Greenhouse Gas Emissions from Production Facilities

A case study at Ericsson

Master's thesis in Quality and Operations Management

MARION ANDERSSON
MOA LUBELL

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF SUPPLY AND OPERATIONS MANAGEMENT

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Report no. E2021:015
Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

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ABSTRACT

With increased pressure to achieve a higher degree of sustainability within businesses and their supply chains, improved measuring practices of emissions are required to be able to evaluate their environmental impact. Measuring emissions becomes challenging when wanting to include parties further down the supply chain based on e.g. the accessibility of data and information. As of today, measuring the environmental impact is often not performed through a holistic perspective, which is important to understand the full magnitude of the emissions emitted. Consequently, the purpose of this thesis was to investigate and map Ericsson and the external units' sustainability work related to facilities, in order for Ericsson to create a baseline related to the external emissions and in turn, be able to improve the total carbon footprint of their supply. The external units refer to two of Ericsson's preferred suppliers, which are responsible for the outsourced production.

This thesis was performed as a qualitative case study at Ericsson. Data were mainly collected through interviews conducted in two rounds. In the first round, the focus was to gain contextual understanding about Ericsson and the subject, whereas in the second round, the focus was on the external units. Additionally, documentation from the companies was studied and observations were made through participation at arranged meetings.

It has been concluded that measuring sustainability and facility emissions is a much more complex process than expected when including external parties, as it requires proper allocation methods and strong collaboration between the parties involved. This thesis used a revenue-based approach to estimate the emissions for Ericsson, as products for other customers of the external units are being produced within the same facilities. The result indicates that the share of emissions between Ericsson and the external units does not correspond to the share of production. The calculations were assessed to have low accuracy based on the allocation method used and in order to increase the accuracy of the measures, other allocation methods are required. To be able to use alternative methods, more information is needed and therefore, the relationship between the parties involved, in terms of collaboration and trust, needs to be further developed. Sourcing activities were also assessed as important to develop for increased possibilities of information sharing. To conclude, recommendations were formulated based on three areas; sustainability work, allocation methods, and increased information sharing.

Keywords: Measuring emissions, production facilities, supplier relationships, information sharing.

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Lastly, the external units have been of great help for driving the project forward and we appreciate the time they dedicated to assisting us in our work.

Marion Andersson
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Moa Lubell
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ABBREVIATIONS

- ABC: Activity Based Costing
- CET: Carbon Emission Trading
- CO_2e: Carbon Dioxide Equivalent
- EMS: Electronic Manufacturing Services
- ESS: Ericsson Supply Site
- E2E: End-to-End
- GHG: Greenhouse Gas
- GWP: Global Warming Potential
- ICT: Information and Communication Technology
- ISO: International Organisation for Standardisation
- OEM: Original Equipment Manufacturer
- RQs: Requests for Quotations
- SCM: Supply Chain Management
- SDGs: Sustainable Development Goals
- TBL: Triple Bottom Line

1 INTRODUCTION

This chapter provides context to the study, where the background of the project and the problem statement is presented, as well as the company in which the study will take place. This will be followed by the purpose and research questions addressed in the study. Lastly, the report's structure is outlined.

1.1 Background

Today's competitive and globalised market is characterised by economic growth and prosperity (Grant, Wong & Trautrims, 2017). However, during recent years, sustainability has taken on a sense of importance and urgency, which has contributed to a change in the market. Sustainability has become more crucial for consumers and stakeholders, as decisions about which products and services to purchase are more often based on different sustainability criteria (Galberth & Gosh, 2013). As a result, companies are challenged with handling not only the environmental, social, and economic effects of their activities systematically but also with the task of providing information about it to their stakeholders (Herzig & Schaltegger, 2006). In particular, companies' environmental performance has in recent years started receiving much attention and in order to be able to report about environmental progress, a defined baseline and continuous measurements are required (Ilinitch, Soderstrom, & Thomas, 1998). Therefore, it has become important for companies to be able to measure and calculate their environmental impact (McKinnon et al., 2015). According to Sullivan (2009) it is complicated to achieve robust measuring and even though most large companies have established processes and systems to manage and trace their emissions, there are some significant weaknesses in many of them.

Supply chain management (SCM) has proven to be critical in the dynamic environment characterising today's market (Melnyk, Narasimhan & DeCampos, 2014). As mentioned by Olhager (2013), manufacturing firms have successively shifted focus and perspective to remain competitive in the global market, from an internal production operations approach to a supply chain operations approach. Turker and Altuntas (2014) highlight that this approach includes achieving sustainable supply chains, as a result of the external pressure regarding sustainability. Consumers often hold the Original Equipment Manufacturer (OEM) responsible for the lack of sustainable practices along the supply chain and SCM practices are therefore of importance in order for companies to achieve sustainability (Hartmann & Moellern, 2014).

Ericsson is the case company for this master thesis, a global leading actor providing Information and Communication Technology (ICT) with the vision to empower an intelligent, sustainable, and connected world. The company was founded in 1876 by a Swedish inventor and entrepreneur named Lars Magnus Ericsson. Today, Ericsson has a broad product portfolio and is supplying its products and services all over the world. Recently, Ericsson launched the 5G network, the fifth generation of cellular networks, which will enable higher performing and reliable connectivity for everything from smartphones to industrial robots. The network provided by Ericsson is handling approximately 40 percent of the world's mobile traffic and the company is actively working with developing innovative solutions for telecommunication (Ericsson, 2021). During the last years, Ericsson experienced a change in their organisational structure and leadership, increasing their focus to incorporate sustainability work. One of the central objectives of the company is to achieve a higher degree of environmental sustainability throughout its business operations and during the year 2020, Ericsson was ranked as the 12th most sustainably managed company in the world (Wall Street Journal, 2020).

1.2 Problem Statement

Ericsson is actively working towards creating more sustainable solutions and aims to be a forerunner within sustainability by having zero CO_2e emissions in their internal operations by 2030. As of today, Ericsson is working with sustainability based on three focus areas; responsible business, environmental sustainability, and digital inclusion. The company wants to further investigate the environmental dimension of sustainability, to broaden the perspective of their environmental impact. A part of this is to investigate the impact of their supply, in particular their production facilities. As of today, Ericsson has four internal production sites, referred to as Ericsson Supply Site (ESS), and seven external production sites, referred to as electronic manufacturing services (EMS), which are located worldwide. The internal production represents 30 percent of total production, whereas the external production represents 70 percent. Based on the annual Sustainability and Corporate Responsibility Report from 2020, Ericsson had internal facility emissions of 81 Ktonne CO_2e, where the internal production facilities accounted for approximately 1.75 Ktonne CO_2e. However, there is limited information about emissions related to their external production facilities in the supply chain. Ericsson is therefore interested in further investigating the environmental dimension of their supply and include information about emission from their external production facilities in their sustainability reporting. These production facilities of the supply have not been investigated before, in terms of their energy source and CO_2e emissions.

There are two large and global manufacturing companies responsible for the outsourced production at Ericsson. These companies are also supplying manufacturing services for other companies apart from Ericsson. This makes it more complicated to define the share of emissions that Ericsson is responsible for within each external production site. Currently, Ericsson has limited information about the external sites' sustainability work and emissions. Therefore, Ericsson wants to gather more information about the emissions within these production facilities to be able to define a baseline for Ericsson's global carbon footprint related to their supply. Henceforth, the two external companies responsible for the outsourced production will be referred to as the external units.

1.3 Purpose

The purpose of this master thesis is to investigate and map Ericsson and the external units' sustainability work by analysing the current situation based on their energy sources and CO_2e emissions. Furthermore, recommendations on how to improve the sustainability work, which allocation method to use, and how the relationships between Ericsson and their external units can be developed are presented, as well as recommendations on how the sourcing strategy can be improved. In order to achieve the purpose, three research questions have been formulated.

RQ1: How do Ericsson and the external units work with sustainability today, with focus on energy sources and CO_2e emissions?

RQ2: How can the external units' emissions be allocated to accurately represent Ericsson's share of emissions?

RQ3: How can Ericsson in the future develop their collaboration with their external units related to sustainability?

By formulating a method about how Ericsson can calculate and allocate CO_2e emissions from their external units, the sustainability objectives defined by Ericsson can easily be achieved through tangible targets, developed relationships, and increased trust.

1.4 Report Disposition

In Table 1, the content of each chapter is briefly described and provides an overview of the report structure.

Table 1. *Disposition of the report*

Chapter	Content
1. Introduction	The background of the thesis is presented to introduce the context and the problem statement of the study. This is then followed by the purpose and the research questions of the thesis.
2. Theory Chapter	Previous literature within the field is presented. It includes areas of how to measure environmental impact, the GHG Protocol, allocation principles, SCM related to globalisation and outsourcing, and Green SCM.
3. Methodology	The methodology of the study is described. The research strategy, research process, data collection and data analysis methods, research quality, and ethical considerations are included.
4. Empirical Findings	The empirical findings of the study is presented based on the data gathered. The case company is introduced first, together with their sustainability work and sourcing strategy. Thereafter, information about the internal and external production sites is presented.
5. Analysis and Discussion	The data collected and the theory gathered is analysed and discussed to answer the formulated research questions. Limitations of the reasearch are discussed and potantial future reseach areas are presented.
6. Recommendations	The recommendations are further described and presented in relation to their effort and time of implementation.
7. Conclusion	The study's significant findings are presented.

2 THEORY CHAPTER

In this chapter, relevant theory of the research is presented. Firstly, an overview of the term sustainability, climate change, and how to measure it is introduced. Thereafter, different allocation approaches are presented. Lastly, the terms of supply chain management, outsourcing, and its effects on sustainability are explained.

2.1 Sustainability

There are several different definitions of what the term sustainability represents. One commonly adopted definition is "*Development that meets the needs of the present without compromising the ability of future generations to meet their needs*" (Gimenez, Sierra & Rodon, 2012, p. 150). However, this definition is difficult for companies to interpret and apply in their operations. Another definition that is more tangible and applicable is the Triple Bottom Line (TBL), which consists of three different dimensions; environmental sustainability, social sustainability, and economical sustainability (Gimenez et al., 2012). The authors explain environmental sustainability as the footprint companies leave behind, in terms of waste, pollution, energy usage, emissions, and consumption. Whereas social sustainability refers to equality, diversity, well-being, justice, rights, and needs of the individual. This applies both in internal communities, such as employees, as well as to external ones. Lastly, economical sustainability refers to the profitability of the company or organisation (Gimenez et al., 2012). Using the term sustainability has become increasingly popular within organisations and in research. Many companies have implemented sustainability strategies to enhance their productivity and create a competitive advantage (Bateh et al., 2013). However, the meaning of the term is constantly changing, which leads to companies often developing their own narrow view of sustainability and only considers aspects that are directly related to the company's performance (Bateh et al., 2013). Sustainability is a concept that is complex, and it is not possible to find or create a standardised definition that covers all aspects (Bateh et al., 2013).

2.1.1 Global Warming

Global warming refers to the effects on the climate as a result of human activities, for example, burning fossil fuels and large-scale deforestation. These phenomena cause large amounts of GreenHouse Gas (GHG) emissions to the atmosphere, which absorbs infrared radiation and contributes to global warming (Houghton, 2005). There are in total 27 GHGs divided into six categories; carbon dioxide (CO_2), methane (MH_4), nitrous oxides (NO_x), hydrofluorocarbons (HFC), perfluorocarbons (PFC), and sulphur hexafluoride (SF_6). CO_2 accounts for approximately 85 percent of the total greenhouse gases in the atmosphere, by far the largest proportion (Cullinane & Edwards, 2010). One way to evaluate the different greenhouse gases' global warming impact is through the global warming potential (GWP), which is a universal unit of measurement that indicates the effect of a specific gas in terms of one unit of carbon dioxide (GHG Protocol, 2011). If the GHG has a high GWP value, the gas has a longer lifetime in the atmosphere and is more effectively absorbing infrared radiation, resulting in higher temperatures around the world (GHG Protocol, 2011). To be able to compare the different

GHGs, they can be presented as carbon dioxide equivalents (CO_2e), calculated by multiplication of the mass of the greenhouse gas with its GWP (Cullinane & Edwards, 2010).

2.1.2 Global Sustainability Goals

There are several challenges connected to sustainability, for example, air and water pollution, global warming, poverty, and equality. In order to handle the future challenges, the United Nations Member States decided in 2015 to adopt an agenda for Sustainable Development by 2030. This agenda consists of 17 Sustainable Development Goals (SDGs), including matters like ending poverty and other deprivations together with strategies to improve education and health, reduce inequality, create economic growth, and preserve forests and oceans (UN, 2021a). The goals balance the three dimensions of sustainability; environmental, social, and economic (UN, 2021a), as mentioned previously as the TBL.

The same year as the SDGs were established, another framework regarding climate change was formulated, called the Paris Agreement (UNFCCC, 2021a). The Paris Agreement is a legally binding international alliance, with the objective to limit the increasing global average temperature to a minimum below 2 degrees Celsius, but preferably below 1.5 degrees Celsius. Today, 189 countries have joined the agreement, including Sweden. To achieve a climate-neutral world by the mid-century, the binding countries need to reduce their GHG emissions drastically and jointly adapt to the impact of climate change (UN, 2021b; UNFCCC, 2021a). To be able to track the actual progress of the Paris Agreement, the countries have established an enhanced transparency framework, whereby the countries will start reporting their actions and climate change mitigation progress by 2024. The framework also contains international procedures for the reviewing processes of the submitted reports (UN, 2021b). UNFCCC (2021b) presented a report of the progress of the Paris Agreement from 2021, where it was revealed that the committed nations have to redouble their climate efforts in order to reach the goal of limiting the rise of the global temperature by ideally 1.5 degrees Celsius.

The predecessor to the Paris Agreement is the Kyoto Protocol, an international agreement to reduce and limit GHG emissions (UNFCCC, 2021c). The Kyoto Protocol was agreed on in 1997 and was taken into force in 2005. As of today, 192 parties have joined, including Sweden, and binds exclusively developed countries, as it recognises that they are primarily responsible for the current high levels of greenhouse gas emissions in the atmosphere (UNFCCC, 2021c). 37 industrialised countries and economies agreed to reduce their emissions by an average of 5 percent over the five-year period 2008-2012, compared to 1990 levels. In 2012, the Doha Amendment was adopted to the Kyoto Protocol, with the objective to reduce GHG emissions of the binding countries by an average of 18 percent between 2013 to 2020. However, the amendment has not yet been taken into force (UNFCCC, 2021c).

2.2 Measure Environmental Impact

In order to improve within the area of climate change, there is a need for measurements and a defined baseline. According to Mendelsohn (2007), it is difficult to measure the impact of climate change. On a global level, the atmospheric carbon dioxide concentrations, global average surface temperature, rising sea levels, acidifying oceans, changing cryosphere, and extreme weather events are measured and analysed to evaluate the changes (Climate Change Committee, 2021). However, the need to measure environmental impact is not only applicable on a global scale, it is becoming increasingly important for companies as well. Consumers, shareholders, government regulations, employees, and the general public are paying more attention to companies' environmental performance and thereby, measurements are becoming a central part of stakeholders' decision making (Ilinitch, Soderstrom, & Thomas, 1998). Despite the increasing interest in companies' environmental activities, the actions regarding defining, measuring, and controlling the phenomena have been sparse. Companies can in some cases measure their impact within areas such as carbon dioxide emissions and water consumption, while biodiversity and soil degradation are not robustly assessed. However, few companies assess their environmental impact on an aggregated level (Di Fonzo & Hime, 2017). In order to make the measuring meaningful, the following principles should be fulfilled; comparable and measurable, easily accessible, possible to aggregate, replicable, be responsive to changes in businesses, able to support business decisions, and be taken into account in a local context (Di Fonzo & Hime, 2017).

One way to evaluate and determine environmental impact is to quantify GHG emissions. According to Sullivan (2009), most large companies have established processes and systems to manage and trace their emissions. However, there are some significant weaknesses in many of them. Velychko and Gordiyenko (2009) states that there are several approaches to estimate GHG emissions, for example, direct measurement and proxy data. Direct measuring is the quantification of GHG emissions by the usage of direct monitoring. Proxy data is when information about human activity (activity data or AD) are combined with coefficients that quantify the emissions per unit activity (emission factors or EF), by the following equation:

$$Emissions = AD \cdot EF$$

An emission factor can be defined as a static factor that converts activity or product data into GHG emissions, e.g. kg CO_2e emitted per litre of consumed fuel (GHG Protocol, 2011). Emission factors are commonly used for electricity or fuel, where the factors are multiplied with the amount used to get the total amount of GHG emission (Evans & Sidat 2018). Whereas activity data is defined as a quantitative measure of activity that results in GHG emissions (GHG Protocol, 2011). Examples of activity data can be kWh of electricity usage or quantification of used fuel. Companies have to report what kind of activity data and emission factors were used for their calculations (GHG Protocol, 2011).

2.2.1 Measure Emissions Related to Facilities

To reach national and global GHG reduction targets, a crucial part is to reduce the CO_2e emissions emitted from facilities (De Wolf, Pomponi & Moncaster, 2017). When assessing emissions related to facilities it is important to cover the whole life-cycle of the building, and not just the operational emissions (Röck et al., 2020). The GHG impact can be divided into two areas for facilities; operational and embodied impact (De Wolf et al., 2017). It is often assumed that the operational impact of facilities is higher than the embodied impact, which has led to more regulations that cover the calculation and reduction of the operational impact, whereas embodied impact lacks comparable methodologies and regulations (Ibn-Mohammed et al., 2013).

The operational impact refers to the CO_2e emissions that are emitted when operating a facility. The operational CO_2e emissions include all activities related to the usage of the facilities and maintaining the indoor environment as desired, over the lifespan of the facility (Ibn-Mohammed et al., 2013). This included cooling, heating, lighting, appliance, and ventilation (Ibn-Mohammed et al., 2013). The operational CO_2e emissions depend on the residents of the facility and can therefore be influenced throughout the facility's life-cycle.

The embodied impact refers to the amount of CO_2e emissions emitted when building a facility (De Wolf et al., 2017). As previously mentioned, the methodologies for calculating the embodied impact are often inadequate. A common way to calculate the impact is to use different life cycle methodologies, such as LCI or LCA, that include several different stages to receive a representable value of the embodied impact. De Wolf et al. (2017) account for the process, where the first stage is the product stage, which includes raw material, transportation of material from extraction to the production site, and the actual production. The second stage is the construction process and consists of transportation from gate to site and the installation process. Thirdly, the use stage includes the impact from the usage of components, repair, replacement, and refurbishment. The fourth stage, end-of-life, covers the deconstruction and demolition, transportation to landfills, recycling facilities, disposal, and waste processing. This visualises the complexity of calculating the embodied impact compared with the operational impact. Almost all the embodied impacts occur at one point in time, at the initial construction stage of the facility, and the rest during maintenance and renovation (Ibn-Mohammed et al., 2013). The usage of different methodologies when calculating embodied impact results in comparison issues, mainly due to lack of local and accurate data, unclear boundary conditions, and lack of demonstration projects and benchmarks (De Wolf et al., 2017).

2.3 Greenhouse Gas Protocol

The GHG Protocol initiative was launched in 1998 with the mission to develop a common international standard for how to measure and report GHG emissions (WRI & WBCSD, 2004). The GHG Protocol provides guidelines for two different but linked standards; the GHG Protocol Corporate Accounting & Reporting Standard and the GHG Protocol Project Quantification Standard. The first is a step-by-step guide about how to quantify and report the GHG emissions, while the second is a guide for quantifying reductions of GHG mitigation projects. The standards have had widespread adoption as it supports companies to understand and manage their GHG inventories as well as improving the possibility of tracking and comparing progress over time (WRI & WBCSD, 2004). In similarity with reporting and accounting financial matters, GHG accounting is based on certain principles; relevance, completeness, consistency, transparency, and accuracy (WRI & WBCSD, 2004). These principles are intended to ensure that the reported information about a company's emissions is true, faithful, and fairly accounted for. The first principle, relevance, ensures that the GHG inventory reflects the company's GHG emissions, in order to support decision-making for both internal and external users. Completeness, on the other hand, accounts for that all relevant emissions sources and activities are reported, within the inventory boundary. While consistency makes sure that common methodologies are used to make GHG calculations, enabling relevant comparisons over time. The principle of transparency addresses to which degree the information about the processes, procedures, assumptions, and limitations of the GHG inventory is presented factually and coherently, based on a clear audit trail. Lastly, the accuracy ensures that the data should be adequately precise so that potential users can make decisions with the assurance that the reported GHG information is credible (WRI & WBCSD, 2004).

When measuring the total amount of GHG emissions, a limited focus to only include direct emissions owned by the company in question may lead to misinterpretations and lost opportunities (WRI & WBCSD, 2004). Therefore, up-and downstream indirect emissions of a company's operations are significant for conducting a proper evaluation. The GHG Protocol has defined three scopes to help characterise the different direct and indirect emission sources (WRI & WBCSD, 2004). Scope 1 includes the direct GHG emissions from e.g. combustion in own properties or emission from own vehicles, while scope 2 includes indirect GHG emissions related to electricity from e.g. purchased electricity facilities (WRI & WBCSD, 2004). It is mandatory to report emissions related to scope 1 and scope 2 when reporting through the GHG Protocol. Scope 3, on the other hand, includes indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions, e.g. outsourced activities, business travels, and extraction of raw materials (GHG Protocol, 2011). Which parts of the scope to include or not are decided at the corporate level (WRI & WBCSD, 2004). However, to report emissions related to scope 3 is important to manage the full spectrum of GHG emissions that exist along the value chain. Few selected parts are mostly included in the scope due to the complexity of calculations in the activities. Otherwise, scope 3 is excluded completely. It is difficult to provide generic guidance for which activities to include in scope 3 (GHG Protocol, 2011). When accounting for emissions in scope 3, it is often valuable to focus on one or two major emission-generating activities. To ease the selection of activities to include it is important to understand the value chain of the organisation and determine relevant categories. By understanding the value chain, critical partners contributing to significant amounts of emissions can be identified (GHG Protocol, 2011). Once the activities are decided upon, quantifying the emission within the scope may be difficult. However, lower accuracy of the data is accepted due to the complexity of the calculations (GHG Protocol, 2011). It is often more important to understand the magnitude of the emissions and possible changes that can be done within the activity to lower their emissions. Therefore, estimates are accepted if the transparency of collected data and calculation methods are present (GHG Protocol, 2011).

2.4 Allocation

To allocate emissions can in some instances be necessary to be able to conduct proper measuring. Below, different allocation approaches are presented, both related to sustainability and financial matters.

2.4.1 Allocation of Emissions Permits

In order to achieve the goals set to reduce the GHG emissions in the atmosphere, a consensus between countries of sharing responsibility for the reduction is required for it to be possible (Zhou & Wang, 2016). Carbon Emission Trading (CET) is a widely adapted tool used for realising CO_2 emission reduction and in 2005, the largest trading market was initiated, the European Union Emission Trading Scheme (EU ETS). It was developed due to the restriction of "emission-space" in the atmosphere, demanding strategies for allocating the total amount of emissions allowed between nations. The CET system is therefore used to allocate CO_2 emission permits among participants (Zhou & Wang, 2016). When allocating emission permits on a national level, several criteria that are commonly used for the base of the allocation have been presented in the literature (Zhou & Wang, 2016). These are presented in Table 2.

Table 2. *List of allocation criteria.* (Zhou & Wang, 2016).

Criteria	Description
Sovereignty/ Grandfathering	Distribute permits in proportion to histroical emissions
Egalitarianism	Distribute permits in proportion to population
Ability to pay	Distribute reduction responsibility in proportion to GDP
Economic activity	Distribute permits in proportion to GDP
Horizontal equity	Distribute permits to equalize net welfare change
Vertical equity	Progressively distribute permits
Histroical responsibility	Distribute reduction responsibility in proportion to cumulated emissions
Merit (efficiency)	Distribute permits inreversely to emission intensity

2.4.2 Activity-Based Allocation

Another area where allocation is made is the Activity Based Costing (ABC) method. This method is commonly used in the financial sector. ABC differs from traditional cost estimation methods and is a method that assigns costs to different activities and uses financial and non-financial variables to allocate the costs (Baker, 1998). Furthermore, the method allocates a higher degree of indirect costs, also referred to as overhead costs, such as transportation and rent. ABC consists of two major elements, performance measures and cost measures, which are being measured in activities, resources, and cost objects (Baker, 1998). Activities refer to events that take place as a part of a certain job and can be either work tasks or processes performed by a person or a machine (Gerdin, 1995). Whereas resources can be defined as elements needed to perform a certain activity, such as employees, technology, and material. The resources are often quantified in monetary terms due to calculating purposes (Gerdin, 1995). Cost objects refer to any product, service, project, customer, contract, or any other work unit for which a cost measurement is needed (Baker, 1998). ABC describes the relationship between cost drivers and activities in the following way; "*resources are assigned to activities, then activities are assigned to cost objects based on their use*" (Baker, 1998, p.2). The cost is separated and matched to the level of activity that utilises the resource. The ABC method is using a two-stage allocation process when allocating the overhead cost per unit of product or service (Hasan, 2017). This has been visualised by Cooper et al. (1992), see figure 1. Firstly, the overhead cost is assigned to the activities, which is dependent on finding a suitable resource's driver. In the second stage, the cost is assigned to the product or service based on its use of activities.

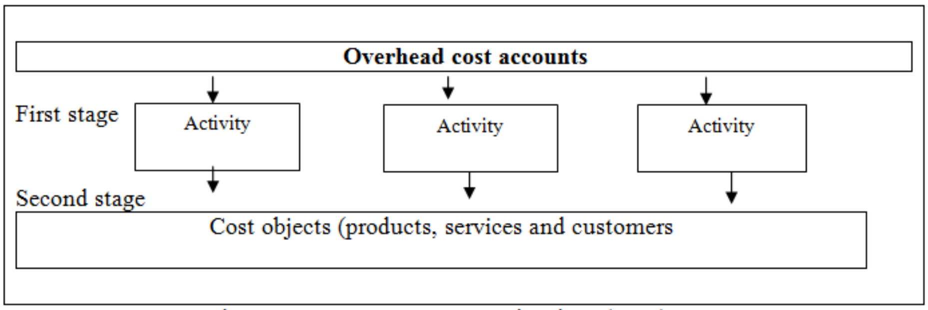

Figure 1. *Two-stage allocation procedure for ABC system*. (Cooper et al., 1992).

Allocation-based methods are not exclusively used in the field of economics, it can also be applied in sustainability matters. Marinho Neto et al. (2018) have integrated aspects of environmental sustainability into a traditional ABC method, with the aim to provide an innovative business model, where not only economic issues are in focus. This method, referred to as ABC_{env}, is an advancement of traditional ABC and is considering emission aspects as drivers instead of cost. ABC_{env} focuses on environmental activities such as air and water pollution, recycling, waste management, among others. The method also includes which of the activities that can more intensively affect the final result of emission reduction. Thus, different activities can be a target of improvement to achieve an overhead emission reduction, and not only support the company on which product to produce and in what amounts (Marinho Neto et al., 2018).

2.5 Supply Chain Management

Supply chain management has evolved over the past decades and is now an important part of every business (Ballou, 2007). It has its origins in logistics, defined as the process of coordinating activities associated with supplying products such as transportation, inventory control, warehousing, and facility location. The focus of logistics was primarily coordination of activities within a function, excluding coordination of other functions within the firm or other external members. As technology developed, the term expanded and developed into SCM. The Council of Supply Chain Management Professionals (CSCMP) defines SCM as presented below.

"Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies" (Ballou, 2007, p. 338).

Supply chain management has proven to be important for companies to remain competitive, especially in a market that is characterised by a dynamic environment as the one of today (Melnyk, Narasimhan & DeCampos, 2014). An effective SCM process can improve the organisation's financial position by reducing different operating costs and improve customer satisfaction by being able to deliver the right amount at the right time to the right location (CSCMP, 2021).

2.5.1 Globalisation and Outsourcing

Globalisation has had a large increase as a result of the development of international transport infrastructures such as ports, roadways, and railroads, along with international trade liberalisation. This has escalated the length of organisations' supply chains (Grant et al., 2017). As supply chains have experienced geographical expansion, decisions about related activities and how they shall be governed have become increasingly important (Kandil, Battaïa & Hammami, 2020). Depending on the organisational structure, different business strategies can be applied, such as outsourcing, insourcing, offshoring, and back-shoring, among others. The main difference between the strategies is related to ownership and location of facilities (Kandil et al., 2020). By Kandil et al. (2020), outsourcing is defined as when activities are relocated to external providers. A contract is negotiated with a third party to execute a specific operation, which can be performed either in the same or a different country as the origins of the organisation. Insourcing, on the other hand, is when a company is performing an activity or process in-house, where the company is the owner of the facilities and remains in control no matter the location of the operation. When an in-house activity is moved abroad it is called offshoring, defined to be when activities are relocated to be performed in another country than the origin of the organisation. Back-shoring is the strategy applied when activities are relocated back to the country or company of origin (Kandil et al., 2020).

As mentioned before, the market of today is characterised by a dynamic environment. Conditions in the market and within corporate boundaries have intensified, products' complexity and technology have expanded, and demand for higher quality and delivery performance has increased (Momme, 2002). This has made several companies adopt outsourcing as a strategy to remain competitive since outsourcing has several advantages. These are increased flexibility and quicker response to changes, lower labour wages, logistics facilitation, availability of competencies, and easier access to new markets (Kandil et al., 2020). Organisations are often outsourcing standardised processes and low-quality labour operations to be able to focus on core competencies and grow within those areas. Even though there are many advantages of outsourcing, it comes with certain risks. For example, communication and coordination difficulties, loss of control, longer lead times, larger inventories, and a decrease in product and process development capabilities (Kandil et al., 2020). As mentioned in an early study by Bettis, Bradley, and Hamel (1992), core competencies should not be outsourced, since outsourcing should be applied to areas of less importance. It is important to separate the R&D operations and manufacturing operations when outsourcing to not lose the competitive advantage that comes with a well-established R&D operation. (Bettis et al., 1992). Outsourcing can be performed in different ways for example, by using single or multiple sourcing. Single sourcing is defined as when the OEM is purchasing products from one supplier (Skjøtt-Larsen et al., 2007) and multiple sourcing is defined as when more than one supplier is used for supplying the same products (Horowitz, 1986). With a single sourcing strategy, long-term relationships are easily established and the possibilities of improving the supply chain performance are increased (Johansen, Howard, & Miemczyk, 2014). However, by using a multiple sourcing strategy, risks are reduced by utilising an alternative supply option. Additionally, competition between suppliers is increased, leading to possibilities for price reductions (Johansen, Howard, & Miemczyk, 2014).

Whether or not to outsource is a decision made at the corporate level. There are various analytical models presented in the literature to assist managers in the decision-making process related to outsourcing (Kandil et al., 2020). Different models are considering different variables, some focus on cooperation and competition scenarios, while others focus on uncertainty in demand and quantity adjustments. There has been an increase in consideration of environmental aspects into the decision-making process, which has influenced the development of many environmental-based models. One popular environmental-based model often referred to is one by Zhang, Padmanabhan, and Huang (2018). The model studied the impact of environmental regulations and was one of the first papers discussing the increasing offshored pollution. The authors described how organisations placed their offshoring sites within “pollution-friendly” countries to avoid fines for their emissions (Zhang et al., 2018). As a result of the increased attention to environmental impact related to the supply chain, many companies are starting to back-shore to regain control and thereby reduce the total amount of emissions (Kandil et al., 2020).

2.5.2 Supplier-Buyer Relationship

Establishing well-founded relationships with suppliers in the supply chain has been recognised as necessary to gain a competitive advantage (Mitręga, & Zolkiewsji, 2012). Sillanpää, Shahzad, and Sillanpää (2015) mentions that the need for buyers to collaborate and create long-term agreements with their suppliers has increased over the years to remain competitive. Nowadays, suppliers are not only supplying goods to the buyers, as they have become strategic partners and are important for OEM development.

2.5.2.1 Power Imbalance

As concerns about sustainability and ethical issues have increased, more pressure is placed on companies to be able to take accountability for malpractices of their suppliers, and sometimes their suppliers' suppliers (Touboulic et al., 2014). According to Touboulic et al. (2014), power imbalance based on the resource-dependency theory is an important area to investigate to understand who drives and implements different sustainability initiatives within the supply chain. The power imbalance is characterised into four different areas; supplier dominance, independence, interdependence, and buyer dominance (Touboulic et al., 2014). Supplier dominance is described to be when the supplier is of high value to the buyer by either handling a critical resource or being one of few on the market. Buyer dominance is thus when the buyer is of high value for the supplier. In an independent relationship, both the buyer and the supplier have a low dependency on each other, and in an interdependence relationship, both the buyer and the supplier have a high dependency on each other. The dominant player in the relationship has larger bargaining power and can thereby drive sustainability initiatives by placing demands on the weaker player. It is therefore important to understand the relationship an OEM has with its suppliers to be able to identify appropriate strategies to facilitate achieving different sustainability goals (Touboulic et al., 2014).

In the article by Touboulic et al. (2014), buyer-dominance is strongly associated with driving and implementing sustainability initiatives based on the pressure buyers are experiencing from several stakeholders. Buyers often exploit their power to try and manage their suppliers, and as suppliers are progressively collaborating, suppliers understand their own power over the buyer. Suppliers can thereby become resistant to changing their practices and create their own demands (Touboulic et al., 2014). In a supplier-dominant relationship, there are, however, lower levels of engagement about sustainability and more engagement about e.g. commercial aspects and price. Power relationships are dynamic and different strategies can be employed by buyers and suppliers to restructure the dependencies. As relationships evolve to incorporate sustainability goals they often move towards interdependence. This will result in loss of power but will in return result in several advantages such as increased security, learning opportunities, knowledge exchange, and greater potential to fulfil sustainability agendas (Touboulic et al., 2014).

2.5.2.2 Trust and Information Sharing

Trust and confidence in other members of the supply chain is an important factor for positive performance outcomes such as cost reductions, increased flexibility, and responsiveness (Capaldo & Giannoccaro, 2015). Trust also encourages stronger collaboration and risk-taking initiatives. Thus, efforts should be placed on developing trust between partners, which is an expensive task that requires time and costs. Therefore, long relationships are necessary to develop trust (Poppo & Zenger, 2002). The benefits of trust must be of high value to justify the trust-building process, otherwise, it is hard to advocate it to managers (Capaldo & Giannoccaro, 2015). A common way to define trust by supply chain scholars is to divide the term into three categories: contractual, competence, and goodwill trust (Capaldo & Giannoccaro, 2015). Contractual trust is when e.g. OEMs expect their partners to adhere to contractual clauses, such as their Code of Conduct. Competence trust is, on the other hand, when it is believed that partners have certain capabilities needed for performing specific tasks. Lastly, goodwill trust is when partners take initiatives for mutual benefits (Capaldo & Giannoccaro, 2015). The effects of trust can thereafter be explained by two theories, where one is transaction-cost-economics theory (Capaldo & Giannoccaro, 2015). Based on this theory, trust reduces the need for searching, monitoring, enforcement costs, and contracting, as well as decreased uncertainty in the information shared. Based on the other theory, relation-exchange theory, an interdependent relationship that yields increased trust increases the possibility of partners sharing information and knowledge, as well as the will to participate in joint learning processes and to explore new opportunities (Capaldo & Giannoccaro, 2015). Trust can be viewed as a complementary mode to govern suppliers and is most efficient when used together with contracts (Liu, Lou, & Liu, 2009). According to Liu et al. (2009), contracts are capable of controlling opportunism, and trust is more capable of improving relationship performance. However, there is also a dark side of trust where too much trust between partners can cause relational inertia, coercive power strategies, and opportunistic behaviours (Capaldo & Giannoccaro, 2015).

Information needs to be shared between partners in a supply chain for it to be efficient and effective. However, organisations are very cautious about what information to share, to whom, and to what extent based on their concerns about the security of confidential or sensitive information (Du et al., 2012). The willingness to share information can either be predetermined or spontaneous, where the first implies data is shared when specified in e.g. contracts and the second implies data is shared voluntarily. Sharing information between partners may enhance physical flows, demand planning, production schedules, among others, and also prevent distortion (Du et al., 2012). The relationship between the partners is a major factor influencing the willingness to share, where trust and interdependence are key. The willingness to share also reflects the quality of the information, such as accuracy, completeness, and reliability. When dealing with complex processes, such as measuring sustainability, more dynamic data is required and a long-term relationship needs to be established for the extent of information sharing to be successful (Du et al., 2012).

2.5.2.3 Collaboration

A reoccurring term that has been mentioned in sections 2.5.2.1 and section 2.5.2.2, is that an interdependent relationship is preferable between partners in a supply chain for improved collaboration. This is further elaborated on by Collazos et al. (2003), which defines interdependence as the heart of collaborative activities. Successful teamwork, whether it is in sports, business, or for a school assignment, is built on a collaborative structure with a “sink or swim together” mindset. This means that everyone involved must realise that they cannot succeed unless everyone succeeds (Collazos et al., 2003). Increased cooperative learning and stronger collaboration can be achieved through goal and task alignment between the parties, which are thereafter resulting in joint rewards (Collazos et al., 2003). This is supported by Sambasivan et al. (2011), which presented the framework seen in figure 2. Relationship capital is in this context describing the quality of the relationship that exists between partners in a supply chain (Sambasivan et al., 2011).

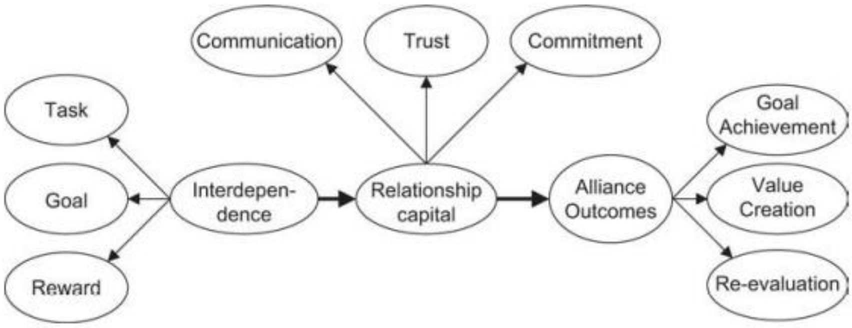

Figure 2. *Framework of alliance relationship*. (Sambasivan et al., 2011).

According to Sambasivan et al. (2011), partners with aligned tasks, goals, and reward systems enable more frequent communication, increased performance, and trust-building. Aligned goals are important for companies to be able to create compatible objectives and work closer together (Yan, 2011). They can also be used for governance by reducing possibilities of opportunism in the supplier-buyer relationship (Jap, 1999). When formulating aligned goals, firms have the desire to collaborate for a long period of time (Jap & Anderson, 2003).

2.5.3 Green Supply Chain Management

Supply chain management is facing several challenges related to environmental impact as the supply chains have expanded to a globalised level. Green SCM is representing the environmental aspect of sustainable SCM (Abdullah et al., 2018) and is an important strategy for companies to adopt to be able to lower their environmental risks and impacts across the entire supply chain (Wu, Tseng, & Vy, 2011). The pressure of adopting green practices is increasing from many different stakeholders, such as customers, societies, and international agencies (Abdullah et al., 2018; Turker & Altuntas, 2014). Green SCM refers to product design, material sourcing and selection, production processes, among others, in the SCM process based on the environmental aspect and may have a direct impact on the decision of supplier and creation of partnership (Wu et al., 2011). Supplier requirements based on the Code of Conduct are often employed to ensure suppliers are working in an environmentally friendly way, in line with the goals of the organisation (Grant et al., 2017). A common environmental initiative is the International Organisation for Standardisation (ISO) 14000 certification (Mollenkopf, 2010). It is generally encouraged by OEMs that suppliers apply for the certification and are often incorporated into the supplier selection process (Mollenkopf, 2010). The ISO 14000 is a family of standards related to environmental management, including required procedures for organisations on how to manage their environmental responsibilities (ISO, 2021).

The implementation of Green SCM is driven by several factors (Mollenkopf, 2010). These are the creation of common global environmental standards among organisations, the global environmental reputation of the organisation, cost reduction, customer demand, and competition. Competition is an important driver since many larger companies are developing environmental management systems, influencing other companies to implement them in order to not fall behind. Yet, the strategy of green SCM is facing many barriers (Mollenkopf, 2010). Suppliers within the supply chain are still resistant to implementing environmental practices due to several reasons. One common reason is related to cost, which makes it hard for OEMs to influence their suppliers. Green SCM is a new concept where there is a lot of information missing about how to implement it on a global level. Data from measuring sustainability is not always available throughout the supply chain and the fear of losing key partners within the chain based on their environmental impact may cause strategic dilemmas (Mollenkopf, 2010).

One crucial aspect of Green SCM is a company's sourcing strategy since the selection and evaluation of suppliers play an important part in achieving sustainability in an OEM's supply chain (Ghadimi, Dargi & Heavey, 2017). The sourcing strategy includes contracting arrangement, supply chain design, supplier selection, facility location, production management, inventory management, and logistics management (Kandil et al., 2020). The contract arrangement defines responsibilities, compliance, incentives, end of the contract, and compensation (Baldwin, 2008; Barthélemy & Quélin, 2006). It is important to have contracts that include clearly defined requirements to align expectations, divide responsibilities, and limit potential conflicts in the collaboration (Mayer & Teece, 2008). If a decision has been made to e.g. outsource an operation, contracting arrangements are signed between the parties involved (Kandil et al., 2020). For projects or collaborations that consist of uncertainty, it is challenging to formulate a contract that covers every future scenario, and therefore, flexibility in the contract is of importance (Cox, 1996). Establishing contracts should reflect the interest of all included, which is a complex task (Barthélemy & Quélin, 2006). Furthermore, requirements included in the contract are often based on the Code of Conduct, as previously mentioned, and are formulated by the OEM (Grant et al., 2017). A Code of Conduct is defined to be a framework specifying commitments made to control and influence business behaviours, often describing how to implement the commitments (Gordon & Miyake, 2001). There has been a growth in the use of Codes of Conduct over the years based on the increasing concerns related to environmental requirements and labour rights (Doh & Guay, 2004). However, Blomqvist, Hurmelinna, and Seppanen (2005) emphasises that contracts alone are not enough to control suppliers, it needs to be combined with trust, also mentioned in section 2.5.2.2.

Traditionally, sourcing decisions have solely been based on reducing costs, where environmental and social aspects have been neglected. However, the increasing amount of sustainable legislation has forced companies to integrate the TBL into their businesses, both production and supply chain activities (Ghadimi et al., 2017). This has resulted in companies that incorporate the full spectrum of the TBL in their sourcing activities gaining a competitive advantage in the market. Also, Akhavan and Beckmann (2017) highlight that proactive and well-formulated sourcing strategy can contribute to improving a company's sustainability performance in general.

2.5.3.1 Production Facilities

When goods are being produced, GHGs are emitted, which contribute to global warming and climate change (Grant et al., 2017). It has been proven that production is one of the major contributors to the environmental impact of the supply chain. It is therefore important for companies to identify opportunities to implement cleaner production to lower the environmental impact. Cleaner production is defined by the United Nations Environment Program (UNEP) *"Cleaner production is the continuous application of an integrated preventive environmental strategy applied to processes, products, and services to increase eco-efficiency and reduce risks to humans and the environment"* (Grant et al., 2017, p. 129). The concept has the overall goal of improving the production process for more efficient usage of energy and materials to prevent undesirable pollution. It can be achieved through technology innovations and renewable energy for higher productivity with reduced consumption, as well as introducing lean principles and statistical process control techniques to reduce waste (Grant et al., 2017).

Using renewable energy within facilities in the supply chain is an easy way to improve operational emissions, which were described in section 2.2.1 (Grant et al., 2017). Renewable energy can either be bought from suppliers or generated on-site. If it is bought from suppliers, it is bought through green certificates. Green certificates are verifications of the origin of the energy produced being green (Bye, 2003). The certificates are issued by the government for each unit of energy produced by renewable energy and can be purchased by consumers to be proportional to their total amount of energy (Bye, 2003). If renewable energy is produced on-site it can be gained from e.g. solar panels, wind turbines, recovered waste energy, or thermal exchange units (Grant et al., 2017). Generating energy on-site makes energy management more complex. This is due to the importance of balancing the demand to the supply, making sure it can respond to fluctuations, and planning for how to manage the excess energy, among other implications (Grant et al., 2017). When comparing on- and off-site generated renewable energy, the on-site alternative is often more costly and has higher investment risk. On the other hand, on-site energy generation may be favoured by governmental regulations and incentives, as well as knowing the energy is actually green (Grant et al., 2017).

Apart from renewable energy, reducing the environmental impact of the facilities can be done through several actions (Grant et al., 2017). When relating to embodied emissions, described in section 2.2.1, redevelopment of already existing sites is a way to avoid additional emissions when building facilities. This has a positive effect on land use and the surrounding environment as well since the same area will be used for construction again. It is also important to use the right construction material for the intentional lifespan of the facility, to make sure that no reconstruction is necessary for the future (Grant et al., 2017). Facilities need to have the ability to achieve and hold specific temperatures, which is facilitated by the use of proper insulation and building fabric. In addition to this, controlled air ventilation can be installed to make sure that no energy is wasted. Furthermore, lighting stands for a large part of the total energy consumption in a facility. It is therefore important to invest in efficient lighting technology together with motion sensors and time-controlled lighting. Installation of windows lowers the need for artificial lighting but is a trade-off for insulation (Grant et al., 2017).

Another initiative to reduce the environmental impact of production facilities is to implement smart factories and smart manufacturing. Smart factories and smart manufacturing are the subject of the 4th industrial revolution, Industry 4.0 (Meng, Yang, Chung, Lee, & Shao, 2018). The purpose of a smart factory is to reduce the risk of accidents, increase the profitability of the factories, and achieve zero-emission production with the use of modern technology. Increased automation through the Internet of Things, large-scale communication between machines, smart sensors, cloud computing, and big data analytics are some of the important driving forces for smart manufacturing. Sustainability and energy efficiency are important goals when designing and implementing these factories, as it is one of the core aspects of smart manufacturing (Meng et al., 2018). More accurate knowledge about the production process can be gained from big data analytics and thereby, improve resource and energy efficiency (Wang, Wan, Li, & Zhang, 2016). In addition to this, the use of smart machines can reduce energy consumption, since information about this can be more easily obtained. The increased communication within the system may also enhance sustainable production by increased coordination and re-configuration possibilities, improving the productivity and efficiency of the process (Wang et al., 2016).

However, several challenges of implementing smart manufacturing have been identified. Some of them are security and safety issues, system integration, and return of investment (Phuyal, Bista, & Bista, 2020). The challenge of security and safety issues is related to the increased need for secure information sharing through the internet, as well as the increased need for creating a safe work environment for humans due to increased human-robot collaboration (Phuyal et al., 2020). Furthermore, the challenge of system integration is related to integrating new technology with existing equipment. Older equipment and machines might not be compatible with the technology, resulting in organisations being required to invest in new equipment and in some cases, new factories (Phuyal et al., 2020). This is related to the last challenge, return of investment. The investment needed for implementing smart manufacturing can be compared with the losses caused in production during the installation and the time needed to receive return on investment, which can take time. Therefore, the investment needs to be carefully analysed before the decision (Phuyal et al., 2020).

3 METHODOLOGY

In this chapter, the study's methodology is described. First, the research strategy and the research process are presented, followed by the data collection methods. Thereafter, the data analysis is described together with the research's quality. Lastly, the research's ethical considerations are evaluated.

3.1 Research Strategy

A qualitative research strategy was used to conduct the study and answer the formulated research questions. The qualitative strategy is emphasised on analysing interpretations of words and non-numerical data (Bryman & Bell 2011). The reason for performing the previously mentioned strategy was because non-numerical data was used as the foundation of providing well-founded answers to the research questions. However, numerical data will be present in the report but is assessed to be viewed as additional qualitative data based on the fact the researchers have only evaluated the data and not calculated or compiled it themselves.

To describe the relationship between theory and research, Bryman and Bell (2011) present two different approaches; an inductive and deductive approach. These can be combined into an abductive approach. An inductive approach is often used in combination with a qualitative research study and is described as the approach where theory is an outcome of the research. A deductive approach is on the other hand combined with a quantitative research strategy where theory is tested through a hypothesis that is either rejected or accepted (Bryman & Bell, 2011). The abductive approach, however, allows back and forth movement between data and theory (Awuzie & McDermott, 2017). During the study, theory and research were researched simultaneously, in the shape of a process where literature was reviewed, the theory chapter was updated, and the research questions redefined, at the same time as data was collected. The process was therefore following the abductive approach, characterised by an iterative nature and having equal distribution of theory and data (Creswell, 2014).

The research design of a study guides the process of collecting, analysing, and interpreting data (Yin, 2003). As described by Bryman and Bell (2011), the research design of a case study is defined to be when a single case, either an organisation, location, person, or event, is intensively analysed in detail in its real-life context. In this study, a single case study was conducted together with Ericsson. This research design was assessed to be the most appropriate for the study due to the complexity of the research subject, since it involved external stakeholders and multiple units within the case company.

3.2 Research Process

The research process of the study consisted of four main phases; initial contextual understanding, definition of problem and scope, data collection, and analysis & conclusion. As mentioned in the previous section, the process of the study was characterised by an iterative nature rather than linear. An overview of the research process and its phases are visualised in figure 3.

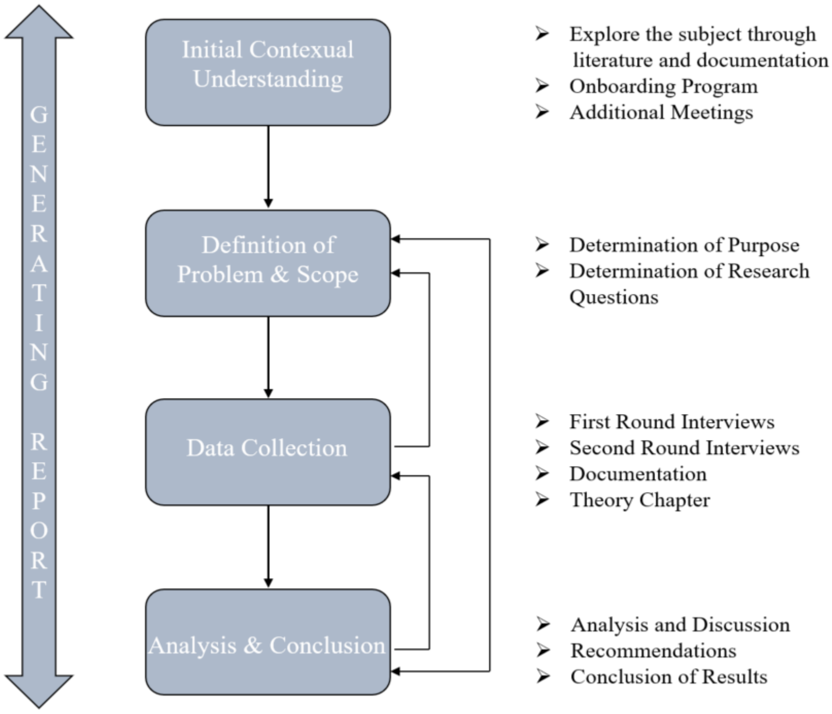

Figure 3. *Illustration of the research process*

In the first phase, the focus was to gain a general understanding of the case company and the research area. This included three main activities, where the first part was to explore the subject through various sources, such as literature and documentation. Thereafter, meetings were arranged with Ericsson's employees in order to create an understanding of the company and its challenges. Simultaneously with this, the researchers attended an Onboarding Program, described in section 3.3.2, to further familiarise themselves with the organisation and gain a contextual understanding of several areas and departments within Ericsson. During the second phase, the knowledge collected from the first phase was applied to formulate a relevant problem definition and made it possible to determine the scope of the study. After phase 1, the scope was set together with Ericsson to investigate a selected number of external production sites and their sustainability work. Thereafter, the study's purpose and research questions were formulated, and the next phase was initiated. After a period of time, a request arose from Ericsson to change the scope of the study to broaden the perspective and instead include all of the production sites operated by the external units within the study. This phase was considered as one of the most crucial and time-consuming since the scope and problem definition was challenging to determine together with the direction of the study.

The third phase consisted of collecting data, where the main source was through interviews. The interviews were performed in two rounds, further described in section 3.3.1, and were held internally at Ericsson's and with the external units. The objective of the interviews was to gain a profound understanding of how Ericsson and the external units are working with sustainability but to also gain access to the external units' emissions. Before and parallel with the interviews, the researchers examined documentation from Ericsson and the external units, in order to gain insights into the current situation and their achievements, see section 3.3.3. The collected data was documented as empirical findings, see chapter 4, and a collection of theory within the subject was compiled and presented in the theory chapter, see chapter 2. In the last and fourth phase, the findings were analysed together with the information from the theory chapter. Thereafter, recommendations were formulated to reach a finalised conclusion. This phase consisted of discussions back and forth with Ericsson in order to make valid and valuable recommendations for future improvement within the subject.

3.3 Data Collection

This section presents how the data for the study was collected. Different data collecting methods were used to analyse the subject from numerous perspectives, which is preferable to gain a holistic perspective of the problem (Yin, 2009). The data was collected through internal and external interviews, participation-observation, and documentation.

3.3.1 Interviews

Primary data was collected through online interviews with members from Ericsson and the external units. Most of the data used for the analysis was derived from these interviews. The reason for choosing interviews as the main method of collecting data was due to the qualitative elements of the thesis and also due to the flexibility that interviews offer. Furthermore, interviews can reveal information regarding attitudes, behaviours, and social backgrounds (Bryman & Bell, 2011), which were aspects that contributed to answering the research questions. There were no specific numbers of interviews set at the beginning of the project since the process was of iterative nature, resulting in interviews proceeding until the researchers had enough information. Before the interviews, the researchers compiled an interview guide that acted as a foundation for the interviews, see appendix A. It described which kind of information was needed for the researchers to continue with the process and which parties or persons that could potentially support with the required knowledge. The interviews were conducted in two rounds. Firstly, interviews were conducted with different members of Ericsson to gain an understanding of the current situation, the relationship with their external units, goals, and vision regarding sustainability, among others. These interviews were mainly semi-structured and were guided by a number of predetermined subjects and questions (Bryman & Bell, 2011) that were listed in the interview guide. The interviews from the first round are listed in table 3. The semi-structured interviews provided the interviewees with the possibility to further elaborate their answers and gave the researchers the possibility to ask further questions in response (Bryman & Bell, 2011).

Table 3. *List of interviews in the first round*

Number	Title	Length (min)	Topic
1	Senior Supply Chain Manager	60	Introduction to Ericsson's supply chain structure
2	Senior Supply Chain Manager	30	Complementary questions to previous interview
3	External Supplier Manager	60	External production facilities, primary focus Hungary
4	Sustainability Driver	60	Internal CO_2e measurement system
5	Supply Chain Manager - Outbound	50	Collaboration with external partners
6	Member of Supply Sustainability Program	50	GHG Protocol
7	Sourcing Manager	30	Sustainability at Sourcing
8	External Supplier Manager	30	External production facilities, primary focus Poland
9	Senior Sustainability Specialist	30	CO_2e calulations internal facilities
10	Supplier Relation Manager	45	Information EMS Company 1
11	Supplier Relation Manager	30	Information EMS Company 2

In the second round, interviews were initially conducted with Ericsson's external units. These interviews contributed knowledge about how the external units work with sustainability, their relationship with Ericsson, and their vision for future sustainability work, among other areas. After the interviews with the external units, a number of complementary interviews were held with employees from Ericsson. This was because additional information was needed to complete the findings. These interviews were also semi-structured with several predetermined questions from the interview guide. This structure gave the researchers control over the interview while still maintaining flexibility. The interviews from the second round are listed in table 4.

Table 4. *List of interviews in the second round*

Number	Title	Length (min)	Topic
1	Company 1	60	Presentation of Company 1's sustainability work
2	Company 2	60	Presentation of Company 2's sustainability work
3	Senior Supply Chain Manager	45	Information about internal production facilities
4	Senior Sustainability Specialist	40	Internal emission reporting and allocation methods
5	Member of Supply Sustainability Program	45	Smart manufacturing

Both researchers were present during all interviews and, as mentioned before, all were held online through Microsoft Teams. This was also important to be able to divide the workload and responsibilities, having one person responsible for asking questions and the other responsible for recording the meeting and taking live notes. It was also important that both researchers were present to make sure that there were no misinterpretations regarding the data collected. The interviews held were no longer than one hour to ensure that the quality of the interview was not interfered with (Gillham, 2008).

3.3.2 Participation-Observation

An Onboarding Program was offered by Ericsson for students conducting their master thesis in collaboration with them. The goal of the Onboarding Program was to give the students more knowledge about Ericsson as an organisation and to build them a network of contacts within the organisation. The program consisted of nine arranged meetings where the students participated passively by listening, see the list of meetings in table 5. The researchers participated in all of the nine meetings which contributed to the contextual understanding. The information gained from the participant-observations served as additional data for the study.

Table 5. *List of participation-observation*

Number	Length (min)	Topic
1	60	Introduction to Supply Sustainability Program
2	60	Introduction to Ericsson
3	30	Responsible sourcing
4	45	Climate action - greenshouse gas emissions
5	45	Circular business focus area
6	55	Climate action & Circular economy
7	45	Networks SCM sustainability work
8	45	Supply chain design
9	45	CO_2e performance indicator

3.3.3 Documentation

Documentation is important in order to create a holistic understanding of the current situation and the potential problem (Davidson & Patel, 2003). The gathered documents of the study were treated as secondary data, which means that the content within these documents was not collected for this particular study (Eliasson, 2010). The documentation used was provided by Ericsson and their external units and included both official and internal documents, such as Code of Conduct, sustainability reports, annual reports, and other processes related to sustainability. Also, documentation regarding the external units' emissions was provided, based upon calculations made by the companies themselves.

3.4 Data Analysis

According to Bryman and Bell (2011), there is no clear description about how to analyse qualitative data. The data gathered is often unstructured and of large volumes, making it hard for researchers to find an analytic path. Instead, the data collection and the data analysis occur at the same time, making the process of an iterative nature (Bryman & Bell, 2011). Since the thesis was of abductive nature, as described in section 3.1, the method of analysing the data gathered was done iteratively. Theory was collected and presented in chapter 2, data compiled and presented in chapter 4, and an analysis and discussion of the information gathered related to the research questions was performed simultaneously. It was assessed that inserting the result from the data collected into chapter 4 directly after it had been acquired was the most efficient method for handling the gathered data. When compiling the data, it was structured based on the subject of the interview, resulting in a light categorisation, which served as a foundation for the analysis and discussion chapter as well. All interviews were recorded, as described in section 3.3.1, making it possible for the researchers to go back to the recordings if information from the interviews needed to be added afterward, which was of high value in the analysis process.

3.5 Research Quality

To be able to evaluate qualitative research's quality, areas such as trustworthiness and authenticity are most commonly used (Bryman & Bell, 2011), which are presented and elaborated on in the sections below.

3.5.1 Trustworthiness

Trustworthiness consists of the four criteria credibility, transferability, dependability, and confirmability (Bryman & Bell, 2011). These criteria aim to investigate the balance between the interviewee's or the documentation's meaning with the researcher's interpretation of them (Williams & Morrow, 2009). To ensure the trustworthiness of the conducted study, a fair interpretation of collected data was ensured by several actions. The criteria credibility refers to whether the research is performed according to principles of good practice and to what extent the research's findings correctly reflect upon its social context (Bryman & Bell, 2011). To ensure credibility of this study, the findings and recommendations have been discussed with Ericsson for input, and the report has been sent out to the external units for validation of facts. Additionally, several data collection methods have been used, such as interviews, documentation, and participations-observations. Furthermore, transferability refers to whether the study's findings can be generalised to other contexts (Bryman & Bell, 2011). To ensure transferability in a qualitative study can, according to Bryman and Bell (2011), be challenging due to the fact that social contexts can vary. Instead, the authors argue that the focus should lie on providing a rich description of the studied context, making it possible for other researchers to evaluate the transferability. Therefore, efforts were made to provide a rich description of the study's context, such as an illustrative background, clear problem description, and thorough company descriptions, see chapter 1 and chapter 4.

The criteria dependability evaluates the study's reliability and to what extent the study's theoretical conclusions can be justified (Bryman & Bell, 2011). The authors suggest an adoption of an audit approach that enables the possibility for others to go through the material. Hence, all collected data was saved until the end of the thesis process. Lastly, the criteria conformability connects to whether the researchers have allowed personal values to influence the study and that the findings are based on the interpretations of the participants (Bryman & Bell, 2011). To ensure the conformability of this study, the interviews were recorded and relistened to, combined with the fact that Ericsson and the external units were given the possibility to read through and confirm the empirical content of the thesis.

3.5.2 Authenticity

Authenticity consists of five criteria; fairness, ontological authenticity, educative authenticity, catalytic authenticity, and tactical authenticity (Bryman & Bell, 2011). The objective of evaluating these criteria is to understand how the performed study can impact the research area (Bryman & Bell, 2011). The criteria fairness relates to which extent different stakeholders' viewpoints are represented in the study (Bryman & Bell, 2011). To ensure the study's fairness, several data collection methods were used, and interviews were held both internally at Ericsson and with the external units, see table 3 and table 4. In addition to this, the internal interviews included participants from different departments and at different levels at Ericsson. Ontological authenticity is regarding whether the study contributes to participants' understanding of the social environment, whereas educative authenticity refers to whether the study contributes to the understanding between the different stakeholders (Bryman & Bell, 2011). These criteria were ensured by including participants from various settings, which enabled the stakeholders to view the study from different viewpoints. Catalytic authenticity relates to if the study acted as a catalyst for changing the environment, while tactical authenticity considers whether the study has made the stakeholders go through with the change (Bryman & Bell, 2011). Measures to ensure these criteria were to deliver recommendations for future improvements within the subject and involve Ericsson during this process, which gave them the opportunity to provide input on how the recommendations could be adjusted to their organisation. In addition to this, discussions regarding which parts of Ericsson that could be suitable candidates for continuing the work with the recommendations were held at the end of the thesis process.

3.6 Research Ethics

Issues related to research ethics can be divided into four areas; harm to participants, lack of informed consent, invasion of privacy, and deception (Bryman & Bell, 2011). All of these areas were carefully considered throughout the study's process and included measures such as informing the interviewees about the purpose of the thesis and collecting their consent to be a part of it. All interviews were recorded if permission was given by the interviewee, to be able to revise the material later on in the process. Most interviews were conducted in Swedish, with the exception of a few being in English when the interviewee was not fluent in Swedish. Parts of the Swedish interviews were thereby translated to English for the data analysis. The recordings were therefore of high importance, reducing the risks of statements changing meaning and nuances being lost in translation (Flick, 2014). Furthermore, the names and details of the interviewees and the external units were held anonymous. The content of the interviews and the collected data were conscientiously analysed with respect to the true content. Lastly, Ericsson and the external units were able to go through the report before it was published, to assure that no confidential or sensitive information was included.

4 EMPIRICAL FINDINGS

In this chapter, the findings of the study are presented. Firstly, Ericsson is introduced, together with their sustainability work and sourcing strategy. Thereafter, the internal and external production sites are described, along with a presentation of the external units and their sustainability work and emission data.

4.1 Introduction to Ericsson

Ericsson is a Swedish-owned company and is a global leading actor within the ICT sector. During 2020, Ericsson had revenue of 232.4 BSEK and had approximately 100 000 employees all around the world. Ericsson has a product portfolio with a high variety of products. The company is divided into four business areas; Networks, Digital Services, Managed Services, and Emerging Business. Networks is the business area accounting for the majority of the products produced and supplied within Ericsson and represent the largest share of the revenue. Group Supply is a unit within Networks responsible for managing the logistics and supply chain of products related to all four business areas of Ericsson, coordinating it with the global supply regions. One part of Group Supply is Networks SCM, responsible for two main operational areas; Supply Chain Management and Supply Product Management. The first mentioned have the responsibility for determining an appropriate E2E supply chain design covering all parts of the product's life cycle. The latter is responsible for supply readiness, supply requirements, and supply chain definitions and optimisation during the product's life cycle.

Ericsson's supply flow is illustrated in figure 4**.** An external component supplier delivers ordered units to a component hub, which then distributes the items further to either an Electronics Manufacturing Service (EMS) site or an Ericsson Supply Site (ESS). The EMS site is an external production facility producing products in large volumes and the ESS site is an internal production facility with smaller-scale production. The products are thereafter distributed to an Ericsson Supply Hub (ESH) responsible for warehousing of products. After that, the products are either delivered to a local warehouse or a customer warehouse.

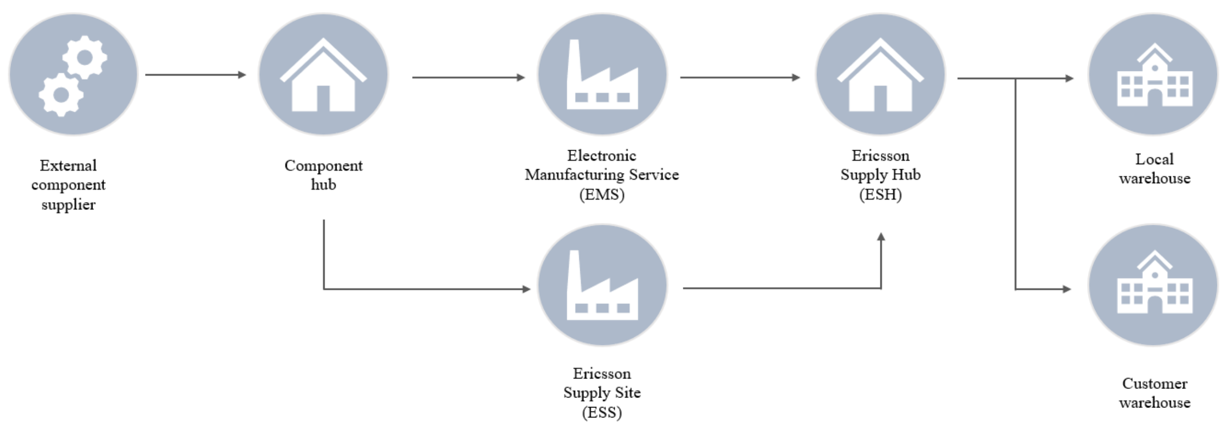

Figure 4. *Simplified illustration of the supply flow*

4.1.1 Ericsson's Sustainability Work

During 2017, Ericsson experienced a change in their organisational structure and leadership, attaining a new strategy defined by "*empowering an intelligent, sustainable and connected world"*. One of the focus areas of the new strategy is thereby to incorporate environmental sustainability work throughout the organisation. As mentioned in the Sustainability and Corporate Responsibility Report 2020, Ericsson is contributing to all of the 17 United Nations Sustainable Development Goals through the technology they deliver. Ericsson is primarily contributing within SDG 9 (industry, innovation, and infrastructure) and SDG 17 (partnership for the goals), two goals central to Ericsson's business. Ericsson is aligning their sustainability targets with the SDGs to ensure that meaningful goals are set. Ericsson is also globally certified with ISO 9001 (quality), ISO 14001 (environment), OHSAS 18001 (health and safety), and ISO 27001 (information security). The sustainability work at Ericsson is driven and governed by an executive team and is divided into six cross-functional workstreams; climate action, energy performance, circular economy, material & substances, responsible sourcing, and position & standards. An additional sustainability initiative by Ericsson is the Supply Sustainability Program, supporting the work of the six mentioned workstreams. The program is operating under the business area of Networks SCM and started in 2020 with the purpose and vision described as "*Empowering sustainable supply chains and feel Proud @ Supply"*. The Sustainability Program is divided into three focus areas; circular business, climate action, and engagement, where one of the objectives is to find opportunities to reduce the environmental impact within the supply. This thesis is a part of the climate action function, which has the purpose to reduce carbon activities to accelerate towards a carbon-free supply. One of the function's objectives is to measure the supply's total carbon footprint to be able to define a baseline for future improvement projects since the suppliers' carbon footprint plays a significant role in identifying the environmental impact of the supply chain.

According to a member of the Supply Sustainability Program, supply plays an important role in achieving Ericsson's overall sustainability objectives. In Ericsson's Sustainability and Corporate Responsibility Report 2020, it is stated that the company "*will engage with around 350 of its high emitting and strategic suppliers to set their own 1.5°C aligned climate targets by 2025"* and that "*Ericsson is Carbon neutral by 2030 in its own operations (related to scope 1 and 2)"*. By last year, 35 of Ericsson's high emitting and strategic suppliers had already committed to the 1.5°C alignment target. Earlier, Ericsson had an objective to *"reduce 35 percent of* CO_2*e emissions from Ericsson's own activities by 2022 (baseline 2016)"*. In the report, it was revealed that this objective had already been achieved in 2020, with a reduction of 57 percent of internal carbon emissions. Regarding Ericsson's facility emissions, it was announced that there was an overall reduction of 59 percent of carbon emissions related to internal facilities in 2020 compared to the baseline of 2016, from 135 Ktonne CO_2e to 81 Ktonne CO_2e. The reduction was a result of actions made by Ericsson to reduce energy consumption and increase the use of renewable energy. According to one of the members of the Supply Sustainability Program, Ericsson has started buying renewable energy attribute certificates and mentioned that they are constantly working with optimising the use of their facilities. Out of Ericsson's total electricity consumption during 2020, 68 percent came from renewable energy sources. Ericsson has created a target to reach 100 percent renewable energy consumption by 2030 internally. The same respondent elaborated that Ericsson views the purchase of the green certificates as a short-term solution. "*The certificates give us the possibility to report our facility emissions close to zero because of the energy source being renewable energy. However, to be fully sustainable we need to invest in other solutions*". Ericsson has therefore started working with projects regarding on-site renewable energy, where the energy will be locally and self-supplied by, for example, solar cells or wind power. The reason why the green energy certificates are a short-term solution was elaborated on by the Senior Sustainability Specialist at Ericsson. "*We are not sure about how the energy is handled when buying the certificates. Sometimes, the plant producing the green energy is located far from the production facility, making it not physically possible to provide our production facilities with the green energy due to the distance*". However, the respondent highlighted that the green certificates are favourable in the sense that they create a demand for green energy in society.

Ericsson is also active in sustainability projects outside their organisation and is one of the leading partners to the Exponential Roadmap Initiative. The roadmap initiative is aligned with the objective of the Paris Agreement; to keep the global average temperature below 2°C, but preferably below 1.5°C. The initiative aims to connect scientists, companies, innovators, and NGOs with the objective to reduce GHG emissions by 50 percent by 2030 through exponential climate actions and solutions. Solutions to reduce GHG emissions are presented in the 1.5°C Business Playbook, together with strategies for how to scale them exponentially. The playbook provides a holistic framework on how companies and organisations can integrate climate action into their business strategies. A part of the Exponential Roadmap Initiative is the 1.5°C Supply Chain Leaders. The Supply Chain Leaders was initiated by Ericsson together with Telia, BT Group, IKEA, and Unilever. The companies are working on reducing GHG emissions within their global supply chains through firm action and collaboration with suppliers, in order to reach the goal to halve GHG emissions before 2030 and achieve net zero-emission before 2050.

Currently, Ericsson is reporting their emissions through the GHG Protocol standard. Ericsson is reporting data related to the mandatory scope 1 and 2, but also additional data connected to scope 3. Many activities can be included within scope 3 and as previously mentioned in section 2.3, it is challenging to define appropriate boundaries for activities related to the scope. Ericsson has decided to report data about business travel, product transportation and distribution, commuting, and use of sold products within scope 3 to broaden their sustainability perspective. According to one of the members of the Supply Sustainability Program, Ericsson now wants to include more activities within the last scope, starting with fuel and energy consumption in the upstream activities and facilities, to get a better understanding of their total environmental impact. Currently, Ericsson is only reporting emissions of their internal facilities, calculated by the following equation:

$$Facility\ Emissions\ (CO_2e)\ =\ Energy\ Consumption\ (kWh)\ \cdot\ Emission\ Factor\ (CO_2e/kWh)$$

It is recommended by the Senior Sustainability Specialist at Ericsson that the same equation shall be used to calculate the external facilities' emissions with relevant emission factors depending on location and source of fuel. Ericsson is currently using emission factors from either the energy provider or from a database created by the organisation Carbon Footprint Ltd.

A third party is responsible for collecting all the data related to the emissions for all internal facilities at Ericsson. The data is thereafter manually inserted into Ericsson's data system, later handled by the department called IndustryLab at Ericsson Research, performing the emission calculations. The data is either collected through bills and invoices, or is read off a measure indicator, sometimes even estimated. The Senior Sustainability Specialist at Ericsson mentioned that "*it takes time to collect all the data and I know that the third party has people responsible for visiting the facilities and gathering the data manually from the different indicators, which is time-consuming*". The Senior Sustainability Specialist elaborated on the advantages of installing smart indicators, automatically reporting the data of the emissions directly into the data system or using artificial intelligence and machine learning to report the data.

4.1.2 Ericsson's Sourcing Strategy

Ericsson is currently outsourcing the majority of its production to the external units. According to one of the Supplier Relationships Managers at Ericsson, approximately 70 percent of Ericsson's total production is outsourced, remaining 30 percent in-house. Historically, Ericsson has had much internal production, with approximately 28 production facilities in Sweden and 60 production facilities in total worldwide. At a later point in time, a decision was made to outsource large proportions of the supply activities. According to a Senior Supply Chain Manager at Ericsson, the decision was mainly based on the opportunities to lower the production costs. Instead, Ericsson focused on core competencies in-house, such as technology and software development. However, Ericsson decided to remain a small part of the production in-house for several reasons. One reason is to use the internal production sites for product and process development as well as to pilot new products. Another reason is to produce customer-specific products at smaller proportions, but also for providing some volume production to preserve production knowledge within Ericsson, making it easier for Ericsson to set demands on their external units. Lastly, keeping some in-house production increases the flexibility for Ericsson and gives them a secure backup if something happens at an external production site.

Ericsson's sourcing strategy considers several variables, where one is sustainability. Several environmental requirements are demanded by the suppliers, covering manufacturing, transport, energy use, and GHG emissions, among others. According to the Sourcing Manager at Ericsson, Ericsson's minimum requirement is that their suppliers follow the basic laws and regulations related to sustainability. Thereafter, the Code of Conduct guides Ericsson in their sourcing work, and the Sourcing Manager emphasised that "*the Code of Conduct is the foundation of how Ericcson works with responsible sourcing and is included in the contract with all suppliers*". Ericsson's Code of Conduct covers four main areas; anti-corruption, human and labour rights, environment, and operational health and safety. The area of environment contains a document that defines specific environmental requirements that Ericsson demands of their suppliers within the areas of products and services, manufacturing, transportation, energy consumption, water management, and lastly waste and circular approaches. Overall, the description of requirements within the different areas are clearly stated and the information must be available upon request of Ericsson. However, within the area of requirements regarding energy consumption, there is an ambiguous formulation related to when and what information can be demanded: "*If energy consumption is identified as a significant environmental aspect, the suppliers must calculate its carbon footprint in terms of CO_2e, using the GHG protocol...*". Additionally, Ericsson requires that their suppliers have to report their carbon footprint in CO_2e with support of the GHG protocol and include scope 1, scope 2, and if applicable, scope 3. The suppliers must also have an active climate action program, aiming for a reduction of their carbon footprint.

For Ericsson to make sure that their suppliers are following Ericsson's requirements and demands, several evaluation activities are executed. Ericsson performs risk assessments and screenings of suppliers as a part of the qualification phase of new suppliers. Through these activities, potential risks related to the supplier are exposed, e.g. legal disputes, poor reputations, and related scandals. The results are thereafter included in the sourcing decisions. All suppliers must complete a mandatory self-assessment questionnaire when becoming a new supplier for Ericsson and also frequently during their time as an employed supplier. The questionnaire is an important tool for Ericsson to evaluate and communicate requirements and expectations, but also for discovering potential risks connected to a supplier. It consists of questions related to the Code of Conduct, the environment, quality management, and other criteria. Within the environmental part, the questions cover the suppliers' overall environmental efforts, energy consumption, conflict minerals, transportation, and waste management, and whether they are able to provide this information to Ericsson or not.

Additionally, audits are performed on suppliers. Since Ericsson has close to 19 000 first-tier suppliers, only a few suppliers are audited each year due to the process being highly resource-demanding. Worth mentioning is that 3 000 suppliers represent 90 percent of the total purchasing spend. "*Audits are conducted within a small selection of suppliers each year, to monitor their work. The selection is based on a risk assessment of the supplier including criteria related to total spend, geographical location, and type of service or product*" was mentioned by the Sourcing Manager. Audits are an effective way to gain knowledge and evaluate how suppliers are working within different areas. Ericsson has engaged a third-party auditing firm to assess the suppliers and 83 audits were performed in 2020 on suppliers located in 36 countries. No deviations were found related to sustainability. If an issue connected to a supplier's sustainability work arises, Ericsson's initial action is to help them improve within the area. The Sourcing Manager highlighted that "*we do not want to terminate the contract at first hand, that will only relocate the problem and not solve it. We want to be able to assist our suppliers when they are in need*". In addition to this, Ericsson encourages their suppliers to set their own goals related to sustainability and wants them to formulate a strategy to reduce their emissions by 50 percent by 2030. Hence, the suppliers will work towards achieving sustainability through their own objectives and not through Ericsson's initiatives or requirements.

4.2 Ericsson's Internal Production Sites

As previously mentioned, Ericsson has decided to not outsource all of their production but has remained approximately 30 percent of the production in-house. The internal production sites are located in China, Brazil, Estonia, and the USA. The location of each site is strategically placed in different regions of the world to be able to supply different customers. Each ESS shall be able to produce prototypes of new products but shall also have the opportunity to provide some volume production. "*Each internal production site is what we call a ´Master Factory´, where the internal sites shall be able to offer support to our different EMS sites in terms of e.g. technical support and test equipment*" was mentioned by a Senior Supply Chain Manager at Ericsson.

As presented in the Sustainability and Corporate Responsibility Report 2020, Ericsson's internal facilities had total emissions of 81 000 tonne CO_2e. A not yet published number presented by the Supply Sustainability Program is that the internal production sites are responsible for 1 750 tonne CO_2e, representing approximately 2 percent of the total internal facility emissions, which is visualised in figure 5.

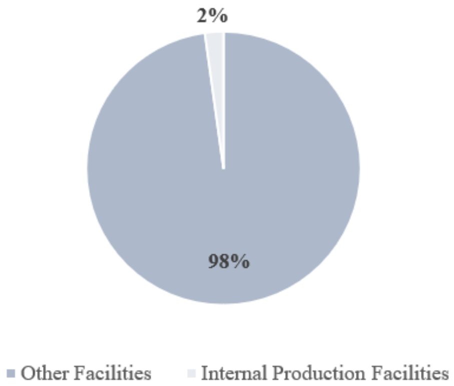

Figure 5. *Visualisation of Ericsson's internal facilities' emissions*

The internal production sites have more well-defined environmental objectives than the external ones since the internal production sites are included in Ericsson's scope 1 and scope 2 reporting. According to the Senior Sustainability Specialist at Ericsson, the internal production sites in Estonia, China, and America are using renewable energy sources, and the site in America has its own solar panels as well. The site in Brazil is using hydroelectric power and according to the Senior Sustainability Specialist it is not reported as green energy, but it is a good, clean energy source. Many operations at the sites are automated and efforts are actively made to lower energy consumption. Each site has e.g. movement sensors, turning off the lights if no one is working within the area. "*If no shifts are working over the weekend we have employees coming in before the first shift on the next Monday turning on the machines that need to be turned on instead of letting them run during the whole weekend*" was mentioned by the Senior Supply Chain Manager.

Ericsson has also focused a lot on smart manufacturing over the last couple of years within their internal production sites. According to a member of the Supply Sustainability Program, many areas of sustainability can benefit from the use of smart manufacturing, which is one of the reasons why Ericsson has decided to invest in smart factories and smart manufacturing. *"With the help of smart manufacturing, Ericsson can, for example, implement smart energy usage and thus lower the energy consumption. This is however only one example of how it can be connected to sustainability improvements".* Ericsson's newest production facility in America is fully designed as a smart factory and is used as a predecessor for other future production facilities. Historically, the internal production sites were highly self-governed, where each site drove their own smart manufacturing initiatives locally. Recently, a decision was made to merge the production sites into one organisation with a common manager and department within the area of Industry 4.0. According to the previous respondent, smart manufacturing has to be adopted at a global level with common strategies of what is desired to be achieved. Ericsson is in the initial stage of the implementation and still has a long way to go, but they know that smart manufacturing is important for the future, especially within the area of sustainability and the possibilities to gain access to real-time data for increased emission reporting.

4.3 Ericsson's External Production Sites

Ericsson's outsourced production is managed within seven external EMS sites, located all over the world. The seven external production sites are operated by the external units. However, the external units are producing the same products but at different locations of the world, strategically placed by Ericsson to increase the flexibility and security of the supply. What products to produce where is a decision influenced by several factors. According to a Senior Supply Chain Manager at Ericsson, the most important factor within this decision is landed cost, which is the total cost of the product produced. The second most important factor is short lead times, to be able to lower the amount of inventory. However, apart from these factors, sustainability is highly important to consider. "*Sustainability is a large project within Ericsson, making it important to consider within all decisions made on all levels of the organisation*", was stated by the same respondent. The external units are producing products for many different companies within several industrial sectors at the EMS sites, and generally, Ericsson's portfolio is representing a small part of the total amount of produced products. Nonetheless, Ericsson's products are of high value, resulting in high profitability for both Ericsson and the external units, according to the Senior Supply Chain Manager at Ericsson.

Ericsson has during the past years developed a mindset to create long-term relationships with their suppliers. According to the Senior Supply Chain Manager at Ericsson, Ericsson should never have short-term solutions with their external units, instead, a partnership shall be developed. "*Since many of the products within Ericsson's product portfolio have a shorter life cycle and are becoming more customised than before, Ericsson does not want to transfer the products between different production sites and are searching for suppliers offering long-term partnership*" was also mentioned by one of Ericsson's Supplier Relation Managers. As a result of this, Ericsson has, for example, decided to only send out Requests for Quotations (RQs) for purchasing or production of new product platforms. Earlier, RQs were sent out more frequently, for example, when products within a platform were introduced. This will make the suppliers feel more secure and may also increase their trust. To remain production at one site for a longer period of time increases the possibility for the supplier to invest in improvements areas related to e.g. their production or sustainability. Ericsson has the desire to also include their suppliers in earlier stages in the development of their products. "*Input from suppliers can help us save money further down in the supply chain*", according to the Supplier Relation Manager. Earlier, Ericsson had an efficiency program together with their external units where knowledge of improvement possibilities was exchanged. "*The external units can easily notice eventual flaws within our construction, which can help us save a lot of money*" was mentioned by the Senior Supply Chain Manager at Ericsson. One of the Supplier Relation Managers described that Ericsson does not currently have any sustainability initiatives with individual suppliers. This is due to Ericsson's aim to treat every supplier equally and therefore, it is difficult to drive any specific sustainability project with a chosen supplier.

As mentioned in the previous section 4.2, Ericsson has started to focus on smart manufacturing within their internal production sites. This work extends to the EMS sites operated by the external units as well. According to a member of the Supply Sustainability Program, it is apparent that collaboration is necessary between Ericsson and the external units within the subject of smart manufacturing for implementation to be successful. Ericsson is the one developing the products produced by the external units, and these are often adapted to be able to be manufactured in an automated production line. Ericsson has a desire to ensure that each external production site has the same conditions and opportunities as the internal production sites to be able to produce the products. Therefore, Ericsson has decided to assist the external units in the implementation of smart manufacturing, if specific solutions are needed to be implemented at the sites to be able to produce their products. If, however, a solution is more general and can be used to produce products for the other customers of the external units, Ericsson does not assist in the implementation. Instead, compensation is offered for each product produced. According to the previous respondent, Ericsson has a good understanding of how the external units are working with smart manufacturing. *"The progress differs a lot between each site and within different parts of the production process. However, things are starting to happen, and everyone has acknowledged that smart manufacturing is an important area to focus on".*

Every quarter of the year, Ericsson is rating each EMS site based on a scorecard Ericsson has developed. This scorecard, the supplier performance card, describes how satisfied Ericsson has been with the external units and their service. "*Since each EMS site is striving for a top rating, Ericsson has a great opportunity to influence their work with the use of the scorecard*" was mentioned by one of Ericsson's External Supplier Managers. The rating is done by a team at Ericsson, assessing the last quarter based on several criteria. The scorecard includes areas such as delivery on time, quality management, risk management, ease of business interaction, among others. The scorecard is not assessing the sustainability work of each site and according to the External Supplier Manager, the scorecard criteria have not been updated in a long time, making some of them outdated.

Apart from the scorecards, Ericsson governs their supplier by what the Supplier Relations Manager described as regular meetings taking place on three different levels. Firstly, there is the executive business review, where the companies' top management meet up once per year and agree on focus areas and objectives to work with for the upcoming period of time. Additionally, there is a management business review three times per year, where the focus areas and objectives are followed up on with management teams from the companies. Lastly, there is a product business review every quarter, where the external units' production sites are evaluated within the focus areas that had been decided upon at the top management meeting. According to the Supplier Relations Manager, these governance systems and their focus areas have not included any criteria connected to sustainability matters.

4.3.1 External Unit 1

External unit 1, further called Company 1, is American-owned and provides manufacturing solutions for several large and well-established companies within different industry sectors such as automotive, telecommunication, and healthcare. Company 1 had revenue of 238.04[1] BSEK in 2020, where 61 percent of it came from their global EMS sites. Company 1 is operating in 35 countries with over 200 000 employees. The company has a well-developed sustainability program, working with several sustainability objectives to contribute to the UN SDGs. In 2020, the company launched their first Climate Action Program, committing to reduce their greenhouse gas emissions by 25 percent by 2025 (baseline 2019), and have decided to expand the use of renewable energy within their facilities. It was stated during Company 1's interview that "*there was a big leap forward in our CO_2e reduction goals between 2015 and 2019, where a large number of ´mega sites´ in Asia went over to renewable energy*". This reduction is evident in their sustainability report, as they went from a total of 1 505 849 Mtonne CO_2e in 2017 to 818 506 Mtonne CO_2e in 2018, a reduction of 46 percent. Currently, around 80 percent of Company 1's total emissions are from energy used in manufacturing operations and they are actively working towards acquiring the best practices within the area to be able to reduce their emissions. According to Company 1, there has been a negative change in the climate regarding collaboration between top suppliers and their best practices, making it hard to identify them. "*We welcome best sharing of best practices. Hopefully, sustainability is the one area where suppliers can find a way to collaborate again to be able to protect the earth*". Company 1 is reporting sustainability measures according to the GHG Protocol's scope 1, scope 2, and business travel and sponsored buses for employee commuting within scope 3. Additionally, Company 1 has received certificates of ISO 14000 for many, but not all, of their EMS sites. "*This is one way for us to ensure that the sites are working up to our standards, but we also have several other checkpoints to make sure that requirements are met and we encourage our customers to perform audits to regulate that their Code of Conduct is being followed*".

Company 1 operates within four of Ericsson's outsourced production sites, located in China, Mexico, Hungary, and India. Company 1 is one of Ericsson's preferred suppliers, belonging to Ericsson's executive category of suppliers. According to one of Ericsson's Supplier Relation

[1] Company 1's revenue 2020: $27.266 B, converted to SEK with the exchange rate of 8,73 SEK/$ (date 31/3 -2021)

Managers, Company 1 is responsible for around 70 percent of Ericsson's outsourced production. The two companies have been in partnership for approximately 12 years and have a well-established partnership. According to one of Ericsson's Supplier Relation Managers, Ericsson is of high importance for Company 1, "*We know Ericsson is a big customer for them since we have a high spend. However, Company 1 does not want to share information about exact shares publicly*". Also mentioned by Company 1 during their interview was that "*Ericsson knows that they have much business with us and that they are extremely valuable*". The relationship has evolved over the years, from being purely about manufacturing to more collaborative. Mentioned during both interviews with Ericsson and Company 1 was that Company 1 had reached out to Ericsson to discuss sustainability targets. According to Company 1, a sample of their key customers was selected for discussions regarding sustainability and future goals, to gain a deeper understanding of what their customers value as important. As a result of this, Company 1 could narrow their focus and thereby satisfy their customers. During the meeting, Ericsson informed Company 1 about the work they are doing with the Exponential Roadmap. However, Company 1 has not had time to review it and is not yet a member of the Exponential Roadmap initiative. Previous to the meeting arranged by Company 1, there has been a limited discussion about sustainability between the two companies. As mentioned by the Supplier Relation Manager at Ericsson, no data regarding sustainability is shared with Ericsson and according to Company 1, the reason for this is because Ericsson has not asked for it. "*Most of the discussions we have about sustainability are about modes of transport. Ericsson has sometimes asked about our sustainability report and we have provided them with it, but it has not been consistent*". Company 1 is open to having more discussions about this subject and wants to explore how the collaboration can be improved within the area.

Company 1 is continuously working to reduce their GHG emissions, partly by procuring renewable energy. The production facilities where products are produced for Ericsson have different types of energy sources. Three of four sites do not use renewable energy as their main source of energy. The site in China is the one site that has wind power as its main source, provided by a third party. "*We are also working on installing photovoltaic power generation to be ready for use in May 2021 for the site in China*" was mentioned by Company 1 during the interview. However, the energy at the site in India is generated by the state government electricity board through the national grid and is therefore assumed to be non-renewable. The site in Hungary has a mix of energy sources, such as fossil fuel, nuclear power, and renewable energy sources. Lastly, the site in Mexico has non-renewable energy sources, such as natural gas. Company 1 stated that they want to expand their use of renewable energy sources and will make future investments for on-site energy production, in the form of solar power at selected sites.

4.3.2 External Unit 2

The external unit 2, referred to as Company 2 henceforth, is a multinational electronics manufacturing company. The company was founded in 1969 and originates from America and Singapore. Currently, the company is operating in over 30 countries with around 100 manufacturing- and service sites. There are around 177 000 employees and during 2020, Company 2 had revenue of 211.35[2] BSEK. Company 2 has customers in several industries, such as telecommunication, automotive, and medicine. The company is actively working with the environmental dimensions of sustainability and is reporting their emissions through the GHG Protocol standard, including scope 1, scope 2, and increasing parts of scope 3. In Company 2's sustainability report, it can be seen that their CO_2e emissions have heavily increased between the years 2018 to 2019. This is because the company has expanded their scope 3 reporting, from just including a few elements connected to their suppliers and business travels to including more elements connected to the final use of the product. "*To map the emissions that the final consumer has generated by using the product is complicated and time-consuming but is an important part to have a more complete picture to be able to actually reduce the total global emissions"*, Company 2 explained during the interview. By 2030, the company aims to reduce its internal greenhouse gas emissions by 50 percent (baseline 2019) and that 100 percent of their preferred suppliers will set their own reduction targets of GHG emissions. Across Company 2's operations, 60 of their production sites are certified with ISO 14001 and the company has committed to certifying all manufacturing operations by 2030. Additionally, the company is actively working with increasing the use of renewable energy in their facilities. "*I think Company 2 has to continuously work with sustainability since it is such a large company with much spotlight on them*" was mentioned by one of the Supplier Relations Manager at Ericsson.

From the interview with Company 2, it was declared that the company is actively working with sustainability and has a well-developed sustainability strategy with science-based targets. Company 2 bases and formulates their sustainability strategy according to what is important for them both internally within their organisation and externally from their customers and suppliers. It is stated that all parts of the company are included in achieving the overall sustainability goals. Company 2 has a sustainability network, which is responsible for the production sites' sustainability work. According to Company 2, "*every month a scorecard is sent out to the responsible people in the network, for them to evaluate how the sites perform within different sustainability metrics*". The progress is reported into a metrics centre, which is a system where invoices and bills of energy consumption are also uploaded. The scorecard is shared with the factory manager in each site, where the manager can see the current status, the yearly progress for the different metrics, and if the site is aligned with the company's overall sustainability strategy. The factory manager can then share the information and potential improvements with the general managers at the sites. In addition to this, Company 2 has both internal and external auditors that validate the sustainability work and data.

Ericsson and Company 2 have collaborated since 2004 and Company 2 is also one of Ericsson's preferred suppliers, belonging to Ericsson's executive category of suppliers. Company 2 operates in three of the outsourced production sites, located in Poland, China, and Malaysia. These sites cover around 30 percent of Ericsson's outsourced production, according to one of Ericsson's Supplier Relations Managers. Over the years, the relationship between the

[2] Company 2's revenue 2020: $24.210 B, converted to SEK with the exchange rate of 8,73 SEK/$ (date 31/3 -2021)

companies has evolved from being purely related to providing manufacturing services, to supporting Ericsson with other services, such as product design and transportation. The progress of the relationship was described by Ericsson's Supplier Relations Manager as "*going from just being production-oriented to a more end-to-end collaboration*". Even though the relationship is described as well-established, Company 2 is not reporting any data regarding sustainability to Ericsson. The Supplier Relations Manager at Ericsson states that Company 2 has fully complied with Ericsson's Code of Conduct, including the environmental requirements, and therefore, no data is currently demanded. Company 2 agreed that their relationship with Ericsson is good and emphasised that "*we want to have a strong relationship with our suppliers and customers and collaborate in sustainability challenges since most of us are working towards the same goal of reducing the global emissions*". Company 2 highlighted that everyone otherwise will suffer the consequences of the environmental changes and global warming.

Company 2 also works actively to reduce their emissions and improve within the areas of energy consumption in their production sites, where the sustainability network is working closely with the sites' facility teams to make it possible. However, it was stated that the extent of the sustainability work varied in the different sites depending on which countries and regions the sites are located in. As previously mentioned, Company 2 is actively working to increase renewable energy sources in their facilities. Despite this, all of the sites that Ericsson has outsourced their production to are described to have non-renewable energy sources such as coal and carbon. Examples of other sustainability initiatives at Company 2's production sites are moving sensors for lighting, led-lighting solutions, solar panels for on-site energy production, and new, more energy-efficient production technologies. According to Company 2, "*we are at the beginning of the sustainability journey, we will have a more aggressive approach in the upcoming years and make more investments connected to reducing energy consumption in our sites worldwide".*

4.3.3 CO_2e Data from External Units

Since company 1 and company 2 are reporting emissions according to the GHG Protocol standard, their CO_2e emissions are reported in a similar manner as Ericsson. All sites collect data related to energy consumption, water usage, waste streams, among others, manually through invoices and bills, which is thereafter used when estimating their emissions and evaluating their sustainability work. Company 1 mentioned during the interview that they are working on improving their data management system to be automatic for higher accuracy. Company 2 mentioned that they also include refrigerants or heating emissions, which is a small part compared with the emissions from the electricity usage. Both companies are using the same equation as Ericsson, presented in section 4.1.1, when calculating their facility emissions, multiplying the energy consumption with the specific emission factor.

The external units preferred to only share limited information about their emissions and other business aspects. However, both offered and agreed on sharing revenue-based CO_2e emissions, where the companies performed the calculations and provided the results for the thesis.

According to Company 1, a revenue-based calculation is not 100 percent absolute but is a fair way to estimate emissions since products for a lot of different customers are being produced at the same production site. The equation that both Company 1 and Company 2 used is presented below.

$$Ericsson's\ share\ of\ emissions\ (CO_2e) = Total\ emissions\ (CO_2e) \cdot Ericsson's\ share\ of\ revenue\ (\%)$$

Company 1 provided data about their CO_2e emissions based on the time period between September 2019 and August 2020. The calculations resulted in Ericsson's share of emissions being 19 872 tonne CO_2e. Company 2 on the other hand, provided data based on the time period between January 2020 and December 2020. The calculations resulted in Ericsson's share of emissions being 19 718 tonne CO_2e. This results in yearly emissions of 39 590 tonne CO_2e for Ericsson's outsourced production. These numbers represent scope 1 and scope 2 of the external units' emission reporting and become scope 3 of Ericsson's emission reporting. The external units' production facilities emissions are visualised in relation to each other in figure 6.

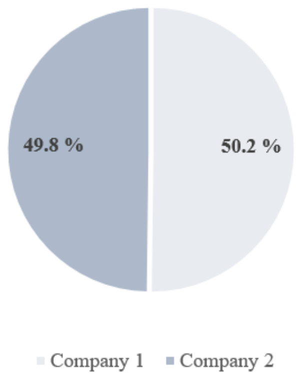

Figure 6. *Visualisation of the external units' production facilities' emissions*

According to the Senior Sustainability Specialist at Ericsson, the revenue-based approach is a sufficient method to use for estimating Ericsson's share of the total emissions. "*Emissions are most often measured for the whole site, and not measured based on emissions from e.g. each machine. Therefore, I believe that the revenue-based approach is a good way to start*". The Senior Sustainability Specialist also mentioned that emissions do not always have to be precise, an estimation is adequate. However, one drawback of the method was stated by the specialist. Meaning, as a result of the revenue-based approach, products of higher cost would therefore have higher emissions, which does not always reflect the truth. The same reasoning can be applied for products produced in higher volumes, generating lower cost opportunities per product, resulting in lower emissions for these products if related to revenue.

The Senior Sustainability Specialist at Ericsson mentioned that Ericsson has little knowledge about which products within their product portfolio are generating more emissions than others. However, the respondent knew that producing circuit boards is generating more emissions than other activities within the production. Therefore, the Senior Sustainability Specialist recommended a different approach than the revenue-based approach to estimate Ericsson's share of emissions, an approach where the production is divided into different areas instead.

“*If the production would instead be divided into different areas, for example one being the production area for circuit boards, our share could be more correctly quantified*”. The Senior Sustainability Specialist mentioned that this approach is more complex, but that this division of areas has already been made in some sense when deciding on the cost for the product. Another alternative approach mentioned by the Senior Sustainability Specialist was to estimate emissions based on time in production. “*One important thing to think about when allocating emissions, no matter the approach, is to consider all the overhead emissions generated which are not affected by amount and variation in production, for example, lighting, heating, and ventilation*”.

5 ANALYSIS AND DISCUSSION

In this chapter, an analysis and discussion of the information from the theory chapter and the empirical findings is performed, with the aim to answer the formulated research questions. Firstly, the sustainability work of Ericsson and the external units is elaborated upon, followed by a discussion about appropriate allocation methods. Lastly, the collaboration and trust between the parties are discussed, along with Ericsson's sourcing strategy, with focus on information sharing. A summary of limitations and future research is accounted for in the last section of the chapter.

5.1 Ericsson and The External Units' Sustainability Work

In the following sections, Ericsson's and the external units' sustainability work in terms of CO_2e emissions and energy sources are analysed and discussed.

5.1.1 CO_2e Emissions

According to the interviews with the companies, both Ericsson and the external units' sustainability work are well-established and integrated with the companies' business strategies. In terms of environmental sustainability, all of the companies have CO_2e emissions reduction objectives for the upcoming years and are encouraging their suppliers to get involved in reducing their environmental impact by creating their own reduction goals. Sustainability matters have become increasingly important and pressure from various stakeholders has made companies start adopting more green practices (Abdullah et al., 2018). As presented in section 4.2, Ericsson's internal production sites emitted 1 750 tonne CO_2e and in section 4.3.3, Company 1's and Company 2's production sites emitted 19 872 tonne CO_2e and 19 718 tonne CO_2e respectively. This results in a total of 41 340 tonne CO_2e for the year 2020, representing Ericsson's internal and external production facility emissions. As mentioned in section 4.3.3, these numbers represent scope 1 and scope 2 of the external units' emission reporting and will become scope 3 of Ericsson's emission reporting. This result is assumed to represent the emissions of the year 2020 even though Company 1's time period of the data was overlapping between two years. A decision was made to assess Company 1's data as a result of their emissions for the year 2020, due to the fact that the data represents emissions for 12 coherence months. This, however, can lower the accuracy of the result but as mentioned by the GHG Protocol (2011), lower accuracy of the data reported in scope 3 is acceptable. This is supported by the Senior Sustainability Specialist, who claimed that emissions do not always have to be precise and that an estimation is adequate. The accuracy of the data is further discussed in section 5.2. The compiled emission data provides Ericsson with an impression of the approximate size of emission quantities at their production facilities.

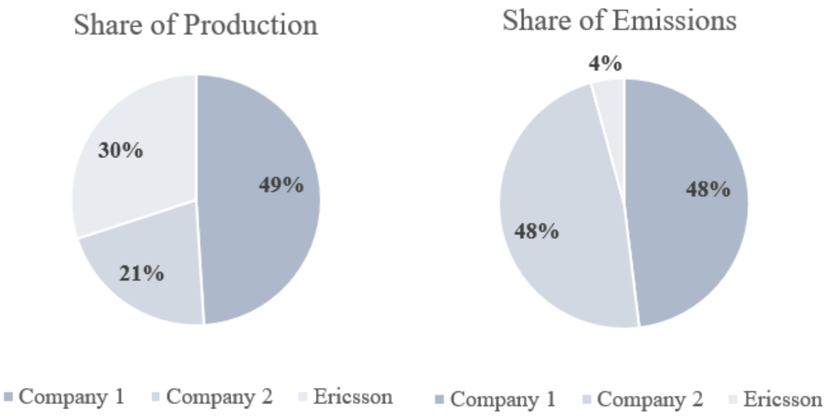

Figure 7. *Visualisation of share of production versus share of emissions*

As mentioned by the Supplier Relation Manager, Ericsson's internal production represents approximately 30 percent of the total production, and the external units' production thereby represents 70 percent of the total production. It was also stated that Company 1 is responsible for approximately 70 percent of the outsourced production, whereas Company 2 is responsible for around 30 percent of the outsourced production. As can be seen in figure 7, the share of emissions of the companies is not equivalent to the share of production. This can depend on various reasons, where one is the chosen method for allocating the emissions. The external companies are responsible for producing products for other customers than Ericsson and no information about how energy-consuming these other products are and their quantities of emissions is available. Therefore, the accuracy of the revenue-based calculations can affect the result since the external units can potentially produce many other products having higher energy consumption than Ericsson's products, which will thereby automatically influence the result of Ericsson's share of emissions. The allocation method is further elaborated upon in section 5.2. Another reason the emission data is not reflecting the percentage of production is due to the degree of renewable sources used at each production site. As mentioned in chapter 4, Ericsson has predominantly renewable energy sources at their sites, whereas the external units have considerably fewer sites utilising renewable energy. The companies' energy management, including the energy sources, at the different locations is further elaborated upon in section 5.1.2. The result of the emission data does, however, give Ericsson a conceptual understanding of the situation.

5.1.1.1 Emission Reporting

The three companies are reporting their CO_2e emissions through the GHG Protocol, where scope 1 and scope 2 are mandatory to report. All of the companies are reporting activities within scope 3 but to varying degrees. As mentioned in section 2.3, it is up to the companies' corporate management to decide which activities to include in scope 3 and few activities are often included. This is due to the complexity of calculating these emissions, since the activities originate from sources not owned or controlled by the company (WRI & WBCSD, 2004). Company 2 is the one company that has included most activities connected to scope 3, followed by Ericsson and lastly Company 1. Company 2 has during the last years expanded their scope 3 reporting from just including a few elements connected to their suppliers and business travels to including more elements connected to the final use of the product. Hence, Company 2 has the highest amount of CO_2e emission according to their reported emissions, which might not reflect the actual situation of the companies' emissions. The external units' reporting of scope 3 has however not affected the numbers and calculations in this report, since it is Company 1's and Company 2's scope 1 and scope 2 that have been the base for the calculations. It is nonetheless important to understand the full magnitude of emissions in order to make the right decisions and lower the total amount of emissions (GHG Protocol, 2011), which scope 3 can be a crucial part of. To only include scope 1 and scope 2 when measuring the amount of CO_2e emission can lead to misinterpretations and lost opportunities (WRI & WBCSD, 2004). According to a member of the Supply Sustainability Program, Ericsson wants to expand their scope 3 reporting, which this thesis is a part of. As can be seen in Ericsson's and Company 2's annual sustainability reports, scope 3 emissions are often relatively large compared with scope 1 and scope 2, which indicates the importance of including scope 3 emissions for an actual understanding of the situation.

5.1.1.2 Operational Impact and Embodied Impact

As of today, Ericsson and the external units are focusing on the operational impact of their facilities, i.e. the CO_2e emissions that are emitted when operating a facility (Ibn-Mohammed et al., 2013). Another perspective to take into account when reporting CO_2e emissions related to facilities is to include the full life-cycle's emissions of a facility, which is emphasised by Röck et al. (2020). In order to understand and account for the total amount of CO_2e emissions, the embodied impact of the facility needs to be included, which is the amount of CO_2e emissions emitted when the facilities are being built (De Wolf et al., 2017). Calculating the embodied impact is complex since it contains several stages and lacks comparable methodologies and regulations (Ibn-Mohammed et al., 2013). However, almost all embodied CO_2e emissions occur at one point in time, which means that the calculations only need to be performed once, while the operational emissions take place on an ongoing basis. A challenge is to decide how the external facilities' embodied CO_2e emissions should be allocated, either to the operating company of the facility, the company who owns the facility, or to the companies that have outsourced their production to the facility.

The operational impact is the most relevant to focus on related to facilities since it is these emissions that the companies can continuously influence and therefore, improve. Since this thesis has focused on all the external unit's production facilities and their emissions on an aggregated level, no investigation of particular production sites has been performed to understand what each site has done individually to decrease their emissions. However, the theory contributes with several examples of what can be done in order to lower operational emissions in facilities, e.g. renewable energy, controlled air ventilation, proper insulation, lightning supported by time-control or sensors (Grant et al., 2017). Furthermore, Wang et al. (2016) emphasise that smart factories and smart machines can contribute to lower the energy consumption at production facilities, with the possibility to gain information about the energy consumption and thereby optimise it.

5.1.2 Energy Sources

Ericsson has predominantly renewable energy sources in their internal production facilities and is actively working towards transitioning to renewable energy sources in the remaining ones. Company 1 stated that they also want to expand their use of renewable energy sources at their production sites and are working to increase the procurement of renewable energy. However, three of the four production sites that Company 1 operates within do not use renewable energy as their main source of energy. The site in China is the only site that has renewable energy in the form of wind power. Furthermore, Company 2 stated that they are working with increasing their use of renewable energy sources, but in the production sites where Ericsson's outsourced production takes place, most of the energy comes from non-renewable energy sources, such as coal and carbon. Grant et al. (2017) declared that changing to renewable energy sources is an easy way to reduce operational CO_2e emissions, which points towards the benefits of using renewable energy and the need for increased efforts within the area.

By 2030, Ericsson wants to have 100 percent renewable internal energy consumption. As mentioned in section 4.1.1, Ericsson has had a reduction of 59 percent of their internal facility emissions from 2016 to 2020. This reduction was mainly due to the change of energy sources to renewable energy. According to one of the members of the Supply Sustainability Program, renewable energy at Ericsson mainly originates from green certificates, which is described to be the first step in the change to be fully sustainable in energy sourcing. However, Ericsson cannot be entirely certain of the origin of the delivered energy, since the certificates only provide confirmation that a certain amount of energy has been produced by renewable sources (Bye, 2003) and not that the delivered energy is actually renewable. The green certificates allow Ericsson and other companies to report their energy emissions as zero, whereas it may not always reflect the reality. In order to be fully sustainable and ensure that energy is actually green, on-site renewable energy production is necessary, for example, solar panels, wind turbines or recovered waste energy (Grant et al., 2017). On the other hand, Grant et al. (2017) stress that producing renewable energy on-site can contribute to complexity in energy management, due to fluctuations in both demand and supply can easily occur. This challenge is assessed to be manageable and on-site energy production should be considered as an alternative towards green certificates.

5.2 Allocation Methods

In the following sections, different allocation methods for the estimation of Ericsson's share of emissions will be analysed and discussed.

5.2.1 Revenue-Based Approach

The data received representing Ericsson's share of CO_2e emissions from the external units was estimated through a revenue-based approach, as described in section 4.3.3. Since both external units are producing products for several other customers within different sectors, it is important to approximate Ericsson's proportion of the total emissions at the different sites where their products are being produced. This makes the process of estimating the emissions more complex and necessary allocations are needed. A decision was made to allocate the emissions through a revenue-based approach for the thesis, making both Company 1 and Company 2 willing to share information about their emissions. It was agreed that the external units would perform the calculations by using the formula presented in section 4.3.3. Using a revenue-based approach is a common way to do allocations. In table 2 in section 2.4.1, where different allocation criteria are presented, two of them (ability to pay and economic activity) are related to a nation's GDP, defined to measure the growth of a country's economy, and one (horizontal equity) is related to a nation's net welfare. It is assumed that the reason for often doing allocations based on an economic situation is because of the simplicity of the method. Information about an economic situation is often already known, which facilitates the process since no additional calculations or gathering of information has to be made. Ericsson's share of emissions was thereby allocated through the revenue-based approach due to the simplicity of the method. When interviewing both the external units and members from Ericsson, the method was assessed as acceptable even though the result would not be completely accurate. However, as mentioned previously, lower accuracy of the data is acceptable since the calculations can become exceedingly complex (GHG Protocol, 2011). This is applicable when accounting for emissions in scope 3, in which the given data from the external units will be included.

The revenue-based approach does, however, have drawbacks. The risk of using such a simplified method is that the result is not representable and gives a false understanding of the real situation. As mentioned by the Senior Sustainability Specialist at Ericsson, a result could be that more expensive products yield higher levels of emissions and lower-priced products yield lower levels of emissions. This might not give a truthful representation of which products are generating more emissions and having a higher environmental impact within the different production sites. The previously mentioned issue related to low information about the other products' energy consumption being produced, discussed in section 5.1.1, is another drawback of the method. As discussed by the Supply Sustainability Program, Ericsson has the desire to use the result of the thesis to be able to create a baseline for supply's total carbon footprint, including the external production facilities, and thereby create science-based targets to drive improvement projects related to scope 3. Consequently, due to the low accuracy of the data from using the revenue-based approach, wrongful decisions can potentially be made based on deceptive information, and therefore, higher accuracy should be considered as important.

5.2.2 Alternative Allocation Methods

Other allocation methods based on criteria presented in table 2, apart from the ones related to an economic situation, can be used for allocating the emissions. The most applicable alternative method for the context of the thesis would be to allocate emissions based on the criterion egalitarianism (Zhou & Wang, 2016). In table 2, the criterion is described to allocate based on "*proportion to population*". Proportion to population can be translated to the proportion of products produced, indicating that emissions can be allocated based on the number of products produced at a production site. Furthermore, as recommended by the Senior Sustainability Specialist at Ericsson, emissions could also be estimated based on time in production per product. However, both of these methods have the same simplicity foundation of calculating emissions as the revenue-based approach and do not include overhead emissions of a facility. Most often, these conditions are also included in the revenue since the number of produced products and time in production sets the standards for the sales price. Therefore, these can be neglected as alternative approaches as they are assumed to be included in the revenue-based approach.

A more appropriate allocation method to consider is the activity-based allocation of emissions. The emissions would thereby be divided into different activities performed, similar to how the cost is divided into activities with the ABC method or by how emissions are divided into activities in ABC_{env} method described in section 2.4.2. Such a method was also recommended by the Senior Sustainability Specialist at Ericsson, who advocated activity-based allocation for higher accuracy of data. The method is considerably more complex and resource-demanding than the revenue-based approach. Several challenges can also be related to the method. One challenge is the steep beginner phase where a new process of how to measure the emissions needs to be established and certain investments are required in terms of new technology to be able to measure emissions of each activity correctly. However, the mentioned challenge can be comparable to a logarithmic function, where the start-up phase is the most difficult, but over time it will level out and become a settled way of working. Another challenge is to divide the production process into suitable activities. Inspiration can be taken from the ABC_{env} method, which focuses on activities contributing to environmental impacts, such as air and water pollution, recycling, waste management, among others, and further assess which of these more intensively affect the amount of emissions emitted (Marinho Neto et al., 2018). When measuring emissions related to production facilities, the mentioned areas might not be suitable. This is due to Ericsson rather needing areas related to activities that are more production-specific and gain knowledge about how much emissions these activities emit, in order to use allocation-based calculations for their sites. It is important to remember that the compiled emission measure of the different activities from a production site needs to be comparable with the emission measures from other production sites. This is strengthened by Di Fonzo and Hime (2017), which argued that for measurement to be meaningful, it should be comparable and replicable. This might become difficult since different products and product families of Ericsson's product portfolio are produced at different production sites, hence generating different activities at different production sites.

Despite the mentioned challenges and drawbacks of using an activity-based approach, it is supported by several advantages. The most meaningful one is that the results of the estimations would become more accurate and more representable of Ericsson's share of the total emissions emitted at a production site. The approach also makes the process more transparent, increasing the visibility of what activities are generating more emissions than others. Thus, improvement areas can be more easily identified. As described by Baker (1998), an activity-based approach is also a good approach to use when working with overhead emissions, such as lighting, heating, and ventilation. Overhead emissions are evident at production sites and by assigning them to different activities, it becomes easier to understand how much of the generated emissions for each activity is independent of the number of products being produced.

The decision about whether Ericsson should use the revenue-based approach or the activity-based approach when allocating their emissions can be guided by two principles. These are the time-perspective and the importance of data accuracy. When comparing the revenue-based and activity-based approaches, the prior is assessed to be a short-term solution with lower accuracy and the latter a long-term solution with higher accuracy. If Ericsson is interested in gaining access to their share of emissions in a quick and simple way, where accuracy is of lower importance, the revenue-based approach is appropriate to use. However, if Ericsson is interested to put more effort into the process to gain a more accurate understanding of the situation and develop the process to be more reliable and transparent over time, the activity-based approach is assessed to be more appropriate. Another aspect that will affect the decision of which approach to use, is the external units' willingness to share the required information. In order to use the activity-based approach, Ericsson needs to gain a higher degree of insight into their external units' businesses. This will require better collaboration that is characterised by trust and transparency. These areas will be further elaborated upon in section 5.3.

5.2.2.1 Smart Manufacturing

Ericsson has started to actively work with implementing Industry 4.0 and smart manufacturing within their internal production sites, an area of work that has also extended to the external units' production sites. Smart manufacturing makes data of all sorts more accessible as equipment and machines are collecting and reporting information automatically. Collecting data about emissions through smart manufacturing can support an activity-based approach, with increased levels of detail and easier access to more data. Another aspect to take into account is whether allocation methods might become obsolete in the future as a result of smart manufacturing, which will make it easier to measure emissions through real-time data. According to Wang et al. (2016), smart manufacturing will be able to provide more knowledge about the production process, which can lead to improved resource and energy efficiency. This is supported by a member of the Supply Sustainability Program at Ericsson, who emphasised the importance of real-time data to be able to draw valuable and reliable conclusions about how to reduce emissions. With the use of smart manufacturing, the efforts to collect relevant data will be decreased and opportunities for improved emission reporting increased.

Implementing smart manufacturing can, however, be challenging, especially within already existing production facilities. More information about whether the equipment within the facilities is compatible with the new technology smart manufacturing requires is needed to be able to make decisions about how to implement the technology (Phuyal et al., 2020). In some cases, there might be a need to build new factories that are fully structured as a smart factory for it to be beneficial. It is assessed that Ericsson's newest production facility is designed as a smart factory due to the simplicity of integrating smart manufacturing in new facilities. Building new production facilities can, however, be questioned from a sustainability perspective. Grant et al. (2017) emphasised that re-developing already existing production facilities is favourable to reduce the embodied emissions and the negative effect new facilities have on the land use and surrounding environment. Nevertheless, implementing smart manufacturing in existing production facilities will need greater investments based on the need for new equipment and paused production during the time of installation, resulting in loss of revenue (Phuyal et al., 2020).

5.3 Increased Possibilities for Information Sharing

As mentioned in the previous section, the external units only shared limited information regarding their emissions and other business aspects. Instead, it was agreed upon that the external units themselves would perform the needed calculations to provide the thesis with Ericsson's share of emissions from their EMS sites. For the external units to be comfortable sharing more information with Ericsson, the relationships in terms of increased collaboration and trust together with Ericsson's sourcing strategy need to be further developed. This is analysed and discussed in the sections below.

5.3.1 Collaboration

As of today, Ericsson is collaborating with the external units within many different business areas, with an exception from the area of sustainability. The external units have both been in partnership with Ericsson for more than 10 years and have evolved over the years to a more collaborative relationship, where Company 1 and Company 2 have become a part of the development of Ericsson's products and production processes. There has however been a change in the market during the last years, with increased pressure from many different stakeholders to adopt more green practices (Abdullah et al., 2018; Turker & Altuntas, 2014). Ericsson has therefore increased their actions of expanding their sustainability work and their desire to collaborate within the area. However, no actions have yet been made to initiate these kinds of activities.

As mentioned by Touboulic et al. (2014), it is important to understand the relationship that Ericsson has with their external units to be able to identify appropriate strategies for Ericsson to achieve their sustainability objectives. Through the interviews, it became clear that the relationship is appreciated by all parties involved and that the external units and Ericsson view their relationship as valuable. However, the relationship is assessed to be independent, as described when the buyer and the supplier have a low dependency on each other (Touboulic et al., 2014). This is based on the fact that the external units have several other customers that they are supplying, making Ericsson one of many. It is also stated that even though Ericsson is a valuable customer for the external units, they are not the customer with the highest spend. Additionally, Ericsson has several alternatives for producing their products since Ericsson has two external units to vary between, which are producing the same products as a security of supply. Ericsson has also retained internal production capacity in-house. This could point towards Ericsson not having full confidence in the external units separately. However, multiple sourcing is often used as a strategy when outsourcing (Horowitz, 1986), to be able to e.g. lower the production cost and reduce the risks (Johansen, Howard, & Miemczyk, 2014) and according to the Senior Supply Chain Manager at Ericsson, internal production is important to preserve production knowledge within the company.

Company 1, Company 2, and Ericsson are all striving to achieve a higher degree of sustainability within their operations but having an independent relationship can make it difficult for either party to drive different sustainability initiatives. All the companies have different sustainability goals and internal action programs. However, this does not mean that sustainability initiatives formulated by either Ericsson or an external party will be automatically agreed upon, based on the structure of the relationship. When it is not stated in the initial contract, there are no obligations to perform additional requests. How Ericsson can reformulate their requirements in their contracts to be able to drive different sustainability initiatives is further elaborated in section 5.3.3. Today, the main reason for either party to agree to different initiatives is based on whether it aligns with their internal sustainability goals and their desire to increase their sustainability efforts.

To be able to drive sustainability initiatives successfully, efforts to develop the relationship to become interdependent are important (Touboulic et al., 2014; Capaldo & Giannoccaro, 2015; Du et al., 2012). An interdependent power relationship is defined as when both the buyer and the supplier have a high dependency on each other (Touboulic et al., 2014) and is the heart of collaborative activities (Collazos et al., 2003). Further described by Touboulic et al. (2014) is that power relationships are generally characterised as dynamic and constantly changing, which is evident in the relationship that Ericsson has with their external units. As previously discussed, the relationship is assessed to be independent. However, there are elements of an interdependent relationship with collaborative characteristics. For example, as previously mentioned, Ericsson is working actively to involve the external units in earlier stages of the product and process development and has also decided to lower the RQs that are being issued to suppliers to achieve stronger collaboration with them. Additionally, the external units have expressed an aspiration to increase the collaboration related to sustainability matters with Ericsson. Company 1 has reached out to Ericsson for knowledge exchange and to discuss sustainability targets, whereas Company 2 encourages a higher degree of collaboration within the subject, with the argument that *"the effects of not taking responsibility for the environmental changes is something everyone will suffer the consequences of".* Based on this, elements of an interdependent relationship are found as efforts are made to become more collaborative, making the nature of the independent relationship questionable. Nonetheless, the companies are not dependent on each other, and therefore, efforts are needed to reach a stable interdependent relationship.

Based on the above-mentioned actions, the collaboration of today within sustainability is assessed to be mostly driven by the external units, whereas Ericsson has focused on collaboration within other areas. This contradicts the theory, where Mollenkopf (2010) states that it is the suppliers within the supply chain that more often oppose against implementing environmental practices. In the relationship between Ericsson and the external units, Ericsson is the party assessed to slow the process within sustainability matters, based on the fact that they want to treat all suppliers equally, making it difficult to drive sustainability initiatives with a chosen supplier, further elaborated on in section 5.3.2. Company 1's and Company 2's point of view regarding sustainability collaboration can resemble Collazos et al. (2003) definition of successful collaboration, which is built upon the mindset "sink or swim together". The authors emphasise that every party must realise that they cannot succeed unless everyone succeeds, which is a mindset assessed to be of high importance when dealing with environmental challenges in particular.

5.3.2 Trust

Company 1 and Company 2 are two of Ericsson's preferred suppliers, indicating that Ericsson has trust in them to deliver and perform what is envisioned. However, as previously mentioned, the external units were not comfortable with sharing specific and detailed information about their business, provoking doubt about the trust within the relationship from their part. Ericsson and the external units have been in partnership for a long period of time and have the desire of continuing their partnership, which points to them having the opportunity to develop stronger trust between each other (Poppo & Zenger, 2002). In section 5.3.1, it is discussed that an interdependent relationship is favourable for driving sustainability initiatives and increasing collaboration. Such a relationship can also have a positive effect on the trust between the parties (Sambasivan et al., 2011). To achieve an interdependent relationship with increased trust, goals and tasks should be aligned between the parties involved (Collazos et al., 2003; Sambasivan et al., 2011) This will make each party increase their commitment to involve one another in their work and increase their willingness to share important information with each other. Some examples in the context of the thesis, common goals could be to reduce their joint emissions related to facilities by 25 percent before 2030 or to increase their use of renewable energy at joint facilities by 50 percent by either on-site energy production or green certificates before 2025. These goals are related to facilities but many more could be formulated in connection to other parts of sustainability, such as transportation or waste management.

By creating aligned goals, a commitment mindset can be established, where all parties are working towards the common goal. Hence, if the common goals are not achieved, both parties are to blame. According to Sambasivan et al. (2011), partners with aligned tasks, goals, and reward systems enable more frequent communication, increased performance, and trust-building. Today, Ericsson is only encouraging their suppliers to set their own objectives related to sustainability. Additionally, Ericsson has exclusively focused on objectives related to reducing emissions of their internal operations and facilities. By creating aligned goals, trust is assessed to increase within all three categories; contractual, competence, and goodwill trust, further described by Capaldo and Giannoccaro (2015) in section 2.5.2.2. The result of the increased trust would potentially lead to the outcome of the relation-exchange theory, where knowledge and information are shared at higher circumstances, and partners are more prone to participate in joint learning activities and explore new opportunities (Capaldo & Giannoccaro, 2015). These aspects discussed are important when working with sustainability. Du et al. (2012) described that complex tasks require dynamic data and durable relationships with a great amount of trust for the information sharing process to be successful. The task of measuring facility emissions and allocating them to Ericsson is assessed to be a relatively complex task and therefore, the trust within the relationship must be developed for the information sharing process of emissions to become successful. It is important to not forget that when goals are achieved, rewards in the shape of joint benefits should be prioritised (Collazos et al., 2003). A reward system is assessed to yield increased motivation for all parties involved to work towards achieving the aligned goals. It can nonetheless be difficult to formulate common goals and tasks with a proper reward system due to separated visions and agendas of the companies.

Even though increased trust between parties from an interdependent relationship comes with many benefits, it is mentioned by Capaldo and Giannoccaro (2015) that there is a dark side of trust. By having too much trust in a relationship, it is described to cause relational inertia, coercive power strategies, and opportunistic behaviours (Capaldo & Giannoccaro, 2015). These are assessed to appear as a result of the advantages of trust, such as lowered need for monitoring and increased privileges for suppliers. It is therefore important to find a balance, which is very difficult. Even though an interdependent power relationship would be achieved between Ericsson and their external units, monitoring and governance activities should remain important, which is further elaborated upon in section 5.3.3. Aligned goals within this context may also act as an additional form of governance, as they would reduce the possibilities for opportunism in the relationship (Jap, 1999).

Since the environment of the market of today is dynamic and drastically changing (Melnyk et al., 2014), the characteristics of the products and production processes within a business are changing fast along with the market. As mentioned by the Supplier Relation Manager at Ericsson, the products' life-cycle is shorter now than before and has an increased degree of customisation, making Ericsson strive for improved and long-lasting relationships with their suppliers to improve quality and performance. However, developing relations takes a lot of time and effort (Poppo & Zenger, 2002), substantially longer than the change of the market. Therefore, it is important to act fast and try to formulate objectives with a shorter time-span, to be able to be more proactive to the market (Akhavan & Beckmann, 2017). As further described by the Supplier Relation Manager, Ericsson strives to treat all their suppliers equally, making it hard to create these shorter, individual goals and drive specific sustainability initiatives together with the external units. This statement is therefore questioned since it can be important for Ericsson to reconsider focusing on a smaller proportion of suppliers when implementing certain sustainability goals, as they have when performing audits. To try to get all suppliers to adhere and reach different goals and objectives is an activity that does take time, and by the time they are achieved, new objectives might be needed to be able to respond to the market. Therefore, when driving different sustainability initiatives, it might be necessary to focus on certain suppliers that have a larger impact on Ericsson's carbon footprint and work closely with them to reach a long-term solution.

5.3.3 Sourcing Acitivites

As of today, one part that Ericsson's sourcing department is responsible for is to ensure and monitor that Ericsson's suppliers follow Ericsson's environmental requirements. As mentioned by Ghadimi et al. (2017), it is crucial that sustainability practices are integrated with sourcing activities in order to achieve more sustainable supply chains. According to the interview with the Sourcing Manager, Ericsson has a minimum requirement that their suppliers shall follow basic laws and regulations regarding sustainability matters. Thereafter, Ericsson's Code of

Conduct guides the sourcing's work of evaluating the suppliers. The Code of Conduct is included in Ericsson's contract with their suppliers and consists of several areas, where one area is regarding the supplier's environmental impact and efforts. This area includes specific environmental requirements that must be fulfilled by the suppliers upon request by Ericsson. As mentioned in section 4.1.2, Ericsson's Code of Conduct has several different areas of requirements. It is assessed that within most of the requirements, it is clear what information that the supplier must declare upon request and which standards that need to be fulfilled. However, within the area of energy consumption requirements, where the calculations of carbon footprint are included, the formulation is slightly more ambiguous: "*If energy consumption is identified as a significant environmental aspect, the suppliers must calculate its carbon footprint in terms of CO_2e, using the GHG protocol...*", also presented in section 4.1.2. It is not stated in which cases energy consumption is seen as a significant environmental aspect, neither which level the CO_2e emissions should be calculated, e.g. on an aggregated company level or site-specific level, making it difficult both for Ericsson and their suppliers to know when and what kind of information that can be demanded. Mayer and Teece (2008) highlight the importance that contracts clearly define the requirements, in order to align expectations, divide responsibilities, and limit potential conflicts in the collaboration. To include more well-defined requirements regarding energy consumption could make it easier for Ericsson to demand certain data related to CO_2e emission of their suppliers, for example, if they want to start applying the previously mentioned activity-based allocation method discussed in section 5.2.2. According to Liu et al. (2009) it is also shown that contracts are capable of controlling opportunistic behaviour, which can be of advantage when setting new demands related to, for example, environmental requirements.

As mentioned by Du et al. (2012), the willingness to share information is either predetermined or spontaneous, where the first implies data is shared when specified in e.g. contracts and the second implies data is shared voluntarily. Based on the relationship that Ericsson has today with the external units, data is not shared spontaneously between the parties. Company 1 mentioned that no data was shared with Ericsson related to sustainability because Ericsson had not asked for it, insinuating that the data needs to be predetermined for it to be shared. Therefore, clearly defined requirements are of high importance in contracts to ensure that access to required data is granted. However, both states are assessed to be important when measuring sustainability. The predetermined state can be important for either party to know what kind of data is expected to be shared among each other and the spontaneous state can be important to be able to drive sustainability initiatives, e.g. to lower energy consumption in facilities.

Furthermore, to make sure that the suppliers comply with Ericsson's environmental requirements, the company has several governance methods related to sustainability, such as risk assessment and screening, self-assessment questionnaires, and audits. In these activities, much focus lies on detecting major sustainability deviations, and during 2020, Ericsson performed 83 audits on their suppliers and no deviations regarding sustainability were detected. Additionally, as described in section 4.3, Ericsson monitors the external units and their EMS sites through criteria within a scorecard developed by Ericsson and through regular meetings on different levels at the companies where they have discussions about different focus areas. However, the last two mentioned activities do not include the criteria of sustainability. Nonetheless, as the concern and awareness regarding sustainability are getting increasingly important for various stakeholders in the society and due to the fact that consumers often hold OEMs responsible for lack of sustainable practices along the supply chain (Hartmann & Moellern, 2014), it is essential that sustainability is included in all activities. Today, Ericsson's governance methods related to sustainability mostly cover happenings from the past, e.g. in forms of audits, and do not focus on preventative actions. A proactive way of working with sustainability is, according to Akhavan and Beckmann (2017), crucial when wanting to improve a company's sustainability performance. To have a proactive way of working can be valuable to be able to influence and have more insight into their suppliers' sustainability work. The external units would also benefit from this since the expectations of them and their future work, related to sustainability, would be more clearly defined.

5.3.3.1 Outsourcing

An additional area of work for the sourcing department is working with decisions related to the outsourced production. Companies often choose to outsource standardised processes and low-quality labour operations in order to reduce cost, increase flexibility, and easier access to new markets, among others (Kandil et al., 2020). As described in section 4.1.2, Ericsson has decided to outsource a majority of its volume production to the external units to be able to focus on their core competencies, such as software development and R&D, in-house. This is emphasised as crucial by Bettis et al. (1992), in order to not lose competitive advantage. The external production sites are spread out over the world and according to a Senior Supply Chain Manager at Ericsson, the decision to outsource was mainly based on the opportunities to lower the production costs. Different product families are produced at different EMS sites and the most important factor influencing the decision of where to produce which products are primarily based on cost, followed by the lead time. Sustainability is stated to be one important factor considered but is not primarily prioritised. This can be compared with the traditional approach for sourcing decisions presented by Ghadimi et al. (2017), where the decisions are solely based on price reduction. However, to take a stand on whether Ericsson's outsourcing decisions are affecting their sustainability work negatively or positively is complex. Since Ericsson has customers spread out all over the world, it can be beneficial from an environmental perspective to have production sites within close proximity. In that way, orders can be delivered from production sites closest to the customer. However, this is not always possible based on requirements from customers or other aspects. Kandil et al. (2020) describe some risks with outsourcing, for example, communication and coordination difficulties, loss of control, and longer lead times. These risks could potentially endanger Ericsson's sustainability work since it is difficult to measure or improve areas that cannot be controlled properly. Sustainability can therefore become a future trade-off against lower cost. Several companies are starting to back-shore their production to regain control and reduce the amount of emissions emitted (Kandil et al., 2020).

5.4 Limitations and Future Research

The focus of the master thesis has been on a single case study, examining the sustainability work of Ericsson and two of their preferred suppliers. The research is thereby to some extent based on the perspective of both the OEM company and their suppliers. However, due to the difficulties of getting in contact with the suppliers, a limited number of interviews were held with them. Additionally, a larger number of Ericsson's suppliers were intended to be included in the study, but due to time restrictions and the complexity of getting in touch with the right contacts, this was not possible. To increase the rigor of the study, additional interviews could have been conducted with the external units and other suppliers should have been included to gain a more holistic perspective of the situation. Furthermore, the scope of the study was set to gain a broad understanding of how Ericsson and the external units are working with sustainability, e.g. in terms of their CO_2e emission and energy sources. The recommendations developed from the study are therefore considerably general. Based on the study's findings, future research regarding more detailed recommendations about how to e.g. lower the total amount of emissions, a closer investigation of each production facility and their sustainability efforts are needed. Another area where future research is required is regarding smart manufacturing and how it can support companies in their transition to become more sustainable. The subject of including suppliers in an OEM's sustainability work is increasing drastically. Nevertheless, few studies on how to do this successfully exist. Future research within the area is thereby needed to be able to evaluate the result of the study and whether it is applicable for other settings as well. By conducting more studies about how to involve suppliers in different sustainability initiatives, applicable concepts could be developed for easier and better implementation of different strategies.

6 RECOMMENDATIONS

In this chapter, the recommendations based on the findings discussed in chapter 5 are presented and divided into three areas. The recommendations are presented below together with a specific letter from the alphabet, which they will be further referred to. Thereafter, the recommendations are assessed based on two categories, amount of effort and point in time of implementation, in table 6. The recommendations are based on Ericsson's situation and prerequisites but could be applicable in the context of other companies with similar challenges as well.

Sustainability Work

A. Since the thesis has focused on emission on an aggregated level, Ericsson should continue to investigate the area of emission related to the external production facilities on a more detailed level. This should include investigations about gathering more specific emission data from each production site, how far each of the production sites have come in their transition to be more sustainable, and the situation of each production site, related to infrastructure and technology development. Thereafter, improvement projects at each site can be decided upon.

B. Based on the fact that Company 2 had higher emissions related to the share of production than Ericsson and Company 1. A suggestion is therefore to start investigating and map the situation of the production sites of Company 2, to be able to lower the total amount of emissions.

C. Company 2 is reporting many activities within scope 3. Since Ericsson wants to expand their scope 3 reporting, a suggestion could be to take part in Company 2's reporting practices.

D. The main focus and improvement efforts for Ericsson should remain on operational CO_2e emissions since it is these emissions that the companies can continuously influence and therefore, improve. One way to reduce the operational impact is to continue the renewable energy transition. Ericsson should therefore increase investments in on-site renewable energy production, for example, solar panels, wind turbines, or recovered waste energy, in order to ensure that the energy is actually renewable. A suggestion is to gradually start implementing on-site energy production initiatives and still have renewable energy that originates from certificates as a compliment until the fluctuations are under control.

E. Since few of the external production facilities are using renewable energy, Ericsson should influence and encourage their external units to implement more renewable energy sources. This would contribute to lower emissions for Ericsson's supply.

F. Additionally, in order to fully account for the life cycle's CO_2e emissions of the company's facilities, Ericsson should consider including embodied impact in their emission reporting for their own facilities. A challenge is to decide how the external facilities' embodied CO_2e emissions should be allocated, either to the operating company of the facility, the company who owns the facility, or to the companies that have outsourced their production to the facility. Nevertheless, Ericsson should focus on their own facilities first and in the future, Ericsson could act as an inspiration for reporting embodied impact related to facilities.

G. As of today, Ericsson has several internal objectives related to sustainability and emissions. Ericsson should also formulate sustainability objectives related to their external operations and facilities as well, i.e. scope 3. By involving the suppliers in the evaluations of emissions would contribute to a more proper understanding of the full magnitude of the emissions.

Allocation Of Emission

H. The emission data from this report is estimated through a revenue-based approach. If accuracy is of high importance for Ericsson, a more appropriate allocation method to consider is the activity-based allocation of emissions.

I. If Ericsson has an interest in using the activity-based allocation method, an evaluation of the method should be performed internally first. Thereafter, Ericsson can demonstrate and share knowledge about how it should be implemented and used at the external production sites to the external units.

J. Ericsson should invest in more research about how to improve within the area of sustainability with the support of smart manufacturing and work closer together with the external units within the area. Smart manufacturing could help the companies improve their emission reporting, among other areas.

Increased Information Sharing

K. Ericsson should work on developing the relationship with the external units further to reach a strong and sustainable interdependent relationship. To achieve an interdependent relationship, aligned goals should be formulated between Ericsson and the external units. This could contribute to increased collaboration with a higher degree of trust and willingness to share information.

L. Even though Ericsson strives to treat all their suppliers equally, a reconsideration should be made to focus on a smaller proportion of suppliers when implementing common sustainability goals. By instead selecting fewer suppliers, a more proactive way of working with sustainability can be accomplished.

M. A reformulation of the environmental requirement of energy consumption in Ericsson's Code of Conduct could be beneficial to avoid confusion or uncertainties. This will make it easier for Ericsson to demand necessary information from their suppliers.

N. Another suggestion would be to include sustainability criteria in all of the already established governance methods for Ericsson's suppliers, such as other contracts, scorecards, and regular supplier meetings, to be more proactive in the sustainability monitoring activities. The evaluation and governance activities should remain within the same department at Ericsson as they are today. However, to involve sourcing in the creation of the new sustainability criteria can be valuable since that department has a profound knowledge of Ericsson's suppliers and possesses an important role in the building of relationships.

O. For Ericsson to gain full control and ensure sustainability performance of the production facilities, a future consideration would be to back-shore the production in-house.

The recommendations are evaluated based on the amount of effort and point in time of implementation, presented in table 6. The amount of effort estimates how much effort is required of Ericsson to perform the recommendation, with the levels of low, medium, or high. The time of implementation assesses when Ericsson should start the implementation of the recommendation, with the span of early, intermediate, or later.

Table 6. *Recommendations in relation to effort and time of implementation*

Recommendation	Effort	Time of implementation
A	High	Intermediate
B	High	Early
C	Low	Early
D	High	Intermediate
E	Medium	Early
F	Medium	Later
G	Low	Early
H	High	Intermediate
I	High	Intermediate
J	Medium	Early
K	Medium	Early
L	Low	Intermediate
M	Low	Early
N	Low	Early
O	High	Later

As can be seen in table 6, recommendations C, G, M, and N are the ones that Ericsson should implement at the first stage to become more sustainable and lower their emissions. The mentioned recommendations are assessed to have both low effort and early implementation, which makes them convenient to begin with. Which recommendations to continue working with is thereafter based on category time of implementation, and the category of effort can be used as guidance or prioritisation within the different stages. In the second stage, Ericsson should focus on the remaining recommendations with an early time of implementation, B, E, J, and K since these are assessed to be of importance within their sustainability work. In the third stage of implementation, the recommendations to prioritise are A, D, H, I, and L since these were assessed to have an intermediate time of implementation. In the last and fourth stage, the recommendations F and O should be considered since these had a later time of implementation, due to their complexity.

7 CONCLUSION

With increased pressure to achieve a higher degree of sustainability within businesses and their supply chain, improved measuring practices of emissions are required to be able to evaluate their environmental impact. Measuring emissions becomes challenging when wanting to include parties further down the supply chain based on the accessibility of data and information. The purpose of this study was to investigate and map Ericsson and the external units' sustainability work related to facilities, in order for Ericsson to create a baseline related to the external emissions and in turn, be able to improve the total carbon footprint of their supply. To be able to conduct the study and draw relevant conclusions, both the perspective of Ericsson and two of their preferred suppliers have been taken into account. It has been concluded that measuring sustainability and facility emissions is a much more complex process than expected when including external parties, as it requires proper allocation methods and strong collaboration between the parties involved.

Ericsson and the external units are actively working with increasing their sustainability efforts and have incorporated it into their business strategies. Regarding the energy sources for the facilities in question, Ericsson is using renewable energy in all of their internal production facilities, while few of the external units' facilities use renewable energy sources. This is reflected in the emissions of the external units' production facilities, which is substantially higher than Ericsson's production facility emissions.

The external units are producing products for other customers than Ericsson in the facilities in question. Therefore, an allocation of the emissions generated is required to properly represent Ericsson's share. Which allocation method to use is driven by different criteria that are of importance, for example, the accuracy of the data. In the study, the emissions were allocated based on Ericsson's share of revenue at the external units, which provided Ericsson with a result of low accuracy. If accuracy is of importance, a more appropriate method to use is activity-based allocation. The question of allocation methods might become obsolete in the future, as a result of smart manufacturing, which will make it easier to measure emissions through real-time data.

In order to perform emission calculations with higher accuracy, access to more information and data is needed from the external units. This can be challenging if the collaboration between the parties is not further developed. The relationship between Ericsson and the external units is assessed to be independent and needs to be further developed into an interdependent relationship, for increased trust and willingness to share information. This can be accomplished by aligning business strategies by setting common goals and focusing on a selected number of suppliers. In order to remain in control and avoid opportunistic behaviour of any party in the relationship, it is important that Ericsson should further develop their governance and monitoring methods of their suppliers related to sustainability. This can be accomplished through reformulation of Ericsson's Code of Conduct and including criteria of sustainability in governance methods, such as contracts, scorecards, and regular supplier meetings.

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APPENDIX

Appendix A: Interview Guide

General information about EMS sites and the external units

- Where are Ericsson's production sites located, both the internal and external ones?
- What kind of products are the sites producing?
    - Are the external production sites producing products for other companies than Ericsson?
- What company is the "owner" of which sites?
- Describe the operating companies and why Ericsson have chosen them
- Large or small size production/facility, in terms of volume?
- How is the collaboration between the external units Ericsson?
- Are the external units reporting any information about sustainability to Ericsson? If yes, how? If no, why not?

Information about Ericsson's supply chain

- Tell us about Ericsson's supply chain structure
- Which companies are operating with the external production sites?
    - Are Ericsson their only customer?
    - What do they produce?
- How is the relationship with the external companies?
    - Long-term/short-term?
    - Contracts or more open?
    - Multisourcing or single sourcing?
- How are they working with sustainability?
    - Are they reporting their work to Ericsson in any way?
    - If yes, how?
    - If no, why not? Does Ericsson have any requirements that they shall report?
- Are the external companies aware of Ericsson's sustainability work?
- Do you have any documentation related to the external companies that we could take part of?
- How many production facilities does Ericsson have internally?

Calculations for Ericsson's internal emissions

- How had this been done previously?
    - What equations and measurements have been used?
    - What kind of data is needed?
    - Are there any assumptions or neglections that you have used?
- How did you access the data needed?
    - Who collects the data?
- Based on the GHG protocol, the emissions are calculated in CO_2e, how is this done?

    - Are your emissions converted to CO_2e?
    - How is CO_2e defined/calculated?
    - Are you using any standards or emission factors for your CO_2e calculations?
- What kind of data is interesting for us to collect to be able to measure the external facilities' emissions in an equal way as the internal ones?
    - man hour, kWh, square meters of the facility, etc
- How is it converted into CO_2e?
    - What emission factors are needed?
    - Where do we find relevant emission factors?
- Since the EMS sites produces products to several companies, we want to find out how we can calculate Ericsson's actual share of emissions
    - Is there any way for us to calculate the emissions related to the number of products produced at the different facilities since not only products from Ericsson are produced there?
    - Are there any standards to follow for such calculations?
- If the companies have their own CO_2e emission data, can these be directly comparable to Ericsson's CO_2e emission data?
- We have gained access to the number representing emission emitted by Ericsson's internal production facilities, can you tell us more about these calculations?
    - How did you collect the data of energy consumption?
    - What emission factors were used?
- Do you know which products within Ericsson's product portfolio have the highest environmental impact?
    - If not, are there any plans for the future to find this out?
- What is your opinion about allocating Ericsson's share of emissions based on revenue?
    - Is there any other way to allocate?
    - What do you think about the ABC method for allocating emissions?
    - Do you know any activity within the production process that requires more energy than others?

<u>Specific information about the EMS sites</u>

- Describe your role within Ericsson and which of the EMS sites you are working with
- General description of the EMS sites and the external units
- Which products are the different EMS sites producing? How is this decided?
- How large quantities are produced at the EMS sites?
- Are the external units producing products to other companies than Ericsson in the EMS sites?
    - If yes, how large share of the production is Ericsson representing in the different EMS sites?
- Describe Ericsson's relationship with the external units
    - Years of collaboration?
    - Regular meetings?
    - Information sharing?

    - Level of trust?
    - Contracts?
- Is there any data transferred between the Ericsson and the external units, related to the production in general?
- Are the external units reporting any data related to sustainability matters or energy consumption?
- Are you aware if the external units are actively working with sustainability?
- Are the external units aware of Ericsson's sustainability work and objectives?
- Are there any audits performed at the external units?

<u>Ericsson's internal sustainability work</u>

- Describe how Ericsson is working within sustainability today
- How is Ericsson reporting its emissions?
- Describe Ericsson's usage of the GHG Protocol
- What objectives does Ericsson have related to environmental sustainability?
- How is Ericsson working with renewable energy?
- Is Ericsson using smart manufacturing within the area of sustainability? If yes, how?

<u>Ericsson's sourcing strategy</u>

- How do Ericsson work with sustainability within the sourcing department?
    - How do you work with getting suppliers involved in Ericsson's sustainability work?
    - Is sustainability a part of the work at sourcing?
        - If not, do you plan on including this in the future?
- What are the requirements on Ericsson's suppliers?
    - ISO standards or others?
    - How do Ericsson follow up on these requirements?
- How is the collaboration with the external units?
    - How long has Ericsson worked together with the external units?
    - How long has there been a partnership respectively?
    - What do the contracts look like?
    - How often are they updated?
    - Do Ericsson have individual contracts for each production site?
- Do Ericsson and the external units have any aligned sustainability work?
- Do you have any requirements of the external units to report any data related to sustainability?
    - If yes, what data?
    - If not, why not?
- Tell us more about Ericsson's Code of Conduct
- Do you have any documentation about the sourcing process and the external units that we could get access to?

Internal production sites

- Tell us more about the internal production sites
    - What is being produced?
    - How is the future looking? Will Ericsson expand/lower the internal production?
    - Are there any ongoing projects to improve the performance of the internal production sites (both generally and related to sustainability?)
        - Smart manufacturing?
        - Efficiency?
- Why has Ericsson outsourced the majority of their production?
    - What is the reason for having two companies responsible for the productions?
    - How is the relationship between Ericsson and the external units?

Questions for the external units

- What is your relationship with Ericsson?
    - What are you producing? Volume?
- How does your company work with sustainability?
- Do you work towards any specific sustainability objectives? Future goals connected to sustainability? Any vision or improvement work?
- How do you ensure that your production sites are working towards these objectives?
- Are you aware of Ericsson's internal sustainability objectives?
- Do you measure your emissions in any way? (CO_2, energy consumption)
    - If yes, is it done on a global level or on-site level?
    - If yes, have mapped different areas of your business (transport, facilities, production)
    - If yes, can you describe how your company performs the calculations? (equations, emissions factors etc)
    - If no, why are you not measuring your emissions?
- What is your most common energy source for your production facilities?
- How are you actively working with decreasing the energy consumption/emission for the production sites? Apart from renewable energy
    - smart factory, energy efficient equipment, lightning, cleaner production
- Do you have any other initiatives to reduce the energy consumption or emissions in your factories?
- Do you know the proportion of Ericsson products produced at each facility?
    - If not, do you have any suggestions how this allocation can be made? (percent of produced products, percent of revenue)
- Company 1: We have seen that you reduced your CO2e emissions drastically between 2017 and 2018 in your sustainability report, what was the reason for the reduction?
- Company 2: We have seen that your scope 3 reporting has heavily increased during the last years, can you tell us more about that?

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DIVISION OF SUPPLY AND OPERATIONS MANAGEMENT
CHALMERS UNIVERSITY OF TECHNOLOGY
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