such as material number, order frequency, and the lot size of each order, which is available in the analytics solution system. In addition to this data, the weight of each article, available in the ERP data warehouse, and the mix of aluminum and steel components from each supplier, retrieved from the questionnaire sent out to the seven key suppliers, were added. After concatenating all of this data into a tangible result, it showed that ACIT sourced **14.76 tonnes** of aluminum, and **20.52** tonnes of steel in 2022.

Moreover, as the empiricism indicates, the impact of CBAM, with today's specifications, will be zero for ACIT. However, **if** ACIT were in the scope, the impact would be approximate **100 tSEK** based on the average emission found in Peng et al. (2022). The same value has been calculated using ACIT's carbon-tool, resulting in **85 tSEK**. As the result indicates in Figure 4.7, the two emission factors used in calculating the carbon price showed a similar output, except for *Brand 4* and *Brand 1.* The reason for the differences between the two models is that Brand 1 and 4 are **only** producing aluminum, and since the average emissions from Peng et al. (2022) compared to the carbon-tool for aluminum differs more than the two emission factors used when calculating steel emissions, the price becomes more sensitive toward aluminum. However, as described in section 4.4, the European Commission will be giving out default values used to estimate emissions of sourced goods, consequently, calculating the carbon price of CBAM. Thus, the analysis of whether the averages in the literature review or the averages in the carbon-tool are the most accurate can therefore not be made.

However, there are some key takeaways shown in Figure 4.5 and Figure 4.7. Looking at Figure 4.5, Brands 1, 2, 3, and 4 are currently responsible for 77% of the weight of components sourced from China. In addition, looking at Figure 4.7 it can be concluded that the same suppliers are responsible for over 80% of the emissions linked to components in China. With regard to these percentages, looking at the spend share presented in Figure 4.4 becomes interesting. The spend share of these four suppliers amounts to 70,1%, meaning that the components produced in these facilities are most likely **simpler**, thus cheaper but **heavier** components.

5.3 Impact of CBAM on ACIT's supply chain

This section will analyze the findings from the empiricism regarding CBAM and its impact on the supply chain, and compare them to the literature review.

As stated in the literature review, European Commission (2021*b*) presented CN codes that will be affected by the legislation once it is fully implemented. Similar data on the components sourced from China at ACIT could not be found by the authors, leaving a gap in information between the directives of the European Commission and ACIT's sourced components regarding product specifications and connection to CN codes. This might be an indication that ACIT's information systems are not compliant with CBAM something that could be further developed to ensure optimization of the flow of information through the supply chain and to ensure coordination among all stakeholders in the supply chain, as described by Jiang & Yang (2007).

According to the findings in section 4, CBAM will not have a direct impact on ACIT. However, the introduction of CBAM could potentially mean indirect expenses for ACIT. The reason is that the costs for suppliers **in** the EU may increase for several reasons. For example, suppliers might be forced to develop traceability systems for their embedded emissions as Sato (2022) and Eicke et al. (2021) stated, or simply because of increased costs for raw material impacted by CBAM (European Commission 2021*b*). These costs can then be transferred to ACIT sourcing, as ACIT is further downstream in the supply chain. However, as this is not in the scope of the thesis, this indirect impact has not been investigated further.

Looking beyond costs, the global trend regarding supplier requirements imposed by buyers becomes more and more stringent, thus, the complexity and challenges for suppliers have increased (Shumon et al. 2019). More specifically, implementing new methods and additional processes could be difficult to handle for the supplier, especially if they lack the necessary expertise and workforce needed to follow said requirements (Shumon et al. 2019, Michelin et al. 2015). Carbon tax regulations, which ultimately lead to supplier requirements Shumon et al. (2019), are more easily managed with a centralized supply chain design, as used by ACIT. It was proven to increase supply chain profit and decrease the contribution to carbon emissions, mainly due to the centralized decision-making mechanism (Wang et al. 2017).

The answers from the questionnaire in Table 4.1 showed that only two out of seven suppliers did answer the question regarding the embedded emissions in the raw material purchased from their suppliers. The results may indicate that either the suppliers do not have access to that kind of data due to not tracking their embedded emissions, or the information sharing between the supply chain actors is not sufficient leading to transparency issues. Fraser et al. (2020) states that a multi-tier sustainable supply chain mindset (MT-SSCM) relies on mapping, transparency, and traceability. Furthermore, Kembro et al. (2017) also described these functions as essential for enabling a sufficient supply chain with regard to information sharing and MT-SSCM.

The empiricism indicated that the majority of the Tier 2 suppliers in China were unknown for ACIT meaning that almost every Tier 2 supplier could not be found in any data system. This differs a lot from the information that ACIT has on the Tier 1 suppliers, where data easily can be extracted from the analytics solution system and the ERP. As Gardner & Cooper (2003) stated, it is important for a company to extend its scope beyond Tier 1 suppliers to create a map of the supply chain which is beneficial for companies seeking strategic supply chain management. Furthermore, with an extended interest of scope beyond Tier 1 suppliers opportunities regarding cross-tier alliances, new products, and cost reduction can be made which are important factors to consider when seeking a strategic supply chain management (Theodore Farris 2010).

Furthermore, when observing the map of suppliers upstream of the supply chain in Figure 4.6, the location of the Tier 1 suppliers is shown primarily in one cluster, the Guangdong region in China. As the map shows, five out of seven Tier 1 suppliers have their production facilities in the region. By observing Figure 3.20 in the literature review, the Guangdong region of China has the highest intensity of recycled aluminum according to Peng et al. (2022). In the same region, the primary aluminum production showed to be negligible which may be an indication that the aluminum sourced from the region is recycled aluminum. The GHG intensity in the Guangdong region for recycled aluminum is between 0.7-0.8 tonne CO_2e per tonne recycled aluminum Peng et al. (2022) which is close to the value (0.632) that Brand 1 answered in the questionnaire.

Although this does not confirm that the Tier 1 suppliers in this area use recycled aluminum

in their production, nor deny that Tier 2 suppliers outside this area do not produce recycled aluminum, this shows that there is an abundance of recycled aluminum production close to ACIT's Tier 1 suppliers. This is of relevance to ACIT for several reasons.
First, these Tier 2 suppliers of recycled aluminum are located in the close geographical vicinity of ACIT's Tier 1 suppliers, thus, the transportation lead time between suppliers in the supply chain is short. This is in line with the responsive supply chain strategy that ACIT seeks, as shown in Table 3.1.

Second, using these recycled aluminum suppliers in the Guangdong region would greatly minimize the carbon footprint of the component sourcing in China. As displayed in Figure 4.7, the aluminum component producers have the most significant carbon footprint of all steel and aluminum component producers, a footprint which could be severely reduced if the emission factors were between 0.7-0.8 tonnes CO_2e/tonne, as it is for recycled aluminum producers, instead of between 13.06 - 15.9 tonnes CO_2e/tonne which is the current estimate for primary aluminum producers.

Finally, If scope 2 emissions were included in the scope of CBAM, the emissions that need a cover of CBAM certificates for aluminum production would increase by almost 4x (The International Aluminium Institute 2022*a*). Looking at Figure 3.20, the Guangdong region has a relatively low grid mix intensity and a negligible grid mix intensity for the electrolysis process which is the most emission-heavy process of aluminum production (World Economic Forum 2020). This means that ACIT can push their Tier 1 suppliers in this region to utilize the geographically close raw material suppliers, thus enabling greener production, minimized certificate costs, and a supply chain that meets their responsive strategy.

6 Discussion

This section will comment on the results found in the analysis and discuss a theoretical scenario, in which ACIT is in the scope of CBAM and also heavily impacted by the legislation. The aim of the discussion is to deepen the connection between a company that is in the scope of the legislation and how such a company's upstream supply change would be impacted and subject to change.

6.1 Discussing the theoretical impact of CBAM

After thorough research, analysis, and deduction, it could be concluded that ACIT is neither in the scope of the CBAM legislation nor is the impact of the legislation European Commission (2021*b*) **if** they were in the scope sufficient to trigger any supply chain design, strategy, or management changes. Although this is an important conclusion for the case company, and also the answer they seek, the extensive research has more to offer. During the research, it was made clear that there are several factors not covered by this thesis that are of relevance to this field of study, factors that can contribute to a wider understanding of the legislation and how it will impact a company's upstream supply chain. Therefore, the following section will discuss a theoretical scenario where ACIT is in the scope of CBAM, and also heavily impacted by the legislation. This was primarily done to increase the practical impact of the CBAM since it was something that the authors found as a gap in the literature. The section will therefore discuss how changes in the supply chain management of ACIT could mitigate the impact of CBAM legislation, whilst maintaining a competitive supply chain strategy in line with their goals. This will act as material for ACIT if this theoretical scenario would become a reality in the future, but also for other entities seeking answers in this field of study.

6.1.1 How ACIT would reduce the upstream supply chain impact of CBAM - a theoretical scenario

In this scenario, ACIT is in the scope of the CBAM legislation and is also heavily impacted by it from a monetary perspective. This situation has triggered an investigation into potential measures that could be taken that mitigates this impact and also ensure a resilient upstream supply chain. It has been concluded that the affected components are essential for ACIT, and the changes must happen by altering the supply chain setup. Figure 6.1 illustrates a roadmap that ACIT could take to mitigate the impact of CBAM, based on the previous sections in the thesis.

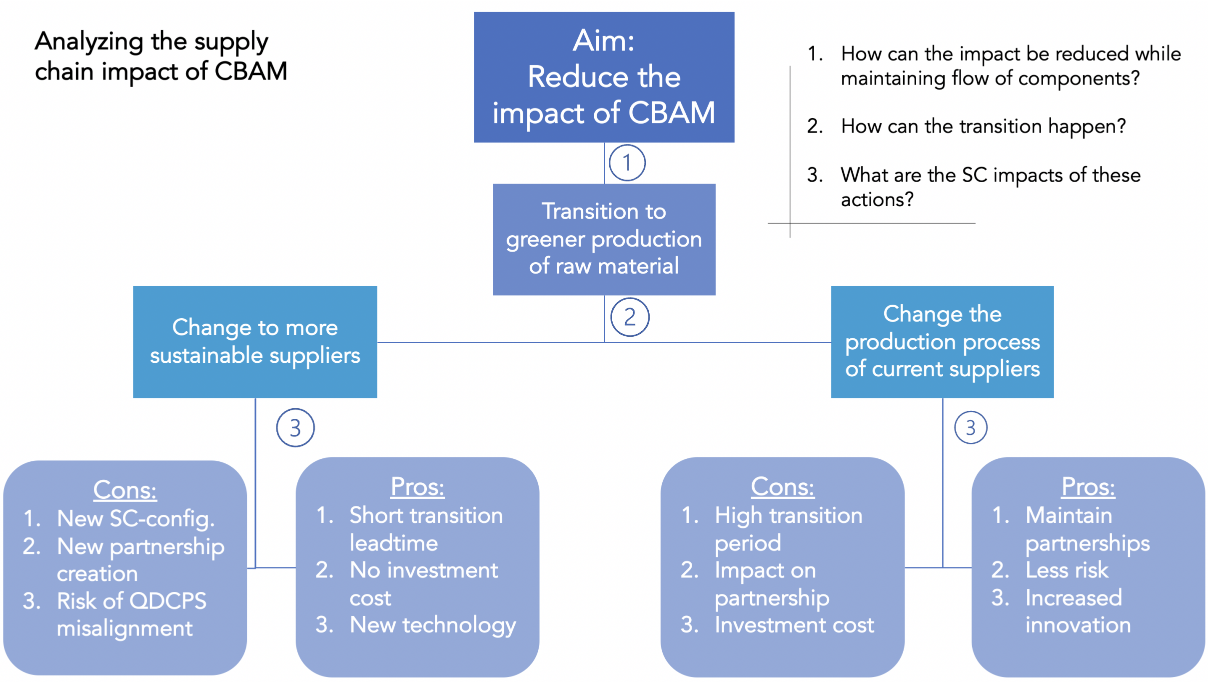


Figure 6.1: A roadmap to reduce the impact of CBAM (*Source:* authors).

The first step is to transition toward greener production of raw materials. As it has been confirmed in this scenario that the components are essential, changing the characteristics of the components or reducing the sourced amount is not in question. Since CBAM targets the embedded emission in the raw material sourced from countries outside the EU, changing to a greener production is the only change a company can control to reduce the monetary impact of the legislation, as the certificate price is dependent on variables outside the company's control (European Commission 2021*b*, 2003). In other words, operational processes with less embedded emissions will result in a decreased monetary impact (Schippers & De Wit 2022).

This leads to the second step of the framework; How can ACIT source less carbon-intensive components? There are two paths ACIT can take when trying to minimize the embedded emissions in their current components, the first alternative is to change to a supplier that is more sustainable in its production than the current suppliers and the second alternative is to help your current suppliers to change their production processes and become more sustainable (Schippers & De Wit 2022). Worth noting is that moving to a supplier within the EU would mean that sourcing activity is no longer covered by the CBAM, however, it would instead be covered by the EU ETS which would not necessarily mean a lower monetary impact unless the new supplier is less carbon intensive than the previous supplier (European Commission 2003).

In order to showcase the trade-offs between the two choices, the pros and cons of each choice will be weighed against each other. First, changing suppliers has several benefits for ACIT, and should not be too complicated as the components have been identified as leverage items in the "Purchasing Portfolio Matrix" (Kraljic 1983). In addition, there are also several other benefits that are of interest:

- **Short transition lead time** - The transition period to sourcing components with lower embedded emissions would be short as the new supplier would already have the technology and knowledge in place. This means that the first shipment from the new supplier would already be more sustainable compared to the previous supplier.
- **No investment cost** - Instead of investing in your current suppliers to change their ways, using new suppliers that are already more sustainable in their production would minimize the investment costs.
- **New technology available** - The new supplier possesses knowledge and technology which ACIT would not be in contact with if they had not changed suppliers. This information and technology can help spark new ideas and also make ACIT more competitive.

However, there are also negative sides to changing suppliers. By changing to new suppliers of the components, there is risk induced in the supply chain as it is no longer certain that the supplier can meet the requirements of the supply chain (Weele 2014). ACIT tracks its suppliers based on five categories: Quality, Delivery, Cost, Production, and Sustainability (QDCPS). Although the requirements are contractual, the risk of disruption in the supply chain due to a new supplier not being able to reach the demands can become severely costly if, for example, the disruption causes downtime in the factory further down in the supply chain. Moreover, ACIT has been identified as having a responsive supply chain, with the primary goal of responding quickly to demand. To successfully use such a supply chain strategy, suppliers need to have capacity flexibility if demand suddenly increases, have short lead times, and have to be reliable in the partnership (Chopra & Meindl 2013). This partnership already exists with the previous suppliers and does not have to be proven. The partnership aspect is also a matter which ACIT takes very seriously, as shown in the empirical data. Each buyer within the organization has partnerships with suppliers and works actively to not only better the relationship for ACIT but also for the supplier. Changing to new suppliers would deteriorate the relationship Weele (2014), going against a part of the sourcing strategy within the company.

The second alternative is for ACIT to push the current suppliers to make changes in their production, or in their sourcing processes, to actively reduce the embedded emissions in their components. This also has several benefits for ACIT:

- **Maintain partnerships** - As previously stated, helping ACIT's current suppliers change their ways to become a more sustainable company would maintain, or even grow, the partnership between the companies (Weele 2014). This aligns with the company's ideology of working with suppliers that are partners rather than a factory-feeding business. Moreover, as seen in the literature review and identified in the quantitative analysis, most of the direct embedded emissions come from the Tier 2 supplier and the production route they have chosen for the raw material. Growing the partnership can lead to better transparency between the companies, transparency which is seen as a key for a sustainable supply chain management (Fraser et al. 2020, Kembro et al. 2017). The transparency and growing partnership could potentially mean that ACIT can influence where the suppliers source their material from, consequentially reducing the embedded emissions if the suppliers agree to use a raw material supplier which uses production routes that emits less carbon.
- **Less risk** - The current suppliers have already been tested in action with regard to the supplier requirements QDCPS. Although the situation may change as the transition to less carbon-intensive production is started, the suppliers have already been "battle-tested" and ACIT can be more accurate in their forecasting as they can base it on previous data. (Weele 2014, Kraljic 1983)
- **Increased innovation** - Helping a supplier transition can lead to increased

innovation both within ACIT but also in collaboration with the supplier. This knowledge can then be distributed to other partnerships and overall increase the performance of ACIT's supplier base. (Weele 2014)

However, there are also challenges when remaining with the same suppliers that can put strains on the supply chain (Porter 1985). For example, the transition period might be long and complicated for both companies and during this time ACIT might be forced to surrender a lot of expensive certificates that would not be needed if they would have changed suppliers immediately. This might negatively impact the partnership and even cause disruptions in the supply chain as the suppliers go through changes. Finally, there is also an investment cost linked to ACIT if they chose to stick with their suppliers and help them become more sustainable. The suppliers will require help with this investment as the initiative is ACIT's.

6.1.2 Conclusion of the theoretical scenario

There are a lot of trade-offs that need to be evaluated, and a lot of information from different suppliers would have to be gathered to make a decision. Internal factors at ACIT would also need to be evaluated, such as who should be responsible for surrendering emission certificates in compliance with the legislation, and if investment in system supports is needed to track the CN codes that are covered by the legislation, and also how the supply chain should be set up with these new influences. Ultimately, a company with a transparent upstream supply chain that utilizes the least carbon-intensive production routes from raw material to sourced components will be the least impacted by the new legislation, and the trade-off that remains is how much supply chain re-configuration ACIT, in this case, deems as profitable and sustainable.

Based on the interviews, the literature review, and the analysis, the authors' recommendation for ACIT in the **theoretical scenario** is to investigate if there are current suppliers of similar components that are less carbon-intensive, have a more transparent upstream supply chain, and that are willing to help ACIT become compliant in the legislation. This way, ACIT would cover most of the benefits displayed previously and suffer less risk, which is the main negative part of changing to new suppliers. By having this mix of the two approaches, ACIT can build upon the existing relationships with the identified suppliers, quickly reduce the embedded emissions as the new supplier's materials and production processes emit less carbon, and maintain a supply chain that is not completely re-configured but adjusted. Consequently, ACIT would, after the identification process of which suppliers to partner with, rapidly move toward a greener supply chain that is not only resilient to carbon trade legislations but also transparent, and in line with their strategic goals.

7 Conclusion

This section will summarize the findings of the thesis, give a recommendation to ACIT, and discuss the contribution of this thesis to the case company as well as to the field of study.

7.1 Summary of the thesis

The aim of the thesis was to estimate the embedded emissions in ACIT steel and aluminum components sourced from China, and with this information, analyze the impact the European Commission's CBAM legislation will have on ACIT's upstream supply chain. The study is a holistic single case study conducted with an abductive approach, and the unit of analysis, overarching the three research questions, was: "*The Carbon Border Adjustment Mechanism's impact on ACIT's upstream supply chain of steel- and aluminum components from China*". Moreover, the study was conducted using both quantitative and qualitative data, each contributing to answering the three research questions. The quantitative data was used to calculate the weight of the sourced goods, the emissions linked to those goods, as well as the monetary impact of the CBAM legislation. Qualitative data was used to understand the scope of the legislation and how the upstream supply chain of steel and aluminum components from China to ACIT is currently set up, from ACIT to Tier 2 suppliers.

7.2 Answering the purpose and research questions

The literature review and gathered empirics allowed for a thorough analysis with the research questions in mind. This in turn resulted in the purpose of the thesis being fulfilled. Although one of the goals of the study was to find accurate emission data from the suppliers in order to make as accurate of analysis as possible, the values found in the literature and through interviews were triangulated and validated enough to make for a trustworthy result. With these values, an estimation of ACIT's embedded emissions could be made, and with the realization that ACIT is not in the scope of the CBAM, thus not having an impact on the upstream supply chain, the purpose of the thesis was fulfilled.

Additional theoretical analysis was made to provide more information if ACIT were to be in the scope of the legislation in the future. As this analysis resulted in a negligible monetary impact for ACIT, the theoretical analysis was brought further, investigating what supply chain measures would be relevant if the monetary impact would be greater.

To conclude the findings and analysis, each research question and its final answer will be explained in the following sections.

7.2.1 RQ1 - What is the weight of raw materials acquired by ACIT through component sourcing from China?

The weight of raw materials acquired by ACIT through component sourcing from China forms the basis for further analysis of ACIT's supply chain. To fully understand the environmental impact of ACIT's sourcing in this category of components from China, it is necessary to calculate the embedded emissions. This analysis requires accurate information on the weight of the raw materials being sourced.

The first research question was mostly based on quantitative data. All of the data used to calculate the answer to the research question is readily available at ACIT, however, it had not yet been compiled into the same equation and linked to the different suppliers. To calculate the embedded emissions in the steel and aluminum components sourced from China as well as to understand the size of this part of the supply chain, the information proved to be a key stepping stone for further analysis. This highlights the importance of effective data management and integration in order to fully understand the supply chain and its impact.

After combining the data from the different systems, it could be concluded that ACIT currently sources **35 280kg** of steel and aluminum components from China. Of this weight, roughly 58.2% is steel (20 520kg) and 41.8% (14 760kg) is aluminum. This breakdown of the raw materials is also an important factor in understanding ACIT's supply chain and identifying areas for improvement and areas that are performing well.

This information can help ACIT track its inventory levels, manage supplier relationships, and make more informed decisions about sourcing and procurement, including the calculation of embedded emissions and the identification of opportunities for optimization and improvement.

In conclusion, the weight of raw materials acquired by ACIT through component sourcing from China is 35,280 kg, with 58.2% being steel and 41.8% being aluminum. Overall, calculating the weight of components sourced from China can improve the transparency, sustainability, and compliance of ACIT's supply chain. By realizing the weight and origin of the raw materials, ACIT can make informed decisions about sourcing and procurement, understand and reduce its environmental impact, and build a rigid foundation for future challenges in this scope.

7.2.2 RQ2 - What are the embedded emissions of ACIT's sourced components from China?

The embedded emissions of the components were calculated both using theoretical emission factors for the different materials and by using the internally developed emission factors currently used for assessing the life cycle footprint of ACIT's products. The goal was to use accurate emission data from the suppliers to calculate the embedded emissions, however, as the suppliers were not able to disclose these numbers due to lacking technology, this could not be fulfilled. The calculations showed that the current steel and aluminum component sourcing of ACIT has 88 tonnes of embedded CO_2e emissions using the emission factors found in the literature, and 74 tonnes of embedded CO_2e emissions using ACIT's internally developed emission factors.

The calculation of these emissions was based on the total weight found in the first research question. The result showed that although the steel components have a greater weight than the aluminum components, the environmental impact of the aluminum components is heavier.

The questionnaire did not result in sufficient emission data for an analysis, however, using the supplier's answers, it was possible to do a mapping of ACIT's upstream supply chain which showed that five out of seven Tier 1 suppliers are located in the Guangdong region. The region has a high intensity of recycled aluminum production and negligible primary aluminum production which could be an indication that the aluminum sourced from the region is recycled. With the Guangdong region having an abundance of recycled aluminum, and with the majority of the Tier 1 suppliers being located in the region, an opportunity to be more sustainable and maintain a responsive supply chain, due to short transportation lead time, could be made by sourcing more raw material from Tier 2 suppliers in the region. This was not analyzed further in the thesis but is a key takeaway for ACIT to investigate further in the future.

7.2.3 RQ3 - Is ACIT in the scope of CBAM, and what would be the impact of the legislation on the upstream supply chain?

The findings in the empirical section indicate that ACIT will **not** be in the scope of CBAM. Since ACIT is not included in the EU ETS legislation, it can not, as of now, be in the scope of CBAM. Furthermore, the findings regarding how the CN codes, included in the CBAM legislation by the European Commission, are linked to ACIT's sourced components could not be decided by the authors. The main reason for this was that the authors could not find any system support at ACIT that links sourced components to certain CN codes.

Moreover, a theoretical analysis was made on the impact of CBAM **if** they were in the scope. The impact was deemed to not be of high significance for ACIT's sourced components from China. More specifically, the price of CBAM certificates needed to cover the emissions, if taking the emission factor from the carbon-tool, would be **85 tSEK**, and **100 tSEK** respectively with the emission factor taken from the literature. The carbon price of CBAM is essentially linked to two variables that may change in the future. The first one is the EU ETS certificate price which may fluctuate since it is listed on an open market. The second variable is the scope of emissions that will be impacted by CBAM, currently only looking at scope 1 (direct) emissions. The European Commission will evaluate CBAM after its introduction and potentially extend the scope to Scope 2 emissions. This will have an impact on the total cost connected to CBAM, especially when calculating the embedded emissions from aluminum products. Since 75% of the total emissions in the aluminum sector is Scope 2, a potential extension of the legislation will increase the price significantly, almost 4x the current cost for aluminum components.

Even though CBAM will not directly impact ACIT, it may still cause indirect expenses on its supply chain. If ACIT's suppliers in the EU (not covered in this thesis) are impacted by CBAM, their cost of materials may increase due to the additional expenses of CBAM certificates. In addition to the increased cost of raw materials, the potential implementation of new processes and traceability systems regarding their embedded emissions can lead to new costs, costs that may be pushed downstream in the supply chain. These additional costs may be transferred to ACIT as they are further downstream in the supply chain.

7.3 Contribution

The presented thesis has important contributions to the field of carbon regulations and their impact on supply chain management. The conducted research and the outcomes of the case study contribute to the existing body of knowledge within the field. The following sections will describe both the academic contribution as well as the contribution of the study to the case company, ACIT.

7.3.1 Academical contribution

The academic contribution of the thesis is primarily the increased knowledge of how CBAM would impact a global manufacturing company. The findings both from the literature and the empiricism could be used for companies that seek to develop an understanding of how companies in the EU with suppliers in non-EU countries get impacted by CBAM. The thesis fills the gap, acknowledged by the authors, between the legislation set by the European Commission and the practicalities that follow for companies and their upstream supply chains. By investigating CBAM and its impact on an upstream supply chain, conclusions and decisions based on the findings can be accomplished.

The combination of academic research and real data in the thesis highlight the opportunities and challenges with the introduced legislation. Additionally, the insights garnered in the thesis can empower companies to proactively adapt their strategies, optimize their SC, and decisions based their engagement with EU and non-EU suppliers in light of CBAM.

7.3.2 Contribution to the case company

The contribution of the thesis to ACIT is the general knowledge of CBAM as well as the obtained result showing that they will not get impacted by the legislation. The thesis also identifies critical gaps in the availability of real emission data from China and system support for the accurate classification of products using CN codes. By addressing these gaps, successful implementation of the CBAM directives can be made if ACIT, in the future, becomes in the scope. In addition, the obtained emission data found in the literature can be used as a reference point for more accurate estimations of the emissions from sourced components in China in combination with the model presented regarding the calculation of the sourced weight of components.

Furthermore, the mapping of the upstream supply chain in China can be used as a basis for more strategic decision-making with regard to supply chain optimization and a starting point for an increase of transparency in the upstream supply chain.

7.4 Recommendation

The purpose of this section is to give recommendations based on the findings in the thesis connected to the research questions, but also recommendations in adjacent areas that can become influenced in the future, providing guidance for future research. The recommendations are intended for stakeholders within ACIT, but can also be of use to other researchers in this field of study.

As stated several times in the thesis, ACIT is not in the scope of the CBAM legislation and would not be severely impacted by it if they were. However, as the scope of the legislation can expand, and the cost connected to the CBAM certificates can increase, there are several predictive actions ACIT should look into for the future.

First, regular updates on the legislation are needed to identify if the scope has changed. The trigger of this thesis came from an internal entity identifying that CBAM might impact the company, which speaks for ACIT having a mechanism in place for such legal updates. However, increasing attention to these matters through monitoring or tracking of legislative updates will reduce the risk of unforeseen problems occurring in the future.

Second, during the duration of the thesis research, a lot of time had to be put into understanding whether or not ACIT was in the scope of CBAM, mainly due to lacking system support connected to the CN codes of sourced goods. As the CN codes are the European Commission's way of presenting targeted product categories, the need for structured labeling of the sourced goods can become relevant not only for CBAM but also for other future legislations. Therefore, the authors see this as a sound investment and implementation in daily operations, as it most likely will have to be implemented when future supply chain transparency legislation is put into effect. By commencing this work sooner rather than later, ACIT will be well-prepared for the future and resilient in times when other companies might struggle to adapt to the new requirements.

Third, ACIT is striving for a sustainable supply chain, something which can only be reached through transparency with suppliers and real emissions data. This data could not be found during this thesis work, thus, it is recommended that ACIT continues to work with their suppliers to get hold of this data as soon as possible. With this data, ACIT can make truly informed decisions on how to configure its supply chain in a sustainable way instead of basing the decisions on averages which may be misleading.

7.5 Further research

While the thesis contributes to the understanding of the impact of CBAM on an upstream supply chain, there are several factors to consider for future research within the field. These include investigating the broader implications of CBAM on downstream supply chains and considering the potential interplay between CBAM and other policy measures set by governments. By examining how CBAM impacts downstream manufacturing, distribution, and retailing processes a holistic view of the entire supply chain and its response to the implementation of CBAM could be provided. This research direction would contribute to a more comprehensive understanding of the extensive effects of CBAM on global supply chains.

Additionally, further research could explore the indirect impact of CBAM and other carbon regulations. With today's enhanced globalization among supply chains, the indirect impact of carbon regulations may be significant. By monitoring companies impacted by CBAM, better strategic decisions regarding the choice of supplier can be accomplished.

Furthermore, to increase the practicality and applicability of the research, it could be made on a company currently in the scope of CBAM. By doing so, a more hands-on approach could be made, allowing for a deeper understanding of the actual challenges and opportunities for companies operating under the CBAM framework, rather than relying the impact-analysis on a theoretical scenario.

By engaging with a company that is in the scope of CBAM it will enable the future researchers to gather first-hand data as well as capturing the distinctions and complexities that arise in a real-life operational environment. This will enable a more accurate assessment of the impacts that CBAM has on companies SC.

References

Arcelor Mittal (2023), *Making Steel*, Arcelor Mittal.
URL: *https://corporate.arcelormittal.com/about/making-steel*

Bridenbaugh, P. R., Staley, J. T. & Horn, K. R. V. (2018), *aluminium processing.*
URL: *https://www.britannica.com/technology/aluminum-processing/Ores*

Cetinkaya, S. & Lee, C. (2000), 'Stock replenishment and shipment scheduling for vendor managed inventory systems', *Management Science* **46**, 217–232.

Chopra, S. & Meindl, P. (2013), *Supply Chain Management. Strategy, Planning, and Operation*, Vol. 5, Pearson.

Creswell, J. W. & Creswell, J. D. (2023), *Research design : qualitative, quantitative, and mixed methods approaches*, SAGE Publications.

Eicke, L., Weko, S., Apergi, M. & Marian, A. (2021), 'Pulling up the carbon ladder? decarbonization, dependence, and third-country risks from the european carbon border adjustment mechanism', *Energy Research Social Science* **80**.

Ellram, L. M. & Siferd, S. P. (1993), 'Purchasing: The cornerstone of the total cost of ownership concept', *Journal of Business Logistics* **14**, 163.

EMBER (2023), *Carbon Price Tracker.*
URL: *https://ember-climate.org/data/data-tools/carbon-price-viewer/*

Emirates Global Aluminium (2023), *How aluminium is made.*
URL: *https://www.ega.ae/en/products/how-aluminium-is-made*

European Commision (2019), *The European Green Deal*, European Union, Brussels.
URL: *https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2019:640:FIN*

European Commission (2003), *Establishing a scheme for greenhouse gas emission allowance trading within the Community*, European Union, Brussels.
URL: *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32003L0087*

European Commission (2020), *A Union of vitality in a world of fragility*, European Union, Brussels.
URL: *https://eur-lex.europa.eu/resource.html?uri=cellar:91ce5c0f-12b6-11eb-9a54-01aa75ed71a1.0001.02/DOC_1&format=PDF*

European Commission (2021*a*), *Carbon Border Adjustment Mechanism: Questions and Answers*, European Union, Brussels.
URL: *https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3661*

European Commission (2021*b*), *Proposal for a regulation of the European Parliament and of the Council establishing a Carbon Border Adjustment Mechanism*, European Union, Brussels.
URL: *https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:52021PC0564*

European Commission (2022), *Amendments adopted by the European Parliament on 22 June 2022 on the proposal for a regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism (COM(2021)0564 — C9-0328/2021 — 2021/0214(COD))*, European Union, Brussels.

URL: *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022AP0248&qid=1678180335105&from=EN*

Fischer, M. L. (1997), 'What is the right supply chain for your product?', *Harvard Business Review* **75**, 105–116.

Floyd, F. J. J. (2009), *Survey research methods. (4th ed.)*, SAGE Publications.

Fraser, I. J., Müller, M. & Schwarzkopf, J. (2020), 'Transparency for multi-tier sustainable supply chain management: A case study of a multi-tier transparency approach for sscm in the automotive industry', *Sustainability* **12**.

Gardner, J. T. & Cooper, M. C. (2003), 'Strategic supply chain mapping approaches', *Journal of Business Logistics* **24**(2), 37.

Georgantzia, E., Gkantou, M. & George, K. S. (2021), 'Aluminium alloys as structural material: A review of research', *Engineering Structures* **227**.

Gibbert, M., Ruigrok, W. & Wicki, B. (2008), 'What passes as a rigorous case study?', *Strategic Management Journal* **29**(13), 1465–1474.

Hasanbeigi, A., Arens, M., Cardenas, J. C. R., Price, L. & Triolo, R. (2016), 'Comparison of carbon dioxide emissions intensity of steel production in china, germany, mexico, and the united states', *Resources, Conservation and Recycling* **113**.

Höst, M., Regnell, B. & Runeson, P. (2006), *Att genomföra examensarbete*, Vol. 1, Studentlitteratur.

IEA (2022), *Iron and Steel Technology Roadmap.*
URL: *https://www.iea.org/reports/iron-and-steel-technology-roadmap*

International Energy Association (2022), *Aluminium.*
URL: *https://www.iea.org/reports/aluminium*

Jesson, J. K., Matheson, L. & Lacey, F. M. (2011), *Doing you literature review: Traditional and systematic techniques*, Vol. 1, SAGE.

Jiang, H. & Yang, J. (2007), 'Information technology support system of supply chain management', *Porceedings of the 11th WSEAS International Conference on Applied Mathematics (Math '07* pp. 138–142.

Kembro, J., Näslund, D. & Olhager, J. (2017), 'Information sharing across multiple supply chain tiers: A delphi study on antecedents', *International Journal of Production Economics* **193**.

Korpar, N., Larch, M. & Stöllinger, R. (2022), 'The european carbon border adjustment mechanism: a small step in the right direction'.

Kraljic, P. (1983), 'Purchasing must become supply management', *Harvard Business Review* .

Lee, H. L. (2002), 'Aligning supply chain strategies with product uncertainties', *California Management Review* **April**, 105–119.

Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D. & Zacharia,

Z. G. (2001), 'Supply chain enterprise operations and government carbon tax decisions considering carbon emissions', *Journal of Business Logistics* **22**(2), 1–25.

Metallkompetens (2023), *Den digitala plattformen om metaller.*
URL: *https://metallkompetens.se*

Michelin, F., Reyes, T., Vallet, F., Eynard, B. & Duong, V.-L. (2015), 'Improving the management of environmental requitements in clients/suppliers co-design process', *Proceeding of the 20th International Conference on Engineering Design* pp. 1–11.

Mollenkopf, D., Stolze, H., Tate, W. L. & Ueltschy, M. (2010), 'Green, lean, and global supply chains', *International Journal of Physical Distribution Logistics Management* **40**(1/2), 14–41.

Monczka, R., Trent, R. & Handfield, R. (2001), *Purchasing and Supply Chain Management.*, Vol. 2, South-Western College Pub.

Peng, T., Ren, L., du, E., Ou, X. & Yan, X. (2022), 'Life cycle energy consumption and greenhouse gas emissions analysis of primary and recycled aluminum in china', *Processes* **10**(11).

Perea, E., Grossmann, I. & Ydstie, E. (2000), 'Dynamic modeling and decentralized control of supply chains', *Industrial Engineering Chemistry Research* **40**, 3369–3383.

Perea-López, E., Ydstie, B. & Grossmann, I. E. (2003), 'A model predictive control strategy for supply chain optimization', *Computers Chemical Engineering* **27**, 1201–1218.

Porter, M. E. (1985), *The Competitive Advantage: Creating and Sustaining Superior Performance*, Vol. 1, The Free Press.

Read, S. (2022), 'What is the difference between scope 1, 2 and 3 emissions, and what are companies doing to cut all three?'.
URL: *https://www.weforum.org/agenda/2022/09/scope-emissions-climate-greenhouse-business/*

Saevarsdottir, G., Kvande, H. & Barry, J. W. (2020), 'Aluminum production in the times of climate change: The global challenge to reduce the carbon footprint and prevent carbon leakage', *JOM* **71**(1), 296–308.

Sato, S. Y. (2022), 'Eu's carbon border adjustment mechanism: Will it achieve its objective(s)?', *Journal of World Trade* **56**(3), 383–404.

Saunders, M., Phillip, L. & Thornhill, A. (2007), *Research methods for business students*, Vol. 4, Financial Times.

Schippers, M. L. & De Wit, W. (2022), 'Proposal for a carbon border adjustment mechanism', *Global Trade and Customs Journal* **17**(1), 10–18.

Shumon, R., Halim, Z., Rahman, S. & Ahsan, K. (2019), 'Wow do suppliers address stringent environmental reuirements from buyers? an exploratory study in the bangladesh ready-made garment industry', *International Journal of Physical Distribution Logistics Management* **49**(9), 921–944.

Srivastava, S. K. (2007), 'Green supply-chain management: A state-of-the-art literature review', *International Journal of Management Reviews* **9**(1), 53–80.

The International Aluminium Institute (2022*a*), *Greenhouse Gas Emissions Intensity - Primary Aluminium.*
URL: *https://international-aluminium.org/statistics/greenhouse-gas-emissions-intensity-primary-aluminium/*

The International Aluminium Institute (2022*b*), *Primary Aluminium Production.*
URL: *https://international-aluminium.org/statistics/primary-aluminium-production/*

Theodore Farris, M. (2010), 'Solutions to strategic supply chain mapping issues', *International journal of physical distribution logistics management* **40**(3), 164–180.

Turki, S., Sauvey, C. & Rezg, N. (2018), 'Modelling and optimization of a manufacturing/remanufacturing system with storage facility under carbon cap and trade policy', *Journal of Cleaner Production* **193**, 441–458.

United Nations (2021), *China Population*, United Nations.
URL: *http://data.un.org/en/iso/cn.html*

Wang, C., Wang, W. & Huang, R. (2017), 'Supply chain enterprise operations and government carbon tax decisions considering carbon emissions', *Journal of Cleaner Production* **152**, 271–280.

Weele, A. V. (2014), *Purchasing and Supply Chain Management*, Vol. 6, CENGAGE Learning.

Wei, W., Zhang, P., Yao, M., Xue, M., Miao, J., Liu, B. & Wang, F. (2019), 'Multi-scope electricity-related carbon emissions accounting: A case study of shanghai', *Journal of Cleaner Production* **252**.

Wente, E., Nutting, J. & Wondris, E. (2022), *steel.*
URL: *https://worldsteel.org/wp-content/uploads/World-Steel-in-Figures-2022.pdf*

Woodruff, R. (2003), *Alternative paths to marketing knowledge*, Vol. 6, University of Tennessee.

World Economic Forum (2020), 'Aluminium for climate: Exploring pathways to decarbonize the aluminium industry'.
URL: *https://www3.weforum.org/docs/WEF_Aluminium_for_Climate_2020.pdf*

World Steel Association (2022), *World Steel in Figures 2022.*
URL: *https://worldsteel.org/wp-content/uploads/World-Steel-in-Figures-2022.pdf*

Xu, Z., Pokharel, S., Elomri, A. & Mutlu, F. (2017), 'Emissions policies and their analysis for the deign of hybrid and dedicated closed-loop supply chains', *Journal of Cleaner Production* **142**, 4152–4168.

Yin, R. K. (2018), *Case Study Research and Applications: Design and Methods (6th ed.)*, Vol. 9, Sage.

Åhman, M., Nilsson, L. J. & Johansson, B. (2017), 'Global climate policy and deep decarbonization of energy-intensive industries', *Climate Policy* **17**(5), 634–649.

Appendix

A1 Qualitative data collected

A1.1 Interview Policy Officer for Trade Policy

- Berätta lite om dig själv och vad din yrkesroll är.
- Vilken svensk myndighet är ansvarig för CBAM? Är det den myndigheten man skickar in CBAM-deklarationen?
- Hur ser scopet ut? Är det endast råmaterial som ska vidareproduceras i ett importland inom EU som berörs? Var går gränsen för downstream products?
- Är lagkravet satt på så att ett globalt industribolag behöver ta reda på utsläppen hos en second-tier leverantör dvs råmaterialsproducenter? Kan detta leda till en ökad administrativ komplexitet hos dessa producenter, samt en oärlig transparens i försörjningskedjan?
- I lagkravet refereras produkter påverkade av CBAM med CN-koder samt en kort beskrivning av produkten. Om importföretaget inte tillhandahåller/har systemstöd för dessa koder vid inköp av artiklar går man då via produktbeskrivningen för att ta reda på om man är påverkad, eller sker det någon sorts kontroll av en tredje-part för att korrekt kategorisera dessa produkter? Hos vem ligger ansvaret att kategorisera dessa produkter?
- Hur tror du aluminium-sektorn kommer bli påverkad i och med att majoriteten av utsläppen är Scope 2?
- När det kommer till att ta reda på utsläppen i produktion finns det några riktlinjer för hur dessa ska tas fram? Hur kontrolleras detta?
- Hur kommer default values beräknas? Vilken myndighet är ansvarig för det?
- Kan du gå igenom övergångsperioden från ETS till CBAM? Kopplingen mellan ETS och CBAM certifikat.
- Vilka möjligheter samt risker ser du med CBAM?

- Hur ser den framtida expansionen av CBAM ut?
- Vart går pengarna som betalas in? Green-fund?
- Om man inte täcks av EU ETS, kan man ändå täckas av CBAM då?

A1.2 Meeting - SVE Manager

- Är ACITs inköp centraliserat eller decentraliserat?
- Hur delas logistiken upp internt?
- Vilken avdelning är primärt ansvarig för att hantera försörjningskedjan uppströms?
- Hur ser ACITs inköpsstrategi ut?
  - Hur gynnas ACIT av denna strategi?
- Vad innebär de olika avdelningarna inom inköpsteamet?
- Arbetar inköpsorganisationen med hållbarhet, och isåfall hur?
- Vilka krav ställer ni på era leverantörer och hur trackar ni dessa?
- Utöver dessa, följer ni några särskilda ISO standarder eller dylikt?
- Hur ser ACIT inköpssprocess ut?
- Skulle du säga att den är lik Arjan van Weeles inköpsprocess (bild visad)?
- Jobbar varje avdelning för sig inom inköp eller är det mer tvärfunktionellt?
- Hur arbetar ni med era leverantörer? Genomförs det förbättringsprojekt och rankas de?
- Skulle du säga att ACIT's produkter är mer innovativa eller mer standardköp för era kunder?
- Är kundbehovet konstant eller flukturerande? Hur flukturerande är behovet och hur påverkar det inköpet av komponenter?
- Vad är karaktärsdragen för de komponenter som är i scopet?
- Vilken typ av data och system finns tillgängligt att använda?

- Hur används dessa?
- Har ni något verktyg för att estimera utsläpp på produkter?
- Vad skulle anses vara en signifikant monetär påverkan av CBAM för ACIT? Dvs. minsta kostnaden som krävs för att förändringar ska göras?
- Hur klassificeras produkter i systemen? Sker detta enliggt ett ramverk eller är det slumpmässiga namn?
- Vet du vem som arbetar med CN koder?

A1.3 Meeting - Eco Design Engineer

- Hur arbetar ACIT med hållbarhet?
- Vad är carbon-tool?
- Vad är carbon-tool baserat på för data?
- Vad är dess syfte?
- Anser du att vi är i scopet av CBAM?
- Arbetar ACIT med CN-koder?
- Går dessa att få tag på enkelt, dvs. med systemstöd?
- Om man inte täcks av EU ETS, kan man ändå täckas av CBAM då?
- Vilka företag täcks av EU ETS?

A1.4 Meeting - President MVI

- Hur arbetar ACIT med hållbarhet?
- Vad är visionen för ACITs produkter?
- Hur jobbar ni med innovation?
- Skräddarsyr ni lösningar eller köper kunder "från en katalog"?
- Skulle du säga att ACIT's produkter är mer innovativa eller mer standardköp för era kunder?

A1.5 Meeting - Trade Compliance Lead

- Arbetar ACIT med CN-koder?
- Går dessa att få tag på enkelt, dvs. med systemstöd?
- Vem har koll på dessa koder?

A1.6 Meeting - VP Holding Nordic

- Anser du att ACIT är i scopet av CBAM?
- Är Atlas Copco med i EU ETS, och isåfall, vem är ansvarig för den deklarationen?
- Om man inte täcks av EU ETS, kan man ändå täckas av CBAM då?

A1.7 Mail Conversation with KREAB - Scope of CBAM

- Är ACIT med i scopet för CBAM, och om de är, varför?
- Är Atlas Copco med i EU ETS?
- Om man inte täcks av EU ETS, kan man ändå täckas av CBAM då?
- Vilka företag täcks av EU ETS?

A1.8 Mail Conversation - Group Sustainability Manager

- Är ACIT med i scopet för CBAM, och om de är, varför?
- Är Atlas Copco med i EU ETS, och isåfall, vem är ansvarig för den deklarationen?
- Om man inte täcks av EU ETS, kan man ändå täckas av CBAM då?
- Vilka företag täcks av EU ETS?

A1.9 Meeting - ASO Strategic buyer

- Arbetar inköpsorganisationen med hållbarhet, och isåfall hur?
- Vilka krav ställer ni på era leverantörer och hur trackar ni dessa?
- Vad är karaktärsdragen för de komponenter som är i scopet?

- Vilka leverantörer bör fokuserar i uppsatsen?
- Vad har de leverantörer som uppsatsen fokuserar på för underleverantörer?
- Vad har ni lyckats samla in för data som berör detta caset fram tills nu? (inbäddade utsläpp, tier 2 leverantörer, material, vikt etc.)
- Vet ni vad underleverantörerna använder för produktionssteg i sin tillverkningsprocess?
- Vilka inbäddade utsläpp har de komponenter vi köper in från Kina?

A1.10 Meeting - ASO Sourcing Team Manager

- Arbetar inköpsorganisationen med hållbarhet, och isåfall hur?
- Vilka krav ställer ni på era leverantörer och hur trackar ni dessa?
- Skulle du säga att ACIT's produkter är mer innovativa eller mer standardköp för era kunder?
- Vad är karaktärsdragen för de komponenter som är i scopet?
- Vilka leverantörer bör fokuserar i uppsatsen?
- Hur många leverantörer finns i Kina och har ni koll på deras underleverantörer?
- Vad har ni lyckats samla in för data som berör detta caset fram tills nu? (inbäddade utsläpp, tier 2 leverantörer, material, vikt etc.)
- Vet ni vad underleverantörerna använder för produktionssteg i sin tillverkningsprocess?
- Vilka inbäddade utsläpp har de komponenter vi köper in från Kina?

A1.11 Meeting - Technical cost engineer

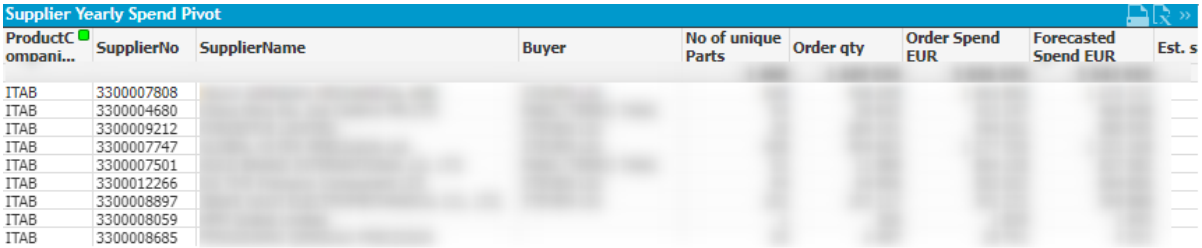
- Arbetar du med TCO-processer och hur ser dessa ut isåfall?
- Skulle du säga att ACIT's produkter är mer innovativa eller mer standardköp för era kunder?
- Vad är karaktärsdragen för de komponenter som är i scopet?

- Vad är kostnadsbärarna för dessa komponenter?
- Vilken typ av data och system finns tillgängligt att använda?
- Hur används dessa?

A2 Quantitative data collected

A2.1 Analytics solution system

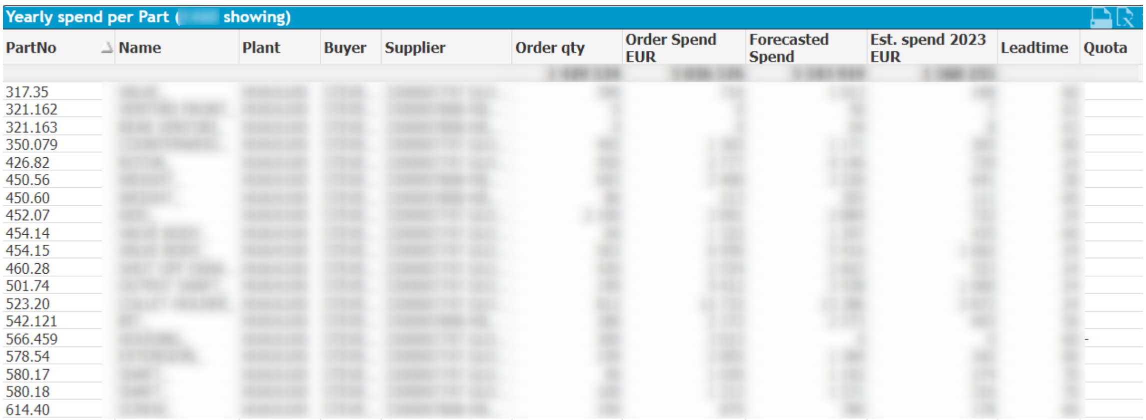
A2.1.1 Suppliers


Supplier Yearly Spend Pivot

ProductCompani...	SupplierNo	SupplierName	Buyer	No of unique Parts	Order qty	Order Spend EUR	Forecasted Spend EUR	Est. s
ITAB	3300007808	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ITAB	3300004680	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ITAB	3300009212	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ITAB	3300007747	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ITAB	3300007501	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ITAB	3300012266	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ITAB	3300008897	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ITAB	3300008059	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
ITAB	3300008685	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

Figure A2.1: A small extraction of the data retrieved from the analytics solution system.

A2.1.2 Parts


Yearly spend per Part ([illegible] showing)

PartNo	Name	Plant	Buyer	Supplier	Order qty	Order Spend EUR	Forecasted Spend	Est. spend 2023 EUR	Leadtime	Quota
317.35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
321.162	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
321.163	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
350.079	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
426.82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
450.56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
450.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
452.07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
454.14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
454.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
460.28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
501.74	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
523.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
542.121	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
566.459	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
578.54	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
580.17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
580.18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
614.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure A2.2: A small extraction of the data retrieved from the analytics solution system.

A2.1.3 ERP/Data warehouse extraction

MaterialNumber	SupplierName	GrossWeight	NetWeight	WeightUnit		Amount	TotWeight
2050506093	[illegible]	57,8	57,8	G	ST	1260	72828
2050525323	[illegible]	53	53	G	ST	73	3869
4110135400	[illegible]	63,5	63,5	G	ST	630	40005
4110135401	[illegible]	360	360	G	ST	630	226800
4110135408	[illegible]	1	1	G	ST	1991	1991
4110160000	[illegible]	153	153	G	ST	6345	970785
4110160001	[illegible]	120,7	120,7	G	ST	250	30175
4110172701	[illegible]	1	1	G	ST	4147	4147
4111010103	[illegible]	314	314	G	ST	1512	474768
4150121200	[illegible]	98	98	G	ST	1747	171206
4150123901	[illegible]	13	13	G	ST	5340	69420
4175009000	[illegible]	588,3	588,3	G	ST	1200	705960
4175009001	[illegible]	590,6	590,6	G	ST	360	212616
4175009201	[illegible]	152	152	G	ST	230	34960
4175009202	[illegible]	152	152	G	ST	0	0
4175009203	[illegible]	148	148	G	ST	468	69264
4175009204	[illegible]	150	150	G	ST	322	48300
4175009205	[illegible]	155	155	G	ST	0	0
4175009206	[illegible]	151	151	G	ST	0	0
4175009300	[illegible]	119,64	119,64	G	ST	1152	137825,28
4175070560	[illegible]	128,17	128,17	G	ST	4187	536647,79
4175070561	[illegible]	100	100	G	ST	0	0
4175073260	[illegible]	201,2	201,2	G	ST	2040	410448
4175076700	[illegible]	13,13	13,13	G	ST	1917	25170,21
4175079800	[illegible]	0	0	G	ST	0	0
4210188903	[illegible]	308	308	G	ST	648	199584
4210188907	[illegible]	265	265	G	ST	0	0
4210188909	[illegible]	0	0	G	ST	0	0
4210433600	[illegible]	150	150	G	ST	2800	420000
4210433601	[illegible]	250	250	G	ST	50	12500
4210433603	[illegible]	1	1	G	ST	233	233

Figure A2.3: A small extraction of the data from the ERP and the data warehouse which was used in the analysis

A3 Supplier questionnaire

Questions	Answers	Comments
Company Name		
Total **aluminium** used in Atlas Copco products (kg) - the yearly amount of raw material used in production of Atlas Copco components/products		
Total **steel** used in Atlas Copco products (kg) - the yearly amount of raw material used in production of Atlas Copco components/products		
Production yield (%) - average percentage of raw material used in final product		
Your raw material suppliers for aluminium and steel		
CO2e/kg raw material - emissions embedded in the raw material from your suppliers*		*If possible

Figure A3.1: Supplier questionnaire used for data gathering