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Carbon Footprint Management In Austrian SMEs: Strategies, Mitigation Measures, Challenges, And Case Studies

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Abstract

The term Anthropocene describes the dawn of an epoch in which human activities have become the dominant force destroying the ecosystem and causing climate change. By contributing at least one-fifth to global greenhouse gas (GHG) emissions, industry has a significant environmental impact. Reducing these emissions requires coordinated action along the value chains building on transnational agreements and regulations. Based on the European Green Deal, EU countries and their industrial companies see themselves forced to react to emerging regulations considering their corporate carbon footprint and mitigation strategies as well as the assessment and improvement of their carbon footprints. In this paper, we report findings of case studies in Austrian SMEs that show how such companies can react to these challenges. We illustrate an approach to identify existing reduction potentials by engineering optimization and product life-cycle design to reduce corporate and product carbon footprints and prepare for future reporting regulations and achieve market advantages.

Keywords

Proceedings; Green manufacturing; Industrial GHG accounting; Carbon footprint; Sustainable production; Engineering Optimization; Product Life Cycle Design;

1. Introduction

Reports of the Intergovernmental Panel on Climate Change (IPCC) but also other scientific sources show that the increase in global GHG emissions is having a progressively negative impact on the climate and will lead to a global average temperature of 1.5°C above pre-industrial levels as early as 2030 [1-4]. The importance of the industrial sector in this context is not only evident globally, where related GHG emissions account for 23% of total emissions, but also at the national level [5,6]. In Austria, for example, the energy consumption of industries (28%) and industrial processes (21%) are responsible for almost half of total GHG emissions [6]. (European) companies regardless of their sector will be required to identify, and where necessary prevent, mitigate, or end pollution, environmental degradation, and biodiversity loss [7,8]. They will also have to monitor and assess the actual and potential impact of their value-chain partners including not only suppliers but also transportation, storage, distribution, waste treatment, and other aspects [9]. According to a recent IPCC report, decarbonization of industrial production must be based on low-emission electricity and heat, energy efficiency improvements via the best available technologies, fuel switching, and the substitution of high-carbon feedstock. Moreover, eco-design, material efficiency, waste reduction, as well as higher recycling rates up to a circular economy might drive this transition [10].

1.1 The European perspective

To succeed in the transition to a resource- and energy-efficient and circular economy and the development of cleaner and less energy-intensive technologies, the European Union sets rigorous targets for GHG

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emission accounting and reductions [7,11,12]. Upcoming requirements include the unified Corporate Sustainability Reporting Directive (CSRD [9,13]), which defines the applicability of the more specific European Sustainability Reporting Standards (ESRS [14]) and the aspects, key figures, and procedures specified therein. CSRD also provides investors with information needed for sustainable investment choices (i.e. by disclosing a quantification of the share of sustainable business activities according to the EU Taxonomy) [15,16]. Furthermore, the Carbon Border Adjustment Mechanism (CBAM) combatting 'carbon leakage' by imposing an adjustment price (carbon tariff) for imported and energy-intensive products [17], is focused. To address the adverse impacts of companies' actions and their value chains inside and outside Europe, Corporate Sustainability Due Diligence (CSD) will be introduced [9]. In the end, the primary goal of reducing GHG emissions inside and outside the EU comes along with establishing transparency and traceability of carbon emissions of companies and their products.

However, for small- and medium-sized enterprises (SMEs), which will be required to comply with these new requirements as early as the year 2026 (see Figure 1), applicable procedures and tools for GHG management, as well as appropriate training offers are lacking or unknown, imposing major challenges.

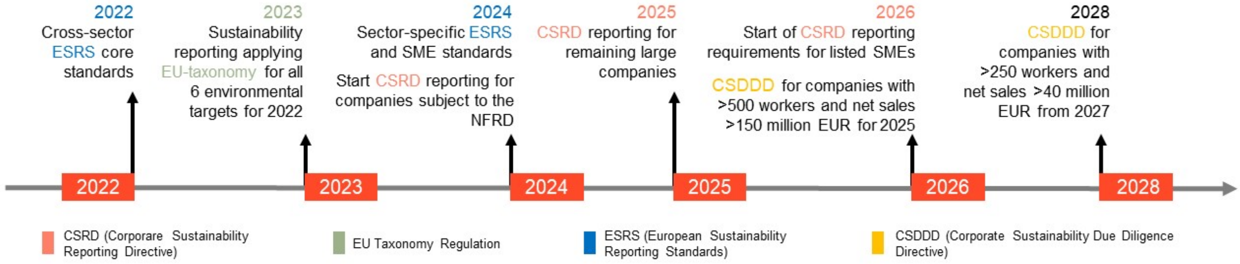


Figure 1: Current sustainability reporting timeline for Europe

1.2 Existing approaches, methodologies and tools

Existing specifications and standards can be distinguished as 'organization-related' and 'product-related' (see Figure 2). Companies can quantify and manage their GHG emissions using the corporate carbon footprint (CCF) as a company-related approach and/or the product carbon footprint (PCF) as a product-related approach [19]. A CCF accounts for the company's emissions as well as all relevant emissions caused along the value chain in which the company is located. CCFs are usually calculated within three different scopes applying the GHG Protocol [20]. CCF studies can include both, direct and indirect GHG emissions to help to focus on the relevant reduction opportunities. When the company starts implementing improvement measures, the impact of these measures must be measured over the years. Because of the impact of increasing output on GHG emission levels, measurements must be referenced to an output-related KPI (e.g. production volume, turnover, …) in the so-called carbon intensity [21].

If the CCF is followed by a detailed analysis of resource use, emission drivers can be identified, and targeted reductions (e.g., in energy consumption) can be achieved, which also lead to cost savings that often exceed the expenses for the reduction measures. As a practice-oriented management tool, a CCF thus provides an overview of the operational GHG inventory and serves to improve operational resource management. Despite the good progress SMEs have made in their sustainability transition, their key characteristics, such as limited resources or operation in niches, are challenging [22].

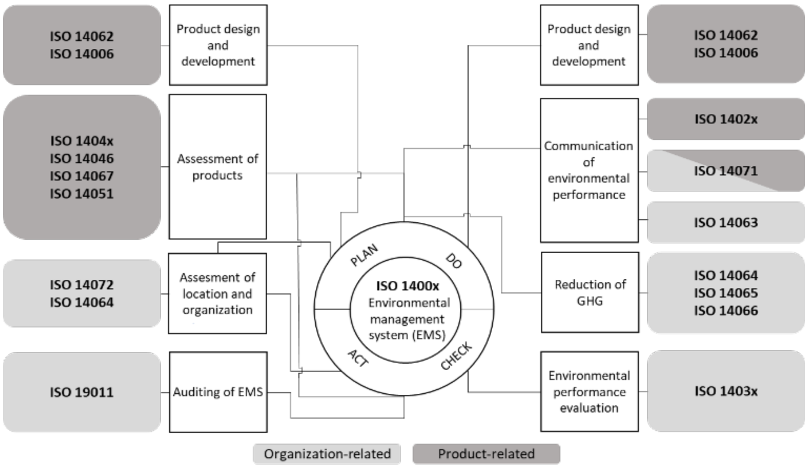


Figure 2: Relation-oriented differentiation of ISO environmental standards [18]

Limited (access to) financial resources hinders capital-intensive investments into cleaner technologies individual and niche market requirements can inhibit transfers from available best practices [22]. Moreover, 58% of SMEs did not employ any employees in so-called "green jobs" that deal with information, technologies, or materials that preserve or restore environmental quality [23]. The resulting lack of skills, knowledge, and expertise comes along with insufficient awareness and information regarding opportunities, environmental regulations, and options.

While there is a growing need in the industry to evaluate resource and especially energy efficiency improvements, including information on potential cost savings, to enable appropriate decision-making [24,25], existing approaches neglect various constraints, such as available resources, existing know-how and employee awareness regarding optimization procedures and measures [26,27]. Nevertheless, the EU's targets for increased energy efficiency and emission reduction force SMEs to present solutions in the short term.

A PCF study is used to quantify GHG emissions associated with activities in the product's life cycle. All process stages from development, manufacture, and transport of raw materials, through production and distribution, to use, after-use, and disposal can be considered depending on the scope of the study. Several initiatives, (inter)national standards, and technical specifications (e.g., ISO 14067, GHG Protocol, PAS50) exist, which guide the user through the calculations [28, 29]. PCFs are particularly useful for the communication of environmental problems or achieved improvements, and serve to identify emission-insensitive processes in the product creation process. Based on the detailed identification of emission drivers per product, relevant measures (especially for product development) can be defined by the management. The connection between CCF and PCF becomes clear when considering that summing up the yearly production volume of all products multiplied by their individual PCF must theoretically result in the CCF.

Similarly, at the corporate level, SMEs lag behind large companies in the application of environmental reporting for products. Besides a shortage of qualified personnel and absence of concrete benefits, the perceived complexity of lifecycle assessments (LCAs) might be the main impediment [30]. Further, several methodological questions remain at the product level [19,28] that calculating PCFs is a difficult and time-consuming task, especially for SMEs. Nevertheless, the increased legislative pressure on ecological performance and the potential competitive advantage from having an environmentally friendly profile increases the pressure on SMEs to report PCF to their downstream partners.

Regarding the aforementioned developments and challenges, a rigorous change is required in the way industrial companies particularly SMEs in that sector, deal with the topic of carbon emissions. This is relevant for both, strategic decision-making on the cooperate (macro) level as well as product- or process improvements on the operational (micro) level. For the macro level, companies need to evaluate all emissions caused and set up a strategic reduction plan for their business activities that meet the EU reduction targets for their sector. Over the course of time, a standardized assessment of the emission reduction concerning the produced output or generated revenue, a so-called emission path, is necessary to manage the process towards net zero emissions. Regarding the micro level, the focus is on embodied emissions and reduction potentials by life-cycle-based assessments. To illustrate potential approaches, applicable methodologies, and tools for data gathering and analysis, as well as available reduction potential and possible benefits for SMEs a case study for each level is reported in the following.

2. Corporate Carbon Footprints accounting and reduction in SMEs- an Austrian case study

The Orasis Industries Holding GmbH is divided into two divisions. One manufactures products and pyrotechnical solutions in the context of automotive safety, mining, and metal processing (division "Pyro"), and the other mobile as well as stationary machinery for solid waste and woody biomass processing (division "Environmental"). In total, the company's production network comprises nine different production sites in Austria, Germany, Slovenia, Hungary, and the Czech Republic. In the course of the project "CO2 neutrality", GHG emissions were systematically recorded at these sites for the years 2019-2022. In total, approximately 9,200 tons of CO2 equivalent were recorded in the base year 2019 and classified into scope 1 (35%), scope 2 (37%) and scope 3 (27%). However, this distribution is not representative as only the employee mobility section was considered in scope 3. Based on the carbon footprint at the company level, three sites with high energy-related emissions were identified. Of these, two sites (one per division) were selected to carry out a structured reduction of energy-based GHG emissions. Based on the pilot application presented here, a procedure model that incorporates SME-specific requirements in terms of resources, knowledge, and financial issues was developed and partly published before (for details see [24]).

First, relevant emission drivers (e.g., energy sources, raw materials, waste, employee mobility, etc.) were defined and the quantities purchased (based on annual invoices) were collected. By calculating the associated GHG emissions and performing a quantity-based analysis (e.g. ABC analysis), hotspots were identified and considered in detail (see Figure 3).

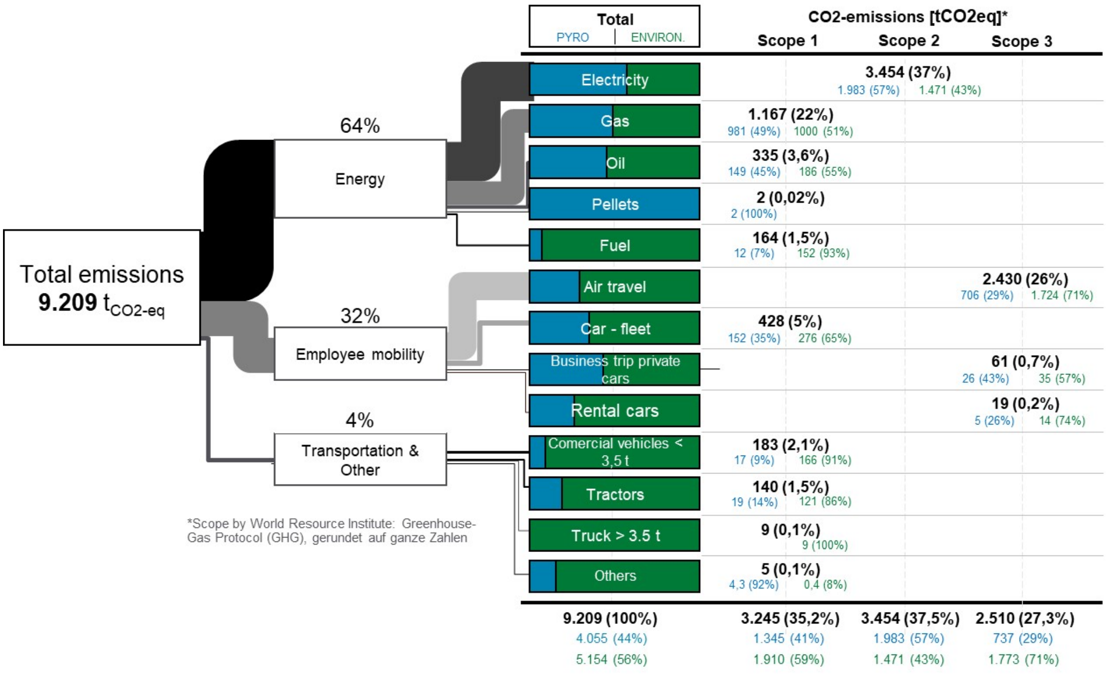
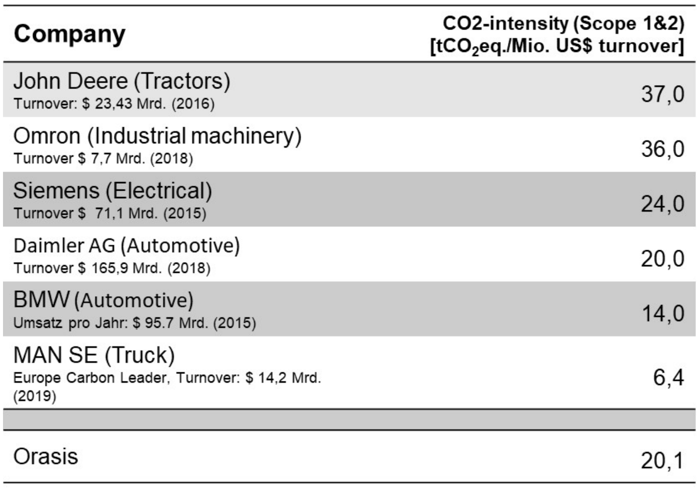


Figure 3: CCF of the case company in 2019

To evaluate the own performance and derive and evaluate reduction potentials, an internal or external benchmark based on relevant key figures (e.g., CO2 intensity, energy consumption) was conducted. Based on these key figures, comparisons can be made with, for example, fluctuations in internal energy efficiency over time, or with the CO2 intensity of comparable competitors, assessing their own performance. For the case company, a comparison of the CO2 intensity (Scope 1 and 2 emissions per turnover) was conducted with similar industries (see Figure 4).



Company	CO2-intensity (Scope 1&2) [$tCO_2eq.$/Mio. US$ turnover]
John Deere (Tractors) Turnover: $ 23,43 Mrd. (2016)	37,0
Omron (Industrial machinery) Turnover $ 7,7 Mrd. (2018)	36,0
Siemens (Electrical) Turnover $ 71,1 Mrd. (2015)	24,0
Daimler AG (Automotive) Turnover $ 165,9 Mrd. (2018)	20,0
BMW (Automotive) Umsatz pro Jahr: $ 95.7 Mrd. (2015)	14,0
MAN SE (Truck) Europe Carbon Leader, Turnover: $ 14,2 Mrd. (2019)	6,4
Orasis	20,1

Figure 4: CO2 intensity benchmark

Second, a rough recording and quantitative analysis of energy-related data is conducted. This resulted in the consumption of 3,7 GWh of electricity and 4,4 GWh of natural gas for the reference year 2019 (for GHG emissions see Figure 3).

In a third step, to identify saving potential a process-oriented perspective on the level of individual consumers is necessary. Therefore, the rated power of over 100 consumers was recorded and their operating and setup times were either determined from the data system used or estimated by the company. Based on this the electricity consumption is calculated and compared to the results of the invoice-based analysis. Overall approximately 5,5 GWh of electrical energy and a gas consumption of around 5 GWh was calculated which exceeds the real consumption for the reference year by far.

Fourth, energy measurements were conducted to determine the real consumption. The consumption of relevant machinery was measured over the course of a representative production week. Based on this data the average consumption for different machinery conditions (i.e. producing, set-up, stand-by, maintenance, etc.) was determined.

Relevant machinery was iteratively defined based on a Pareto analysis regarding their electrical energy consumption (about 1,000 hours of recorded data). The deviation between calculated and purchased power consumption in the end accounted for less than 3%. Overall, 13 large consumers, which account for about 60% of the total electricity consumption (2,3 GWh) were identified. About 13% of the annual electricity consumption (480,000 kWh) was caused by the lighting and an additional 8% (306,000 kWh) was used to generate the required compressed air. All other consumers use about 220,000 kWh of electrical energy and thus were not considered in detail in the further analysis. The largest sources of losses were identified as (1) high transmission losses due to manual control of the heating temperature in combination with a poorly isolated plant, (2) energy conversion losses, (3) compressed air consumption and leakage, and (4) unused waste heat from compressors (although heat recovery systems were implemented for process heat at the paint shop). Furthermore, a detailed analysis of the electricity measurements revealed various 'anomalies' in connection with the standby operation of plant, machinery, and office equipment. Fifth, for the five named energy losses measures were derived and achievable savings were evaluated. In company A energy reduction potential of over 900,000 kWh (45%) was identified. The identified measures were evaluated in terms of reduction in energy costs, GHG emissions, and static payback period to enable prioritization of the measures and to obtain investment approval. For example, the welding gas extraction system operated unnecessarily, even when no welding was done or on non-working days. Implementing a programmable timer for the system enables annual energy savings of circa 65,000 kWh. This results in a cost reduction of over 3,500 €/year (at energy price level of 2019) and reduces GHG emissions by approximately 22 t/year at very low investment costs. Similarly, potential savings were derived for different consumers through demand-based shutdown during non-productive times (e.g., 3rd shift, weekends, holidays) totaling approximately 290,000 kWh/year or €16,000/year. Also, for compressed air significant reduction could be achieved by various measures such as the use of alternative technologies instead of air tools (17,000 kWh/year) or systematic maintenance to minimize leakage losses (100,000 kWh/year). Other proposed measures included the roll-out of energy-saving LED (approx. 160,000 kWh), using compressor waste heat for heating (approx. 80,000 kWh/year), or the installation of temperature sensors to control heating (approx. 120,000 kWh/year). However, also potentials that were not profitable at this point were identified and evaluated in terms of GHG saving. For example, the replacement of outdated insulation of one plant would reduce transmission losses and thus the emissions, but was not further considered due to a long payback period over.

Sixth, all feasible measures were shortlisted and clustered into short (< 3 years), medium (3-5 years), and long-term (<5 years) payback periods. Short-term measures were suggested to be implemented immediately to achieve quick wins in terms of cost and GHG savings while medium- and long-term measures were evaluated individually. In total, measures for saving 772,551 kWh/year (10% of the total energy demand) were further considered. By implementing those measures the case company could save 13% of energy costs and 11% of emissions (calculated for 2019). The ratio of the total investment required to the achievable annual cost savings was 1.3 and approximately 70% of the proposed measures had payback periods of under three years. The procedure presented here was also carried out at the second energy-intensive site of the Orasis Group (Automotive Safety) and, despite very different initial situations, comparable results were achieved (-14% annual energy consumption, -13% emissions, -11% energy costs, investment-to-savings ratio 1.2).

In the last step, emissions tracking and reduction progress over time must be monitored, and a viable long-term strategy for achieving net zero production in line with EU reporting requirements must be developed. For the case of Orasis, several actions were set besides the optimizations reported before. Major savings could also be yielded over the years 2020-2022 by focusing on green energy (solar power) as well as district heating projects in Slovenia, Germany, the Czech Republic, and Hungary. However, extending accounting to all scope 3 GHG emissions (esp. from upstream activities) and setting reduction targets in this area also has the potential to significantly reduce the CCF. For example, in 2020 analysing and reducing air travel had a major impact on the CCF (although not directly quantifiable due to COVID-19 effects).

Targets and performance tracking led to a substantial reduction in GHG emissions, from 9,200 to 4,670 t CO2-eq, between 2019 and 2022. Despite a significant increase in turnover from 298 million to 383 million euros between 2019 and 2022, a reduction of 60% was achieved when normalized to turnover (Figure 5).

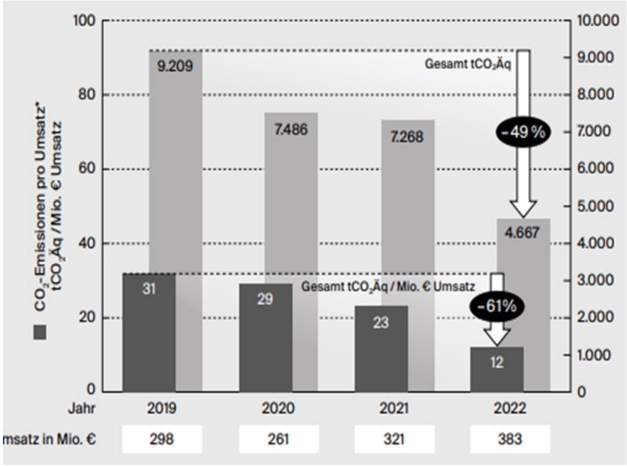


Figure 5: Orasis' GHG emission reduction from 2019-2022

3. Product Carbon Footprints in production SMEs – an Austrian case study

The PCF applies LCA methodology to a product system, focusing solely on the impact category of climate change [32]. Such studies are complex as they involve collecting and allocating inputs and outputs (life cycle inventory), as well as determining process- and country-specific emission factors. For each PCF study the scope including system and time boundaries has to be defined beforehand, which limits the comparability of the results. To simplify and address the aforementioned challenges specific to SMEs, a case study-based procedure model was developed in conjunction with ISO 14067. This model was applied to industrial use cases involving two companies from the automotive supply industry (partly published before by [33]). In this context, the production of three vehicle components (product A: crossmember, product B: subframe, product C: actuator) within the sphere of influence of the related supplier (cradle-to-gate) was considered. Table 1 summarizes the most important characteristics of these components.

Table 1: Characteristics of cases analysed [26]

Product	Number of Parts	Number of Suppliers	Internal processing steps	Internal- & external complexity	PCF reduction potential
A	1	1	1	very low	~85%
B	4	3	3	low	~45%
C	20	8	2	medium	~40%

The data collection procedure is geared to data availability. It addresses current practices concerning complex supply chains and the challenges and limitations of surveying the upstream value chain. Recommendations and templates were developed, covering allocation methods, data collection areas, transportation, electricity mix, and infrastructure considerations, as well as typical specific manufacturing and assembly processes, all concerning Austrian automotive industry-based SMEs. To ensure that the result is not underestimated, conservative assumptions and procedures should be applied.

Although the same approach for the PCF determination was adopted in all cases (see Figure 6), individual situations such as the pro rata utilization of machines and warehouses or distances and means of transportation had to be addressed. The correct allocation of general resource consumption to a single component turned out to be particularly challenging. Also, a lack of relevant data was observed. Several measurements and on-site visits were necessary to obtain the data needed (e.g., energy consumption of specific machinery, operating materials for certain processes, recycling procedures and shares, allocation of energy consumption of automated production lines with multiple products).

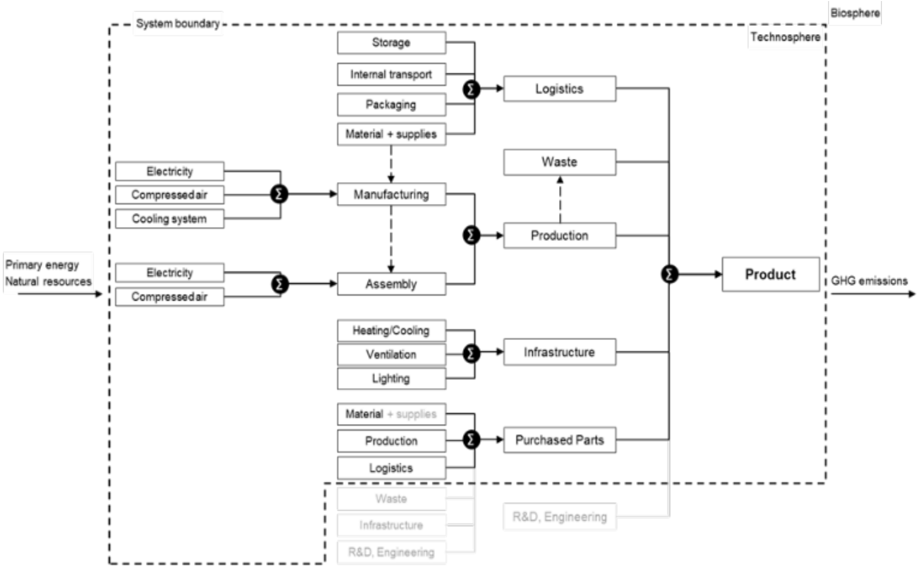


Figure 6 Product system in the PCF studies [33]

Further acquisition of data from suppliers regarding the PCF of their products was a challenge in all case studies. The complexity that is determined by upstream activities in the supply chain can be referred to as external complexity. It is determined primarily by the number and locations of sub-suppliers, as well as their cooperation (esp. data availability). The more individual parts are sourced externally, the more extensive the data collection process becomes. For the case of product B, all 8 suppliers were requested to provide the required data based on a standard template. However, 70% of these suppliers did not provide primary data for various reasons, including unavailable data, confidentiality agreements, and provision of implausible information.

Internal complexity relates to the in-house production of the considered companies located in Austria. It depends mainly on the number of processing steps and how easy and exact material and energy consumption can be measured or calculated. If many different products are produced on the same machine or line, this complexity also increases.

The results of the PCF show that, based on the low carbon energy mix production accounts for a very small share (2-14%) of the PCF. Based on that, a change to more energy-efficient technologies, or a change to green energy or photovoltaics does not result in significant improvements in the PCF. Only the switch to low-carbon material would yield a large reduction in the overall PCF. In the case of simple products and processes, the PCF is influenced by fewer factors, which is why the high PCF reduction potential from appropriate sourcing has a greater impact. Based on the experiences in the case studies (in analogy to [32]), an SME-specific guideline was developed to document the approach, especially the data gathering and allocation procedures. The guideline is divided into 5 sections: (1) preparation of determination, (2) allocation methods and specifications, (3) determination of internal data, (4) determination of external data, and (5) result evaluation (see Figure 7). The determination of internal and external data can be carried out in parallel to bridge waiting periods and save time.

The first part provides advice regarding the data needed, the usual/potential data-holders, and the resulting set-up of a project team. Based on this data what needs to be measured internally can be determined in the first step as well. To standardize the allocations for general resource consumers, two different methods for the allocation of general resource consumers that distinguish between allocation based on the total production volume and the plant area covered by the reference product.

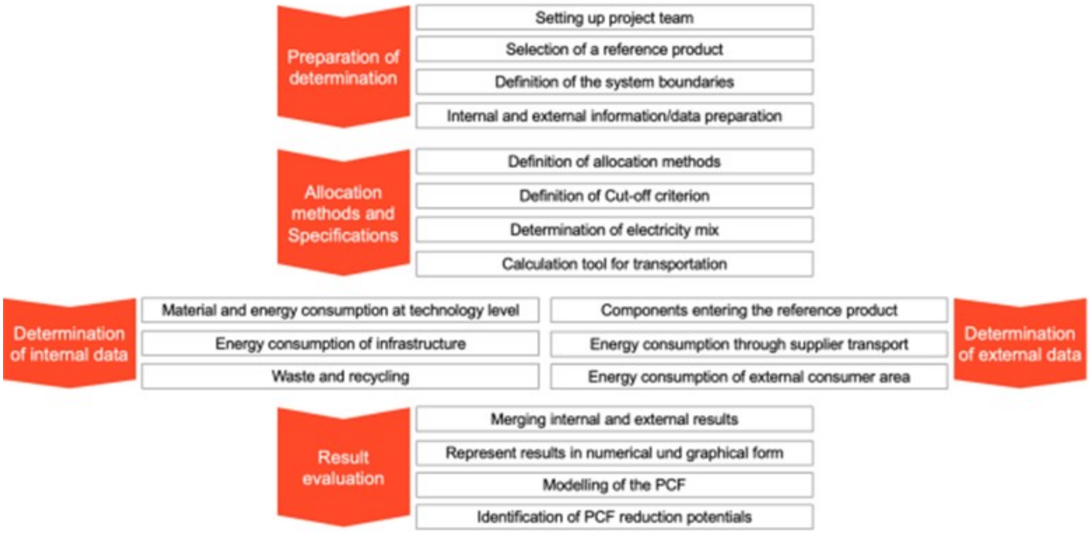


Figure 7: Guideline for PCF calculations in SMEs

Specific guidance is provided for products that cannot be sold (e.g., test parts, scrap parts) and the relevant allocation procedures. For the internal and external data determination, the incorporation of several locations and company-specific factors (e.g., primary data measurement, local energy mix, specific transportation routes, supplier templates, modeling approaches) into the PCF are discussed. Finally, guidance on how to identify and evaluate suitable scenarios regarding the reduction of the PCF within SME structures is provided.

4. Conclusion and Outlook

Reducing the industry's GHG emissions requires coordinated action along the value chains by all involved partners building on transnational agreements and regulations. Industrial companies also have to act to meet emerging regulations and stay competitive. In this paper, we report findings of case studies in Austrian SMEs that show how such companies can react to these challenges. The CCF is an effective tool to develop holistic mitigation strategies while the PCF enables a more specific assessment and improvements on the micro level. We illustrate an approach to identify existing reduction potentials for both areas of CCF and PCF to prepare for future reporting regulations and to achieve future market advantages. To achieve this, it is of particular importance to raise awareness and skill levels regarding the creation of carbon footprints in education and industry quickly. The cases underline the need for technical and procedural competencies as well as a standardized procedure to set the pathway to net-zero and related measures on the corporate level as well as improve upstream activities (e.g., via material selection) and cope with challenges in defining system boundaries and allocating resource consumptions on product level. The experience gained will not only support the companies involved but will also be used in engineering- and executive education.

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Biography

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