Hochschule für
Wirtschaft und Recht Berlin
Berlin School of Economics and Law

Controlling Plus+ Institut (CPI) –
Institut für Performance Management & digitale Transformation

Implementation of Product Carbon Emission Standards – An analysis of barriers and opportunities for start-ups

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Biographic Note

Anna Gneuß graduated from the Berlin School of Economics and Law and ESCE Paris with a German-French Master Degree in International Management in 2022. During this time, she specialized in Global Supply Chain Management and Green Digital Purchasing. Anna has applied this knowledge in a Berlin start-up for sustainable body care where she focused on the symbiosis of economic, ecological and social performance. She is now responsible for integrating newly acquired products into existing processes in a pharmaceutical company and continues to promote the implementation of Emission Standards in companies.

Prof. Dr. **Eberhard Schmid** is professor of sustainable supply chain management at Berlin School of Economics and Law. After gaining experience in logistics and supply chain consulting he focuses on teaching and research in the field of logistics and supply chain management. One special focus lies on the design of supply chain networks with respect to sustainability considerations.

Anna Gneuß schloss 2022 ihr Studium an der Hochschule für Wirtschaft und Recht Berlin und der ESCE Paris mit einem deutsch-französischen Master in Internationalem Management ab. Während dieser Zeit spezialisierte sie sich auf Global Supply Chain Management und Green Digital Purchasing. Dieses Wissen hat Anna in einem Berliner Start-up für nachhaltige Körperpflege angewandt, wo sie sich auf die Vereinbarkeit von ökonomischer, ökologischer und sozialer Leistung konzentriert hat. Sie ist heute für die Integration neu erworbener Produkte in die bestehenden Prozesse eines Pharmaunternehmens verantwortlich und setzt sich für die Implementierung von Emissionsstandards in Unternehmen ein.

Prof. Dr. **Eberhard Schmid** ist Professor für Sustainable Supply Chain Management an der Hochschule für Wirtschaft und Recht in Berlin. Nach mehreren Jahren in der Logistikberatung forscht und lehrt er zu Fragestellungen der Logistik und des Supply Chain Management. Ein besonderer Schwerpunkt liegt hier auf der Gestaltung von Supply Chains unter Nachhaltigkeitsgesichtspunkten.

Implementation of Product Carbon Emission Standards

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Anna Gneuß

Eberhard Schmid

Purpose
The increasing need to account for emissions from products leads to an increased introduction of emission standards in companies. This paper analyses the barriers and opportunities of implementing such standards in start-ups.

Design/methodology/approach
A qualitative approach allows three different perspectives on the topic. A literature review forms the basis, which is completed by eight expert interviews and a case study in form of a product emission analysis of a toothpaste.

Findings
The results show that especially the complexity of the methods and internal capacity problems hinder the implementation. Nevertheless, there is potential such as market differentiation and increased process transparency. Structural, financial, technical and information-related measures support the implementation of product emission standards.

Originality/value
The results provide start-ups with an overview of expected opportunities and obstacles in the introduction of product emission standards. Derived measures provide guidance on the right way to deal with these.

Link to management control research
Growing sustainability efforts require companies to have an overview of the emissions of their products. To exploit new business potential and secure a worthwhile long-term investment, standards need to be integrated.

Paper type
Research Paper

Inhaltliche Zielstellung
Die zunehmende Notwendigkeit Emissionen von Produkten abzubilden, führt zur verstärkten Einführung von Emissionsstandards in Unternehmen. In diesem Beitrag werden die Barrieren und Chancen der Implementierung solcher speziell in Start-ups analysiert.

Forschungsansatz/Methode
Ein qualitativer Ansatz erlaubt drei verschiedene Perspektiven auf das Thema. Eine Literaturrecherche bildet die Grundlage, die durch acht Experteninterviews und einer Fallstudie komplettiert werden. Bei letzterer handelt es sich um eine Produktemissionsanalyse einer Zahnpasta.

Befunde
Die Ergebnisse zeigen, dass besonders die Komplexität der Methoden und interne Kapazitätsprobleme die Implementation behindern. Dennoch gibt es Potenziale wie Marktdifferenzierung und erhöhte Prozesstransparenz. Strukturelle, finanzielle, technische und informationsbezogene Maßnahmen unterstützen die Umsetzung von Produktemissionsstandards.

Originalität/Theoretischer Beitrag
Die Ergebnisse bieten Start-ups einen Überblick zu erwartbaren Chancen und Hindernissen bei der Einführung von Produktemissionsstandards. Abgeleitete Maßnahmen bieten eine Orientierung zum richtigen Umgang mit diesen.

Bezug zum Thema Controlling oder Unternehmenssteuerung
Wachsende Nachhaltigkeitsbestrebungen erfordern, dass Unternehmen einen Überblick über die Emissionen ihrer Produkte haben. Um neues Geschäftspotenzial auszuschöpfen und eine langfristig lohnenswerte Investition zu sichern, müssen Standards integriert werden.

Klassifikation
Forschungsartikel

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List of Abbreviations

CCF	Corporate Carbon Footprint
CF	Carbon Footprint
CO2	Carbon-di-Oxid
EU	European Union
GHG	Greenhouse Gas
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
PCEA	Product Carbon Emission Accounting
PCER	Product Carbon Emission Reporting
PCES	Product Carbon Emission Standards
PCF	Product Carbon Footprint
RQ	Research Question
SC	Supply Chain

1. The potential of applying product carbon emission standards in start-ups

Due to climate change and growing sustainability expectations, companies are obliged to have an overview of their carbon emissions along the supply chain (SC) to gain competitive advantage (Aivazidou et al., 2014). The approach of carbon accounting is a fast evolving area of sustainability management and comprises a variety of methodologies. Since climate change is considered to be one of the six most dominant sustainability challenges besides biodiversity loss or water scarcity for example, transitions must be initiated (Schaltegger and Csutora, 2012).

Due to international treaties on cooperative climate protection such as the Paris Agreement of the United Nations, nations and businesses must track and eventually lower their emissions (United Nations Framework Convention on Climate Change, 2015). Entrepreneurs are urged to take measures against climate change and to transform SCs into low-carbon ones in order to reduce the Product Carbon Footprint (PCF) of a company (Cojoianu et al., 2020; He et al., 2019). Especially multinational companies start to implement reporting practices to track their emission performance along the value chain as a result of diverse internal and external pressures (Comyns, 2018).

For startups however, it is more demanding to standardize their accounting and reporting. A definition of start-ups is given by Röhl and Engels (2021) who describe those as "[…] young companies that were founded within the last ten years and that use an innovative technology or use a new business model, pursuing high growth." (p.382). Their climate performance and the development of their business performance often are not synchronized and reveal further obstacles (Leendertse et al., 2020). So far, large companies have been the focus of research on Product Carbon Emission Accounting (PCEA), which is due to a lack of standardized assessment processes and a lack of relevance of supranational regulations for small and medium-sized enterprises (Hendrichs and Busch, 2012).

The impact of the stressed mismatch increases when looking at the numbers of start-ups in Germany. A rise from 2.857 newly founded start-ups in 2020 to 3.348 newly founded start-ups in 2021 can be observed. In 2019, approximately 6.100 green start-ups existed in Germany. Compared to this, they made up 21% of the total of start-ups in Germany in 2020 (Bundesverband Deutsche Startups e.V., 2020). Green start-ups can be defined as start-ups that align product, strategy and entrepreneurship to have a positive effect on the environment, such as reduced GHG (Greenhouse Gas) emissions (Sadma, 2021). Since a rise in the number of start-ups worldwide, especially green start-ups, has been observed over the past years, the impact of this mismatch further increases (Demirel et al., 2019). Green start-ups in particular have a sustainable business model that is designed to bundle positive effects on the environment, society and the economy. Although this already lays the foundation for climate-protecting business activities, emissions of products and processes have so far been insufficiently quantified. This reflects the need of start-ups to build up knowledge about Product Carbon Emission Standards (PCES), which help to make Carbon-di-Oxid (CO2) values of products visible and measurable. Moreover, they need support regarding the application of Product Carbon Emission Reporting (PCER) technologies and methods (Bergmann and Utikal, 2020).

It can be concluded that founders are largely aware that economic goals must be combined with ecological goals. Nevertheless, they are only limited in their ability to perform a PCF assessment which presents an essential measurement of climate performance. As this lack of ability is likely to hinder the positive development of newly founded start-ups and their market position in tomorrow's competition, reasons for this must be identified (Shin and Searcy, 2018).

This leads to the following research questions (RQ):

RQ 1: Which are barriers and opportunities for start-ups when trying to assess the carbon footprint of their products?
RQ 2: What is necessary to drive start-ups to continuously report their products' carbon emissions?

This paper intends to showcase barriers and opportunities in implementing emissions standards. By providing an overview, actions and necessary business conditions can be derived to improve carbon emission reporting processes in start-ups. This is meant to drive start-ups establishing PCES in their regular accounting processes. Identifying expected barriers and potentials of PCF, supports the adaptation of existing processes and strategies to strengthen sustainability in line with standards.

The remainder of this paper is organized as follows. In section two, different established PCER standards are described and compared. Section three covers a comprehensive review regarding barriers and opportunities of PCFs stated in literature. A multi-method qualitative approach comprising eight expert interviews and a case study in a green start-up was selected and is elaborated in chapter four. Based on this information, findings are presented, compared and categorized in section five. Specific recommendations for action are deducted and specifically related to start-ups. In section six conclusions are drawn and limitations addressed. Further future research directions are discussed.

2. Product carbon emission standards – A managerial solution for emerging challenges

The assessment and reporting of carbon emissions is gaining relevance and is internationally considered as essential. Triggered by the advancing climate change and the need to adapt the economy to it, precautions must be taken legally. At both national and European level, there are now a large number of legal requirements that must be met by companies with regard to sustainability in the SC.

At European level, the **European Climate Act** engages all European Union (EU) member states to reduce emissions by at least 55% by 2030 compared to 1990 levels (European Commission, 2021). The **European Green Deal** supports this vision by promoting carbon pricing, emission trading and the reduction of energy consumption adapted to the different industries (European Commission, 2022a). A third regulation, the **Directive on corporate sustainability due diligence**, is intended to be finalized in 2023, taking companies with more than 250 employees into duty by prescribing the need to report environmental impacts and carbon emissions compliance transparently along the supply chain (European Commission, 2022b).

At national level, the German **Lieferkettensorgfaltspflichtengesetz** is of importance for companies since January 2023. It affects companies with more than 3,000 employees (in 2024 applying for 1,000 employees) and aims to ensure that human rights and environmental risks, including risks related to increased emissions, are identified and minimised along the supply chain (Bundesministerium für Arbeit und Soziales, 2022). Although this specific regulation does not explicitly address GHG-emissions, it becomes clear, that increasing regulations require companies to establish transparency using common standards. Start-ups are not yet explicitly touched by the mentioned regulations.

However, start-ups can voluntarily adhere to PCES in order to embrace economical, ecological and social sustainability. Therefore, Carbon Footprints (CF) are used to assess carbon emissions and are gradually integrated in modern management. The distinction of CF of an organization and CF of a service or product, which corresponds to the Corporate Carbon Footprint (CCF) and the PCF respectively, is important (Chavez et al., 2012; Cordero, 2013). Emissions of direct and indirect CO2 produced within the organizations' stated range (enterprises or projects) constitute CCF (Gao et al., 2014). According to Henriksson et al. (2015), PCFs can be defined as follows: “Product carbon footprints are life cycle assessments restricted to just one impact category, global warming.” (p.1).

A variety of different standards have been set on national and international levels during the last years. PAS 2050, the GHG Protocol and ISO (International Organization for Standardization) 14067 are three relevant standards with an individual guideline for product emission assessment and are widely applied on an international level (Cordero, 2013). The United Kingdom created **PAS 2050**, the first GHG standard carbon footprint accounting standards for goods and services, with the goal of creating standardized guidelines for GHG assessment on a product level in 2008. There are two approaches including different levels of assessment. A first approach is called business to business and involves every level of production, from the cradle to the point of sale. This corresponds to the cradle-to-gate principle. Raw material, manufacturing and distribution to business customer are some of these steps. Business to customer relationship, which spans the entire supply chain to the end of the product life, is the second approach. It is frequently referred to as the cradle-to-grave method (Liu et al., 2015).

ISO standards are designed to guarantee that goods and services have certain qualities like environmental friendliness or safety. A number of corresponding standards for calculating a CF have been created in response to the growth of carbon labels. The most recent standard is **ISO 14067** and has been initially published in 2013. Four principles are proposed by ISO 14067. Those are coherence, which assure comparability between various materials within the same category by choosing recognized assessment guidelines; and fairness, which states that quantified carbon emissions and reductions in GHG emissions should be considered differently. Furthermore, participation and avoidance of double quantification are promoted. To be in compliance with ISO 14067, a communication plan, product category regulation, and third party verification report are required if the outcome is intended to be made

publicly available in the form of a carbon label (International Organization for Standardization, 2019; Liu et al., 2015).

The standards' formats imply that PAS 2050 and ISO 14067's objectives were to standardize carbon footprint accounting systems, but the **GHG Protocol** aspires to offer comprehensive assessment and reporting guidelines. With a basic version first announced in 1998, the GHG Corporate Accounting and Reporting Standard introduces methods to calculate and disclose an inventory of GHG emissions and removals related to a particular product or company (Greenhouse Gas Protocol, 2016). This concept was created for businesses and organizations of all sizes and from all industries. The Product Life Cycle Accounting and Reporting Standard emphasizes the complete life cycle assessment of products whereas the basic Corporate Standard is on an organizational level representing a company's emission inventory. Businesses looking for a deeper knowledge of the items' GHG inventories *design, make, sell, buy, or use* can expect advantages of the application of this standard (Greenhouse Gas Protocol, 2011). The GHG Protocol embraces five principles: accuracy, completeness, consistency, and relevance. These aim at accurately reflecting the organization's GHG emissions (US EPA, 2020). PCFs are calculated by help of three scopes. Scopes 1 (direct emission under the control of the reporting company) and 2 (emissions from purchased energy) account for less than 25% of the total direct and upstream footprint, respectively. Scope 3's indirect emissions from acquired and sold goods contribute to a more comprehensive approach (Cordero, 2013). Figure 1 visualizes the significance of all three scopes and assigns these their origin in the SC.

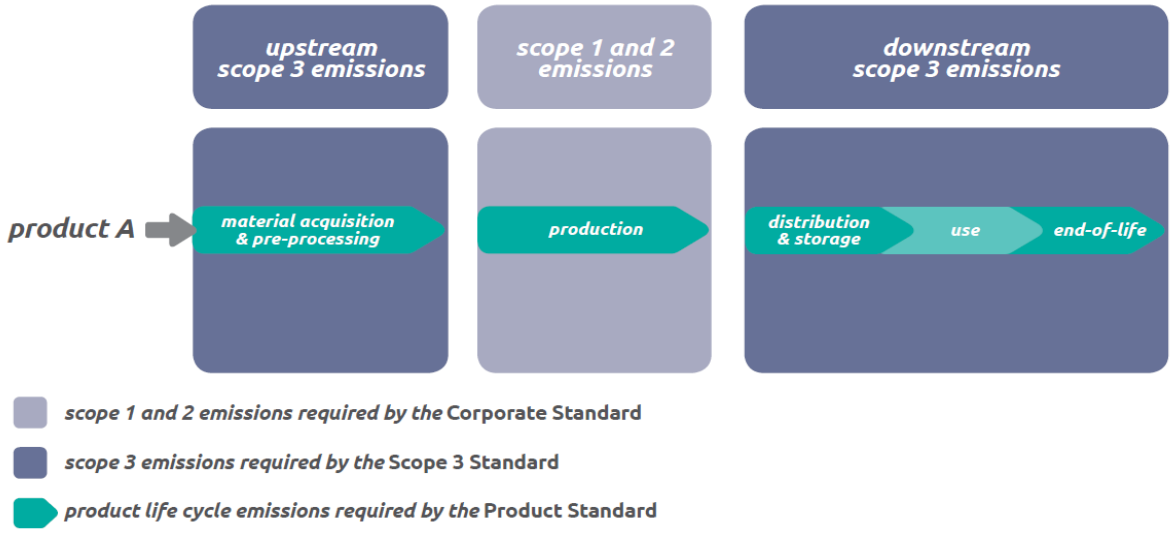

Figure 1: *Scopes 1, 2, 3 according to GHG Protocol Standard* *(Greenhouse Gas Protocol, 2016, p. 8)*

Life Cycle Assessment (LCA)-based methodologies are typically the foundation of PCF procedures (Cordero, 2013). The examination of the entire life cycle is a strength in comparison to other methodologies, which is valid for the PCF approach as it is for the overall LCA approach. LCA covers the entire life cycle of a product and analyses its environmental impacts, which do not relate to emissions alone. Thus, a LCA comprises further environmental elements such as water or air pollution. LCA is similar to PCFs in that it relies on numerical estimations of environmental consequences throughout the life cycle. However, there are some environmental challenges that cannot be adequately represented in numerical terms. It is difficult to envision a reliable flow of primary process data suited for LCA-applications in case of extreme SC changes (Quack et al., 2010).

3. Literature review

Literature on implementation barriers and opportunities is presented below by help of category systems. A total of 24 relevant sources were identified. The publication dates range from 2009 to 2021. The available literature was examined for general findings on PCES implementation. Keywords included PCF, PCES, PCER, PCEA, GHG Protocol, barriers, opportunities, start-ups.

3.1 Implementation barriers of CO2 emission standards

Regarding implementation barriers four main categories could be identified:

- Data barriers
- Barriers associated with carbon emission standards
- Barriers associated with knowledge
- Management related barriers

The predominant problem area or main category concerns the data situation which can be further divided into several sub-categories. He et al. (2018) point out incomplete product data **inhibiting accurate calculations**. This limits a reliable calculation of PCFs. Plassmann et al. (2010) and Shin and Searcy (2018) support these aspects by criticising that product detail **data is lacking**, production steps are difficult to track or fragmentary. Since companies are exposed to data gaps, uncertainties are amplified where primary data cannot be found. Moreover, emissions are hard to trace back to individual sub-processes along the SC and cause assumptions that risk being less detailed (Shin and Searcy, 2018).

The potentially **poor quality of data** depending on the industry and the spread of PCEA provokes bias related to time, geographical, or technological extent. Further aspects that influence the variance of data are rapid changes in the value chain, the effort of information collection, and the reputability of the data source (Quack et al., 2010).

Documented data sets are necessary to classify product information to create meaningful CO2 emission reports. However, data sources are rarely filed publicly leading to the barrier of **limited access to data sets** (Klenk et al., 2012). According to Shin and Searcy (2018), this particularly affects secondary data and highlights access to external sources as a pain point. Data resources are insufficient, unable to monitor progress or allow **comparisons** of products due to a lack of open access (Bolwig and Gibbon, 2009; Kawanishi and Fujikura, 2020). Insufficient data sets have negative impact on businesses. The successful conversion of the approximate product data specified into CO2-equivalents is hindered and reduces the validity of PCF comparisons (Plassmann et al., 2010; Shin and Searcy, 2018).

Validity is also affected by a lack of guidance. Companies find it difficult to identify trustworthy data, cannot distinguish relevant information from irrelevant information, and are unsure how to deal with missing data (Bergmann and Utikal, 2017). Since highly misrepresented CO2 accounting can have a considerable impact on economic and legal factors, the correct handling of data is to be seen as an important challenge (Comyns, 2018; Klenk et al., 2012; Plassmann et al., 2010; Quack et al., 2010). Table 1 shows the described sub-categories and the assigned codes which are used in classifying the interviewee responses in Chapter 5.

Main category	Sub-category	Code
Data barriers		**B1**
	Lack of calculation accuracy	B1-1
	Lack of data	B1-2
	Quality of data	B1-3
	Lack of database access	B1-4
	Comparability	B1-5

Table 1: ***Data barriers***

The standards are **highly complex** which leads to PCF being considered a "[...] black box of company internal carbon management accounting" (Gibassier and Schaltegger, 2015, p. 29). This concerns technical-methodical areas which are characterized by a large number of specific indicators per product category. Most methodologies are only based on the six gases CO2, methane, nitrous oxide, sulphur hexafluoride, per fluorinated compounds and hydro fluorocarbons. Hence, current standards are considered **incomplete** in reflecting the impact of products on the environment and only focus on the climate impact (Klenk et al., 2012; Shin and Searcy, 2018). Calculation steps of standards are too demanding for companies. Bergmann and Utikal (2021) confirm in their study that even after intensive support there is only limited knowledge and self-confidence among those affected. Additional problems occur due to the absence of one dominant standard which was already brought up in 2009 by Bolwig and Gibbon (2009). This finding therefore did not include the GHG Protocol and its product-related guidelines that are seen as a major standard today. Still, more recent papers also highlight this need and measures to fight **information overload** (Comyns, 2018; He et al., 2018). In addition, PCES do not specify requirements for data sources which results in varying applied principles (Shin and Searcy, 2018). Technologically insufficient monitoring, reporting and verification systems increase consistency, harmonization and **uniformity issues** (Tang et al., 2018).

From a legal perspective, governments do not succeed in fulfilling a guiding role in creating uniformity in the international carbon emission market. Since SCs are globally intertwined, stakeholders ask for a consistent and reliable standard to be developed although a certain range for country or product-specific adaptations have to be thought of (Plassmann et al., 2010). Uniformity issues are further intensified through emerging de facto standards which discriminate companies that make use of other methodologies and create artificial market entry barriers (Blundel and Hampton, 2021; Bolwig and Gibbon, 2009; Gibassier and Schaltegger, 2015; Kawanishi and Fujikura, 2020). The absence of mandatory legislation and PCEA regulations is a noteworthy barrier, already overdue to generate consistent climate policies (Comyns, 2018). Table 2 provides an overview on the barriers associated with carbon emission standards.

Main category	Sub-category	Code
Barriers associated with carbon emission standards		**B2**
	Methodological complexity	B2-1
	Incompleteness	B2-2
	Information overload	B2-3
	Lack of uniformity	B2-4

Table 2: ***Barriers associated with carbon emission standards***

Further, barriers associated with required knowledge could be identified.Companies are **lacking awareness** about present environmental laws and. They are not familiar with the current requirements for sustainability reporting at the voluntary or statutory level (Bergmann and Utikal, 2021; Shin and Searcy, 2018). Businesses have not taken the topic of carbon emission reporting seriously (Schaltegger and Csutora, 2012, Shin and Searcy, 2018). With regard to small companies, Bergmann and Utikal (2021)

conclude: “Around 12.7% of the start-ups reported that they had not yet thought about the interconnection between their activities and the UN SDGs” (p. 14). This reflects a **lack of expertise** to understand connections between commercial and sustainable development opportunities. The business focus is on financial short-term benefits as the effects of carbon accounting on sales are not quantifiable and have not been sufficiently proven to date. PCF calculations often collide with strategic, financial, and marketing decisions (Blundel and Hampton, 2021; Bolwig and Gibbon, 2009). Schaltegger and Csutora (2012) add that managers fear neglecting business realities if they adhere to sustainable standards. Future advantages of carbon accounting are underestimated in terms of its importance and long-term benefits (Shin and Searcy, 2018). A weak understanding of internal business processes, especially concerning procurement and production systems, can aggravate conflicting interests and hold back optimization potential (Plassmann et al., 2010). The lack of concrete guidance on PCEA means confusion and uncertainty for managers. Both the amount of databases and the variety of scopes that need to be related to specific products discourage companies from calculating PCFs (Mugnier et al., 2010; Schaltegger and Csutora, 2012). Furthermore, a **lack of credibility** is associated with current emission standards. Verification systems and third-party authentication are missing (Bolwig and Gibbon, 2009). The presentation of calculated CO2 values is misleading for customers who develop scepticism about climate-related claims. Hesitation is transmitted to companies, which thereby lose self-confidence in pursuing sustainable business decisions (Blundel and Hampton, 2021; Bolwig and Gibbon, 2009). The barriers associated with required knowledge are presented in Table 3.

Main category	Sub-category	Code
Barriers associated with knowledge		**B3**
	Lack of awareness	B3-1
	Lack of expertise	B3-2
	Lack of credibility	B3-3

Table 3: *Barriers associated with knowledge*

Further barriers are related to the management of the organizations. **Communication** of PCF is considered difficult by entrepreneurs. Communicated content could be perceived as greenwashing. Common communication guidelines are requested to overcome the lack of stakeholder acceptance (Bergmann and Utikal, 2021; Bolwig and Gibbon, 2009; Quack et al., 2010). Shin and Searcy, 2018 have found out that knowledge sharing in the craft brewing industry is not yet sufficiently developed and needs to be improved. This finding can be generalized to the effect that communication strategies must be adapted depending on the stakeholder (Gibassier and Schaltegger, 2015). Accordingly, **additional time and effort** is necessary.

However, data collection already needs human resources to capture the entirety of the product lifecycle. As technological interconnectivity is not yet fully established, data must be gathered manually or during site visits. This implies a huge administrational burden since emission reports need to be updated regularly to preserve certificates. As staff is particularly limited in start-ups, primary business activities must be given priority and cannot be dedicated to PCER (Hendrichs and Busch, 2012; Plassmann et al., 2010; Shin and Searcy, 2018). Due to the **financial burden** that comes with the establishment of PCES, other business departments compete with the budget that needs to be reallocated when deciding to invest in carbon emission systems. Since investments are necessary, a positive and reliable cash flow is seen as a precondition to incorporate a viable PCER (Shin and Searcy, 2018). Small enterprises without economies of scale suffer from increased costs of certifications per product sold (Bolwig and Gibbon, 2009).

The specifics of **internal management structures** in companies are challenging as environmental strategies are not in place (Hendrichs and Busch, 2012). Inflexible decision-making and lack of integration of carbon emission management into existing hierarchical structures block the implementation of PCES

(Kawanishi and Fujikura, 2020). There are often no internal reporting rules or standardized processes for carbon emission assessments which results in unsatisfactory reporting quality. Links between product and organizational input must be created on a big scale and secured by Enterprise-Resource-Planning systems (Comyns, 2018; Gibassier and Schaltegger, 2015).

A start-up specific challenge is the **lack of support** from business institutions and governments able to enhance visibility in the market. The little business influence due to the small size of the company further causes a rare ability to demonstrate their ecological, economic and social goals contributing to climate change mitigation (Bergmann and Utikal, 2021; Kawanishi and Fujikura, 2020). Table 4 presents the list of the management related barriers.

Main category	Sub-category	Code
Management related barriers		**B4**
	Communication	B4-1
	Time and capacity effort	B4-2
	Financial burden	B4-3
	Internal management structure	B4-4
	Lack of support	B4-5

Table 4: ***Management related barriers***

3.2 Implementation opportunities of CO2 emission standards

Besides implementation barriers, numerous opportunities associated with the implementation of emission standards are identified in the literature. Three main categories could be identified:

- Opportunities regarding optimization
- Opportunities associated with market position
- Opportunities regarding social cohesion

A major advantage is the **improvement of products and production** methods. Carbon intensive stages in the SC can be identified since PCEA means an intensive examination of data and existing processes. Quality management can be enhanced (Bolwig and Gibbon, 2009; He et al., 2018; Hendrichs and Busch, 2012). Emissions are quantified and contribute to better control of activities along the SC (Schaltegger and Csutora, 2012; Usva et al., 2009). Compliance with standards strengthens **transparency** and helps companies to keep pace with technological progress (Blundel and Hampton, 2021; Kawanishi and Fujikura, 2020; Shin and Searcy, 2018).

From a financial point of view, the LCA tracking of a product is an opportunity for cost saving especially concerning energy input (Shin and Searcy, 2018; Tanaka et al., 2021). Emission assessments allow a **self-control of performance** and improved budget planning as additional costs caused by direct and indirect emissions are included in financial forecasts. This favours efficiency and an optimal resource allocation (Hendrichs and Busch, 2012). The opportunities regarding optimization are shown in Table 5.

Main category	Sub-category	Code
Opportunities regarding optimization		**A1**
	Supply chain and product improvements	A1-1
	Supply chain transparency	A1-2
	Measurement and self-control	A1-3

Table 5: ***Opportunities regarding optimization***

The mentioned opportunities are complemented by pointing out potentials according to market position. Compliance with PCES is considered as a **market access requirement**. Decarbonisation has become a national priority which is underlined by evolving institutional pressure on markets, regulations and society. Customers and retailers are increasingly interested in PCF (Blundel and Hampton, 2021; Bolwig and Gibbon, 2009; Quack et al. 2010; Schaltegger and Csutora, 2012). Government incentives provide an opportunity for CO2 accounting companies to boost sales (Blundel and Hampton, 2021). Moreover, customers are willing to pay more for products with a carbon label. This is beneficial for profit maximization and **differentiation**. Products can differentiate themselves from conventional competing products, but also compete with other low-carbon emitting products (Tanaka et al., 2021; Usva et al., 2009). A fast implementation of PCEA is necessary to be prepared "[…] for 'naming and shaming' strategies to be deployed against those countries that fall short of international expectations." (Kawanishi and Fujikura, 2020, p. 3). According to Hendrichs and Busch (2012), non-complex organizational structures simplify a fast implementation and are complemented by a powerful entrepreneurial attitude in small companies.

Customer relationships are strengthened when PCFs are integrated in brand communication which permits the promotion of sustainable values to enforce the firm's reputation. By showing a verified PCF, sustainability marketing is upgraded. The implementation of PCES allows **communication of sustainability efforts** (Bolwig and Gibbon, 2009; Schaltegger and Csutora, 2012; Shin and Searcy, 2018). Furthermore, possible **synergy effects** are highlighted in literature. Committed actors along the SC, can drive joint learning and shared implementation knowledge (Blundel and Hampton, 2021; Kawanishi and Fujikura, 2020; Usva et al., 2009).

Since especially risks along the SC are a growing management issue, a continuous evaluation of PCF provide a way to decrease dependencies on carbon input. As products are subject to a detailed carbon analysis, potential risks and business impacts can be revealed. The resulting awareness about interdependencies of products and their environment facilitate the creation of product related risk profiles. These can be evaluated to predict uncertainties and **mitigate risks** (Hendrichs and Busch, 2012; Kawanishi and Fujikura, 2020), which is another sub-category of the opportunities associated with the market position as shown in Table 6.

Main category	Sub-category	Code
Opportunities associated with market position		**A2**
	Market requirement conformity	A2-1
	Differentiation	A2-2
	Customer relationship reinforcement	A2-3
	Communication of sustainability	A2-4
	Synergy effects	A2-5
	Risk assessment and mitigation	A2-6

Table 6: ***Opportunities associated with market position***

From a social perspective, a company's **engagement towards climate change mitigation** is a key aspect stimulating the transition towards sustainable and circular approaches. The preservation of the environment is dominating future market survival so that the deceleration of climate change becomes a company's responsibility. As the Paris Agreement applies on an international scale, positive peer pressure results to join forces towards the common goal of getting the global temperature to 1.5 degrees Celsius creating social cohesion (He et al., 2018; Hendrichs and Busch, 2012; Kawanishi and Fujikura, 2020; Shin and Searcy, 2018). **Stakeholder education** is further promoted and can attract new investors (Hendrichs and Busch, 2012; Tanaka et al., 2021). This drives a company's stakeholder network to question current purchase decisions and make more informed choices. Awareness about product backgrounds and climate effects is generated (Plassmann et al., 2010; Usva et al., 2009). The preceding factors are reflected in Table 7.

Main category	Sub-category	Code
Opportunities regarding social cohesion		**A3**
	Contribution to climate change mitigation	A3-1
	Stakeholder education	A3-2

Table 7: ***Opportunities regarding social cohesion***

To conclude, the performed literature review exposes that although the topic is not entirely new, there is still a need for further research. Barriers and opportunities are mostly raised regarding special products or the CO2 record of countries. As Hendrichs and Busch (2012) note, mainly large companies have been investigated with regard to barriers, but problems of start-ups have been overlooked.

4. Research methodology: Qualitative approach with interviews and case study

A qualitative approach as illustrated in Figure 2 was used to examine the topic in relation to the RQ formulated. The exploration of the status quo was previously ensured through literature research. Qualitative research is used to further examine barriers and opportunities of introducing PCES in start-ups. This method was deliberately chosen because standards such as the GHG Protocol are not yet sufficiently established in small enterprises to have a large number of practical studies or to make quantitative surveys meaningful. To approach the RQ, interviews with experts from start-ups as well as other involved third parties and a case study on PCF calculation have been selected.

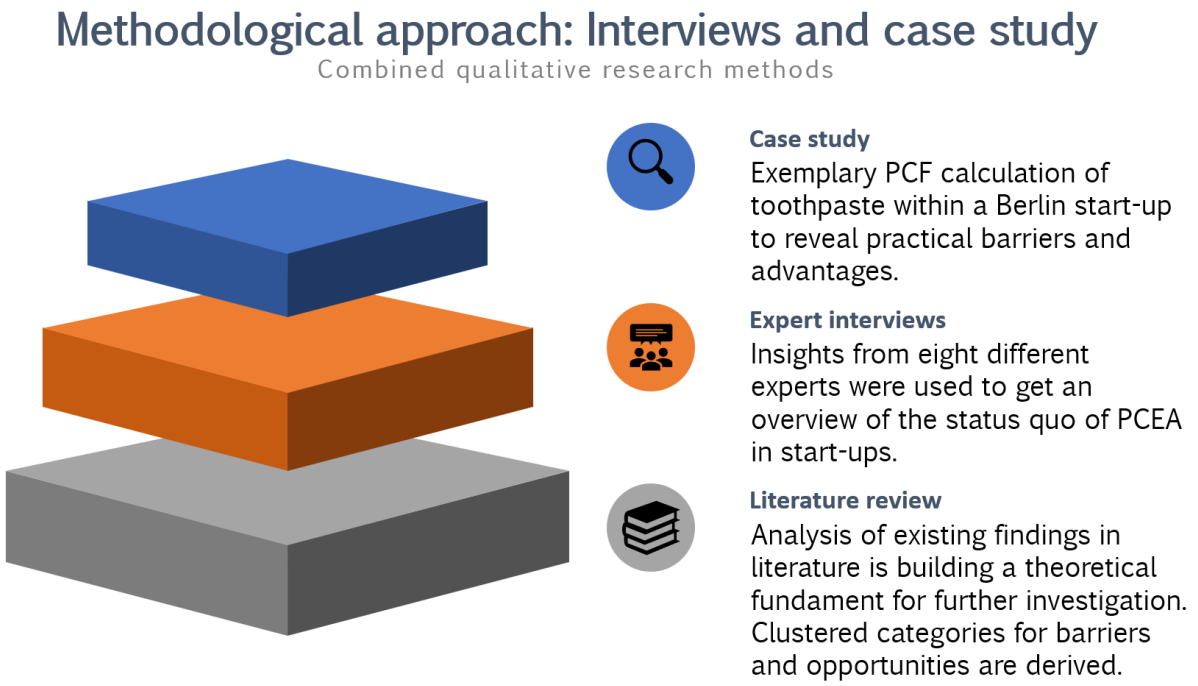

Figure 2: ***Qualitative research approach***

Interviews

Expert interviews are a useful tool to get personal insights to a topic. The selected semi-structured interview type allows room for explanation, but is specific enough to meet the objective of the category test (Claussen et al., 2020). An interview guide consisting of 11 questions to answer the RQ was designed (see Appendix). Based on the category systems set up from the literature review, the guide included questions on the perceived relevance of PCF, barriers and opportunities as well as necessary measures to facilitate the adoption of PCES. The individual sub-categories identified were not explicitly queried in order to gain an insight into which barriers and opportunities are rated as relevant by the interviewees and to obtain potential additional categories. The interviews were transcribed manually without the use of special software. Transcripts were prepared without comments, following the associated rules (Hugl, 2013).

The Berlin start-up *truemorrow,* founded in October 2020 and selling sustainable body care products, is part of the *Circular Futures Initiative*, early promoting circular business models. Through a joint Slack group, potential participants reflecting the defined interview profiles of founders of start-ups, sustainability experts or department heads could be solicited. A total of 16 inquiries were sent out, to which there were eight positive and three negative responses. Five of the inquired persons did not answer. Three of the eight interviews were conducted by telephone, four as online meetings, and one in writing. Different industries were covered such as fashion, body care, material development or food as Figure 3 below illustrates. Manufacturer, retailer and service providers were interviewed.

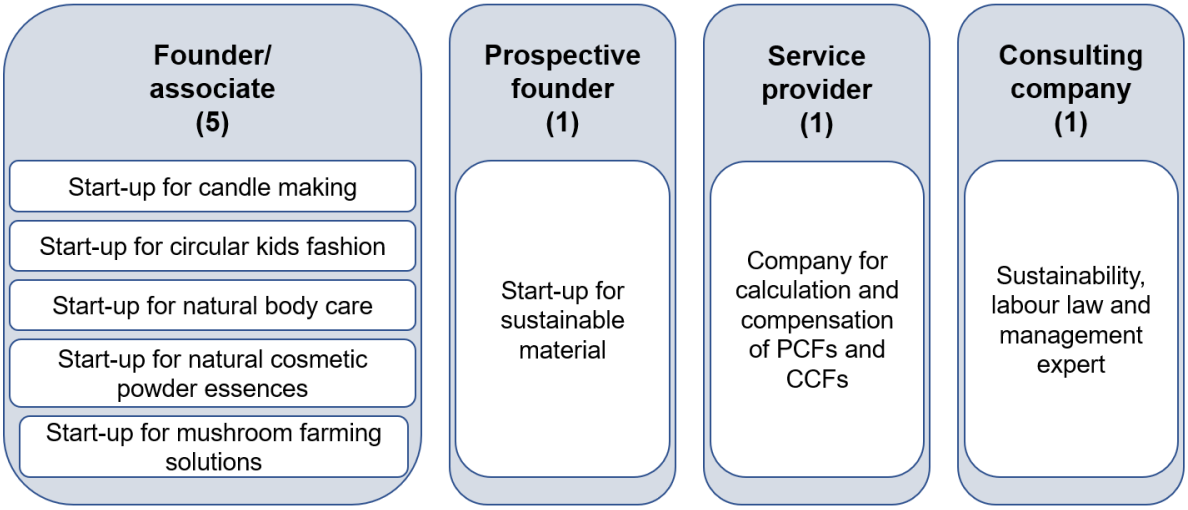

Figure 3: ***Overview of interviewees with sectors***

The procedure for examining the content of the interviews follows Mayring's method (Mayring, 2010). After determining the material and its characteristics, source context, areas of analysis and questioning techniques, Mayring's descriptive design of an analysis was applied (Mayring, 2010). For a qualitative content analysis, specific subject areas are formed deductively in terms of coding, contextualization and evaluation on the theoretical basis of the RQ. The transcribed interviews were reviewed, adapted and categorized systematically. Subsequently, the results obtained from confirming or refuting the categories are used to address the RQ.

Ensuring the quality criteria of qualitative research enables an objective, transparent, and multi-feasible research environment. Transparency is given by clearly pointing out the origin, process and reasons of the interviews and their transcription. Reliability can be ensured, since the designed interview with its questions has been conducted several times and with varying experts. The same coding guide was applied to all interviews. Transferability to other research material can ensure coverage and intersubjectivity so that external persons can come to similar results when they are carried out again (Mayring, 2010).

Case study truemorrow

In addition to the interviews, a single-case case study (Yin, 2018) has been carried out. The process of PCF calculation in the aforementioned company *truemorrow* has been selected as the object to be studied. To enlarge the *Dental* portfolio, a new natural toothpaste in a circularity proven tube was chosen. The ingredients of the toothpaste are exclusively of natural origin and the effectiveness can be ensured through the conception with experts. In the case of the tube, both the lid and the tube are made of mono-material, which simplifies disposal and recycling. Figure 4 illustrates the SC of this new product which is supervised by *truemorrow* starting with the selected producer and ending with the delivery of the ordered item to the customer.

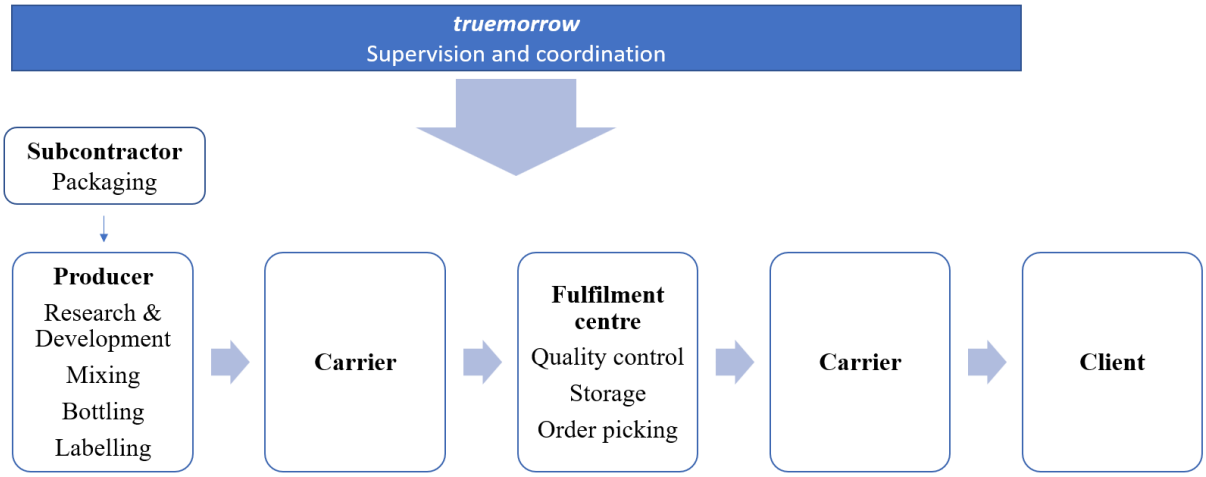

Figure 4: ***Process of value-adding using the sample product***

The start-up has chosen to use the service of a German company that takes over its client's CF calculation. The used online tool comprises several steps that reflect the most important steps of a product life cycle. These steps respect the GHG Protocol and are extended by additional factors. Figure 5 shows the composition of the PCF calculation according to the service provider chosen. The client is responsible for data collection. This data collection process was carried out in order to calculate the PCF for toothpaste as a new portfolio product. Attention was paid to the hurdles and potentials.

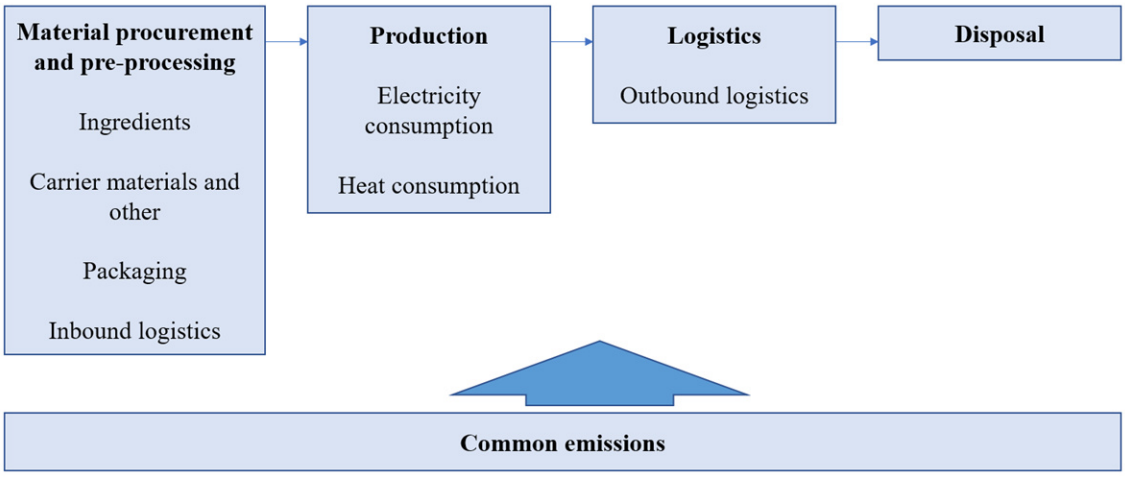

Figure 5: ***PCF steps of the system under study***

5. Results and discussion

5.1 Barriers of product carbon emission accounting

Approach 1 – Interviews

The framed doughnut chart in Figure 6 is representing the overall frequency of the category system's main categories. Since the categories were not explicitly asked for in the interviews, the arguments provided were assigned to the appropriate codes of the category systems for the evaluation. Four pie charts on the right give detailed information about the distribution.

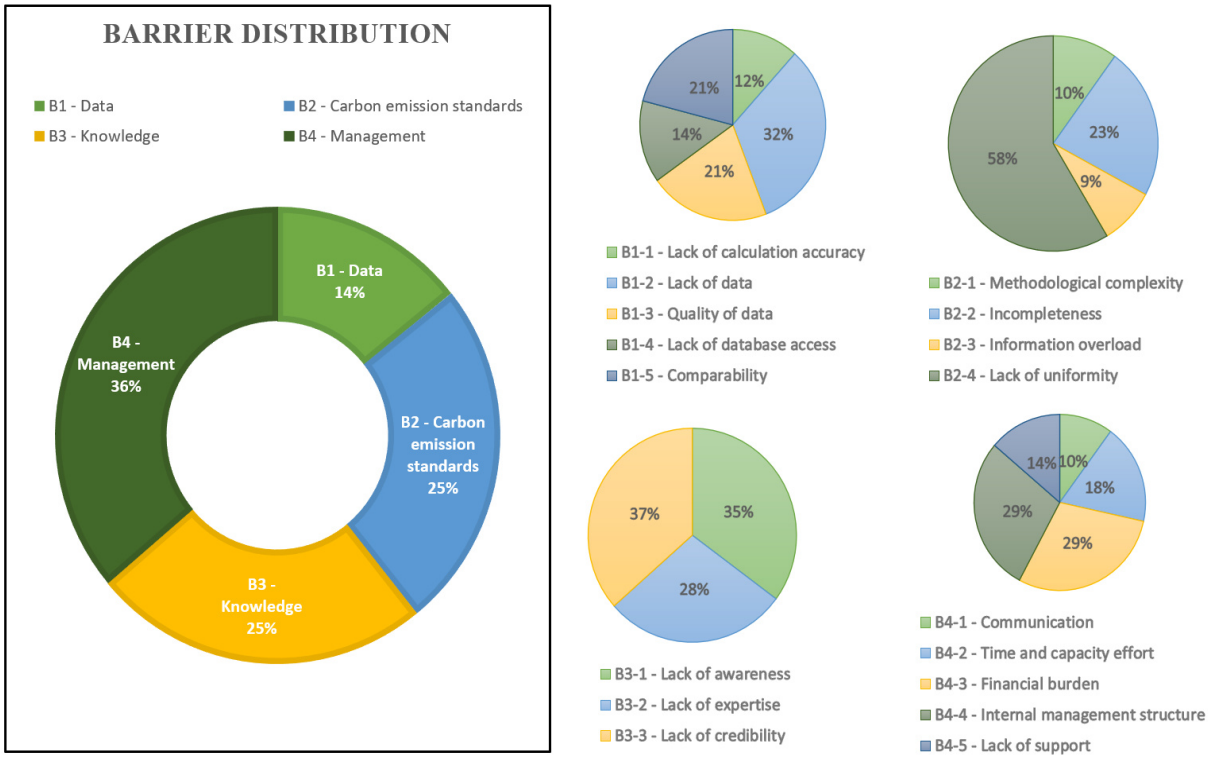

Figure 6: ***Barrier distribution based on interviews***

Most answers are **related to management**. With 29%, internal management structures in companies and additional financial costs are dominant for restraining CO2 assessments. According to interviewee 1, the business model must first be consolidated internally and production must be reliably scalable. Moreover, the small number of employees in start-ups and unevaluated skills of individual staff members hinder implementation efficiency. Interviewee 2 emphasises that they grow slowly which is in line with the statement of interviewee 3 that they are not able to perform CO2 assessments in their current scale. The interviewed consulting company describes that sustainability management systems are not yet existing and their implementation is underestimated.

A key argument that can be retrieved in all interviews is the low priority of PCES implementation compared to daily business decisions. Sales and marketing are of higher importance. Survival in the market must first be ensured. All interviewees agree that establishing PCES means large investments in processes, equipment, accreditation and human resources. Financial resources are scarce in small enterprises and cannot be used for emission detection to ensure long-term business growth. Sustainable products are more expensive to buy compared to conventional products. Fixed costs of PCFs are especially expensive for low producing companies. Other expenses are assigned to compensations. Since it is still uncertain to what extent these investments will actually pay off, founders have so far remained cautious about investing. Two interviewees mentioned that start-ups would support universities for initial PCFs free of charge, as this would not require an internal employee. Incentives and support from politics

are perceived as lacking or too bureaucratic. Communicating PCFs also means uncertainty for companies. On the one hand, no big public relations campaigns can be afforded, on the other hand, one has to be very sensitive about what is communicated to customers to maintain authentic. The exchange with suppliers is characterised by mistrust and the need to keep company data secret.

Regarding Figure 6, 50% of barriers are evenly distributed to **carbon emission standards (B2)** and **knowledge issues (B3)**. Missing awareness, expertise and credibility make up about a third of the category dealing with knowledge barriers each. About half of the respondents have a general understanding of carbon emission management, but no knowledge deep enough to implement standards immediately. Only one of the start-ups surveyed has already calculated PCFs, which shows that there is no experience of PCER in companies. Absence of awareness applies equally to all SC stakeholders. With regard to customers, interviewee 2 emphasises that increased costs of low-carbon products are not understood. Stakeholders are also not completely convinced about PCES. Interviewees 2 and 5 note that PCFs are used to cover up less sustainable areas and can be considered as modern lobbyism. The credibility of existing PCES is deemed non-transparent. The purchasing of labels without any real claim, disproportionate calculation methods and lack of external certification methods create injustice. Small businesses are discouraged from obtaining them, fearing an image bias.

When looking at the dispersion of barriers associated with carbon emission standards, a lack of uniformity makes up the biggest share with 58%. All interview partners agree that a concrete standard must be developed for all companies, valid across countries, industries and products. Legislation is ambiguous and sometimes refers to the EU or is completely voluntary. The lack of binding force discourages companies from performing CO2 calculations.

Furthermore, current standards are considered incomplete. With more standards expected to come in the future, companies are waiting to adopt the most current standards. The most commonly cited challenge is that PCES only looks at CO2. Environmental pollution, the water footprint, toxicity or air pollution are called for as additional important indicators.

Methodological complexity and information overload are interdependent and together form approximately 20% of the total. There is agreement that PCFs can only effectively be calculated with external help. Due to a multitude of information and different tools, entrepreneurs do not find their way into the topic.

Data-related barriers account for the smallest overall share, but are nevertheless not insignificant at 14%. Lack of data represents the dominating obstacle with 32%. Information gathering is seen as a strong challenge. Production data and material origins are unknown in terms of numbers and cannot be accessed due to unclear SC. External consulting is also not possible due to the lack of data, which prevents the CO2 balancing of products right from the start. This problem is especially severe if the company trades but does not produce, according to interviewee 3.

This has an influence on quality of data and comparability which each account for a percentage of 21%. So far, only low-quality data is available. Often, only approximate assumptions can be made due to the lack of reliable data. Data has so far only been reviewed over a short period of time, so that a solid data basis is lacking.

Lack of database access and lack of calculation accuracy contribute 14% and 12%, respectively. The surveyed companies indicate that they do not have access to primary and secondary data. Access to corresponding databases does not exist. Without this, emission data gaps result as retailers mostly depend on decentral data. Moreover, this deficit is consistent with often conservative calculations that amplify inaccuracies. If companies have already accounted for products in advance, an interim audit must ensure that prior calculations have been conducted correctly.

Approach 2 – Case study

The PCF of one tube of toothpaste has been calculated based on the data collection process given in figure 4. This has been done with a self-developed tool of the paid service provider. One toothpaste produced for *truemorrow* equals 0,45 kg CO2. There has no benchmarking toothpaste been found, neither conventional nor natural. Nevertheless, one can assume that this PCF is lower than average given the short transportation distances because of local production, the limited quantity of ingredients, a tube made of mono-material and the toothpaste's natural origin. Table 8 presents the data collected for each PCF category. The stage of product corresponds with the structure of Table 8. During the process of data gathering, **tool-specific, data-specific and management-specific issues** have been identified.

STAGE OF PRODUCT	DESCRIPTION	DATA INPUT
Material procurement and pre-processing		
Ingredients		
	Sorbitol, Aqua, Hydrated Silica, Glycerine and ten other	- 0,28 kg CO2/reference quantity 1 - external calculation by partner because of confidentiality
Carrier materials and other		
	None	Not applicable
Packaging		
	Tube and lid	- High-density polyethylene (injection molding) - 0,011 kg/reference quantity 1
	Outer packaging carton	- Carton S1, small - 0,047 kg/reference quantity 1
	Wooden multi-way pallet	- 1 piece/reference quantity 4.100
	Wrapping foil for pallet	- PE foil, 0,7 kg/reference quantity 4.100
Inbound logistics		
	Raw materials to production site	- Truck 16-32 tons - 0,0519 ton km/reference quantity 1 - estimated total distance divided by load quantity
	Packaging to production site	- Truck 16-32 tons - 0,0411 ton km/reference quantity 1 - estimated total distance divided by load quantity
	Finished goods to warehouse	- Truck 16-32 tons - 0,045 km/reference quantity 1 - estimated total distance divided by load quantity
Production		
Electricity consumption		
	Country-specific electricity mix	- 0,0293 kilowatt hours/reference quantity 1 - average electricity mix
Heat consumption		
	Heat energy sources	- Natural gas - 0,0293 kilowatt hours/reference quantity 1
Logistics		
Outbound logistics		
	Product deliveries Germany wide DHL GoGreen	- Truck 16-32 tons - 0,1636 kg/reference quantity 1 - 491 km distance (average distance) - climate neutral, compensated
Disposal		
	Tube and Lid	- Plastic and rubber waste - 0,0112 kg/reference quantity 1 - average type of disposal with 25 km to site
	Carton	- Paper and cardboard waste - 0,047 kg/reference quantity 1 - Average type of disposal with 25 km to site

Table 8: ***Data collection for product under study***

Tool-specific issues are related to barriers of the online programme. Each PCF-calculation needs to be unlocked by the service provider and a flexible data entry is limited. Specific innovative material for example recycled plastic mono-material was not selectable. Circular approaches and long-term CF minimization cannot be reflected. The level of detail of the disclosures is taken differently seriously by companies and thus leads to a disparity. As there is no checklist, parts of packaging for example can be forgotten or lead to over-input. This favours injustice in compensation costs.

The freely selectable reference quantity can cause additional confusion. It may feel misleading in the display if emissions are not calculated down. In the example, the inputs were mostly related to the reference quantity 1. In some cases, however, as with the pallet and the packaging film, a reference quantity of 4100 was given. Recapitulatory, **uniformity, error resilience and product individualization** are core topics.

The dominating **data-specific** problem is the collection of primary data. As *truemorrow* purchases most products and has them packaged externally, the involvement of multiple suppliers in the data collection process is high. Data exchange was difficult as contact persons lacked in capacities, understanding or interest. Especially the transportation was based on plethora of assumptions. Since truck selection and route changes according to traffic and order situation, the carrier was unable to communicate the exact mileage prior to the transport. Nevertheless, asking for the exact data would not have justified the effort if any accurate statements could have been made at all. In one case, the supplier was not ready to deliver his data. Negotiations with the service provider were necessary for an anonymous data transfer. This favours the error-proneness of calculations, as *truemorrow's* ownership over its own PCF is reduced.

Moreover, secondary data was the only data available for one partner being less significant than primary data. This effect is amplified for products with higher complexity and multiple value-added steps. Within *truemorrow* product data was difficult to find because of incomplete data storage. This leads to a strong search effort and takes time. It can be concluded that there is a strong barrier in the context of **data availability, internal data access and data traceability**.

Finding a targeted negotiation psychology strategy towards suppliers and raising awareness about the company-wide responsibility of data collection are **management-specific** challenges. The managerial advantage of *truemorrow* is that all parties contributing to the examined product are located in Germany. Information can be exchanged more easily due to a common legislation and similar business practices. The Chinese origin of their manual toothbrushes as another product of their portfolio, makes mutual understanding more difficult because of language barriers, cultural differences and shifted accessibility due to differing time zones.

From a management-perspective, there is a business risk. On the one hand, faulty PCEA used publicly in marketing can trigger a loss of image and sales if exposed. On the other hand, the calculation and verification of PCFs also requires an increased time-to-market. *Truemorrow* has often launched products at short-term due to financial conditions and varying market conditions. Verification of PCF is an additional step in the timeline and must be completed to be able to finalize packaging label printing. In summary, information gathering, **flexible partners, reactivity, forward planning and coordination** were lacking.

To combine the findings of both approaches, it can be concluded that especially data and internal management are bottlenecks. Primary and secondary data is lacking or of insufficient quality. Weak data tracking leads to a high degree of assumptions and provokes errors. PCEA is a financial burden and of no priority. Coordination and reactivity in internal management is missing. Incomplete product-related guidelines hinder the acceptance of emission standards.

5.2 Opportunities of product carbon emission accounting

Approach 1 – Interviews

Figure 7 illustrates the distribution of opportunities brought up during the interviews. The doughnut chart on the left indicates that market position makes up exactly the half. The remaining two categories optimization and social cohesion both account for a quarter each. When going into detail, major differences in the sub-distribution appear.

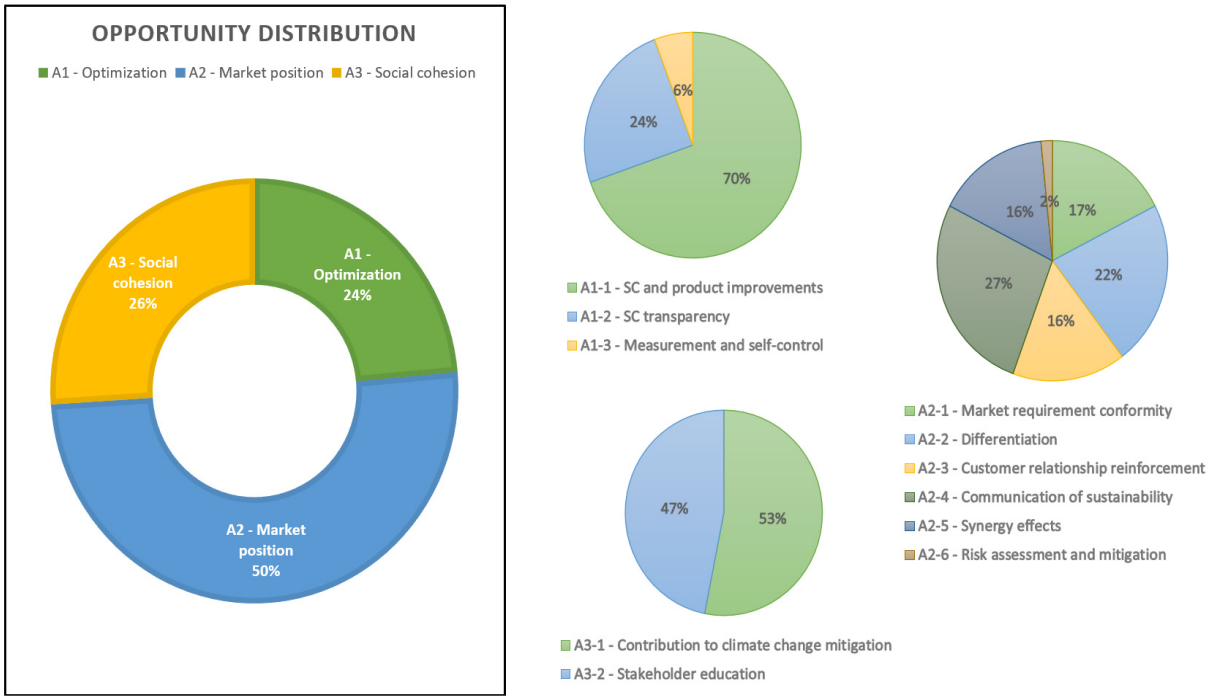

Figure 7: Opportunity distribution based on interviews

Market position is the number one opportunity seen by the interviewees. As PCEA is voluntary for start-ups, sustainability can be credibly communicated to the public. It further provides access to internationally recognized sustainability certificates, such as B Corp mentioned by Interviewee 8. Taking a pioneering role and extra responsibility presents a way to gain a market advantage over large companies. From a marketing perspective, PCFs are a means of conveying corresponding values. Attention is attracted and visibility of environmentally friendly measures is enhanced. Trust in companies increases through compliance with PCES, which in turn can create a loyal customer base.

The commitment to science-based emissions targets may create the overriding possibility that more companies will also feel pressured to consider carbon emission management. Openness for cooperation and regular data exchanges leading to a synchronization of product data along the SC were mentioned.

Risk assessment and mitigation were only mentioned once by interviewee 8. Tracking the product lifecycle provides a picture of the interfaces along the SC. Value chains can be made less susceptible to disruptions if bottlenecks of individual products are known and a reorientation towards less carbon intensive production is initiated.

Both sub-categories of social engagement are almost evenly split with 53% for contribution to climate change mitigation and 47% for stakeholder education. During the interviews, the founders' intrinsic motivation to stop global warming is emphasized. Start-ups want to shape the transition to a market economy that functions in the long term driven by their perceived duty towards society. Employees can be educated through CO2 workshops, gain awareness of the issue and see a sense of purpose in their work.

The last category optimization shows a clear majority of arguments for SC and product improvements with 70%. Specifically, the improvement of delivery routes, transport and packaging were mentioned as examples. Long-term cost savings, proactive product improvements and the expansion of local SC were named as motives. Products that previously had poor carbon footprints can be converted and products with already reduced emissions can be further improved. The goal of CO2 neutrality was expressed by one respondent.

Measurement and self-control have been raised by four different interviewees. Companies can monitor themselves and the amount of product emissions and adjust them if. Product emissions can be assigned to their place of origin which enhances SC transparency. In addition, PCF calculations provide a deep insight into company processes and improves operational understanding of suppliers and manufacturers.

Approach 2 – Case study

In the studied case, the packaging was indicated to have the highest account concerning the final PCF. This is a valuable information for future product optimization. Moreover, the necessity to deal with different suppliers improves the trading relationship and creates the prerequisite for a trusting relationship. This can bring strategic and operational benefits in the medium term. Although *truemorrow* was already in contact with the toothpaste manufacturer for the product development, the demand for the necessary data for the PCF calculation took the relationship to a new level. Partner companies remained interested in the company's efforts for more climate protection and in some cases also considered the possibility of testing the introduction of CO2 assessments. As the chosen service provider includes compensations for carbon emission excess, charitable projects are also promoted.

To summarize, it can be stated that PCEA is mainly a useful way for market differentiation and the external communication of measures against climate change. This correlates with the intention to offer customers solutions or options for less emission-intense products. There is social added value through the promotion of regional SCs or social projects.

5.3 Discussion of the result of primary research

This paper is designed to address the following research questions:

RQ 1: Which are barriers and opportunities for start-ups when trying to assess the carbon footprint of their products?
RQ 2: What is necessary to drive start-ups to continuously report their products' carbon emissions?

By help of a multi-method qualitative approach, several perspectives could be taken to find answers. Literature and empirics fundamentally agree on barriers and opportunities. The deductively developed category systems could be applied to the interview results without exception. Thus, all elements raised in the literature have an impact on the implementation of PCES. Additional categories were not identified during the interviews which indicates that the theory is quite well developed. In the papers examined, more barriers than opportunities were identified. However, the impact of opportunities must not be underestimated although their future significance is not yet fully tangible due to a lack of experience. A successful differentiation from the competition can compensate for a lack of support by having more impact in the long run. The evaluation of the interviews did not reflect the imbalance between opportunities and barriers. On the contrary, the interviewees were positively minded towards PCEA.

Concerning opportunities, no big discrepancies have been discovered between the existing literature and the primary research. Product and SC improvements are major advantages. These are especially related to a future-proof product design and should not compromise a product's quality for cost cutting reasons. Cost-saving and risk management are two aspects that were sparsely mentioned during the

interviews although literature underlined them. The focus is more on easy handling of products, transparency and traceability of SCs. Social cohesion, such as stakeholder education and climate change mitigation, have received only marginal attention in the literature. However, it is a decisive driver for small companies in reality. Furthermore, empirical research shows that opportunities are not only perceived in terms of business. They are less connected to SC and product management but to social soft factors including driving forward the transition and stakeholder education. Customer relationship reinforcement, differentiation or SC improvements require lead time and cannot be achieved overnight. Short-term disadvantages must therefore be carefully weighed against expected long-term benefits. So far, this has not been sufficiently reflected in the literature and only becomes apparent with the help of further resources. Through initial courage to implement standards, financial and strategic foresight, and the skill to organize support at all levels, potentials can be exploited. Although hardly any of the companies interviewed had already calculated a PCF themselves, the response was nevertheless consistently optimistic. Many companies want to introduce related standards as soon as they are financially able. It is less a lack of conviction than a lack of funds.

According to the interviews, lack of financial and human capacities are among the most crucial bottlenecks. There is no lack of awareness among the interviewed founders, likely due to their membership in the green start-up scene. The lack of information largely refers to customers or suppliers. Moreover, already Bolwig and Gibbon (2009) pointed out that there is a need for an internationally accepted standard. After completion of this paper, the GHG Protocol with its separate product guideline has been issued. Nevertheless, start-ups still miss a concrete, all-encompassing standard.

When contrasting the major barriers in literature and practice, differences get visible. This is a valuable insight to answer RQ 1. Data quality and data absence were mentioned as predominant problems in the literature, but the interviewees name management problems as the main challenge. Internal management obstacles such as decision-making difficulties and lack of business prioritisation have shown to be of higher significance than in the existing literature. Market survival through quickly scalable areas such as marketing or sales are considered a top priority. In practice, the establishment of a sustainability department is not included in classic start-up seminars. Technical limitations, such as lack of database access, are mentioned relatively consistently in the literature and interviews. In literature, it is assumed that start-ups independently carry out the CO2 balancing of their products. This is not realistic in practice. None of the interviewees has the confidence to calculate PCFs on their own and needs external professional help. A lack of reactivity on the part of service providers and non-intuitive digital programs with generic entry categories expand the list of barriers.

For barriers, it can be summarized that all barriers have their justification and can largely be related to start-ups. Furthermore, it can be observed that barriers are interconnected. The frequently cited lack of credibility roots in a lack of information for customers especially. There is an equal lack of reliability when data is not consistently collected and calculations are weakened by estimations. This reinforces the lack of credibility of PCFs. Multiple aspects of RQ 1 could be found that fulfil the objective of this paper, the presentation of barriers and opportunities. At the same time, they are linked to RQ 2, as different measures can be assigned to the highlighted elements that lead start-ups to implement PCEA permanently.

5.4 Measures and recommended actions

Internal and external measures must be taken for a successful implementation of PCEA. In the designed questionnaire, the participants were also asked to name important measures. This serves to answer RQ 2 posed at the beginning: *What is necessary to drive start-ups to continuously report their products' carbon emissions?* Furthermore, the opportunities and barriers raised in the interviews can be directly linked to suggestions for improvement. Based on the corresponding answers from the interview guide, functional areas could be identified by the author and were summarised by means of own abstraction and grouping to form the columns visible in Figure 8. Actions need to be taken from a structural, financial, informational and technical side. When analysing the individual arguments, structural measures can be identified as most influential, followed by financial, informational and technical measures in descending order of relevance. Given the amount of arguments per area and the interviewees' perceived relevance of these, a ranking can be made. Start-ups and governments are recommended to follow these suggestions.

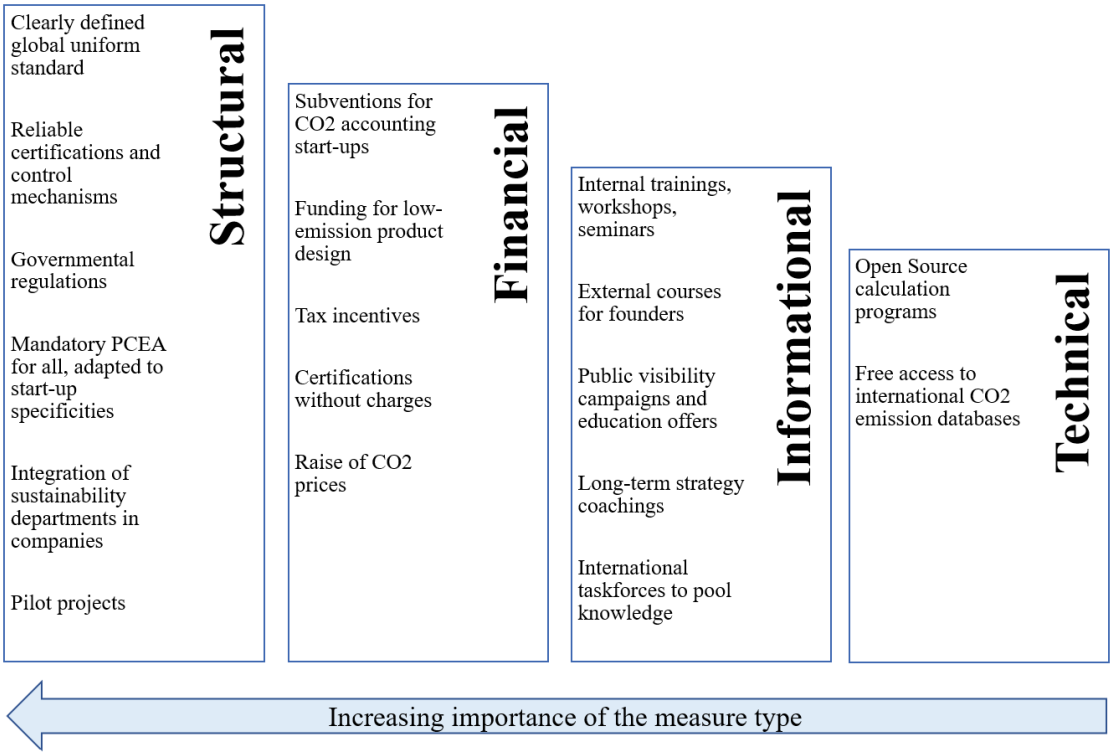

Figure 8: ***Types of measures for PCES integration***

From a **structural perspective**, governments can help creating suitable basic conditions for start-ups to introduce carbon emission standards on their own. Following the major barrier of inconsistent standards currently, governments and international organizations might engage in guiding a process towards the development of universally accepted PCES. They must be compatible with different products, sectors and company sizes and contain understandable implementation steps. The GHG Protocol is already a widely used standard, but details are still missing in some places. This standard can be used as a reference and may only need to be extended.

Governments should adapt the existing legislation on carbon emission reporting and guarantee that start-ups are not disadvantaged. Moreover, it is recommended for start-ups to set up a department for sustainability. CO2 assessments of products must not just perceived as a side-line activity, but as a central component of corporate management to be pursued on a permanent basis. Pilot projects, possibly also in cooperation with universities, can take away initial implementation uncertainty. Processes and calculations can be tested without obligation and even relieve the additional financial and capacity burden of PCER.

From a **financial point of view**, start-ups need support from the beginning. A barrier of high significance is the additional financial burden. PCF calculation has to be done externally due to method complexity and means expenses or missing revenues resulting from the required priority shift. This shift can be promoted by tax incentives, funding for low-emission products or subsidies when voluntarily operating PCER. The approach of carrying out CO2 emission calculations free of charge would eliminate high fees from service providers and facilitates to opt for PCEA. An alternative, which is in contrast to the measures just mentioned, is to increase taxes on CO2. This could be understood as a kind of sanction for high-emission products and indirectly supports green start-ups having low-carbon products but are unable paying calculations. However, solvent large companies can cover the additional price through higher profits and keep the actual benefit for start-ups low.

Additionally, **informational** activities need to be put in the spotlight of start-ups' strategies. Robust knowledge needs to be built up to create awareness, enable entry into emission standards and ensure self-help when data problems arise. The establishment of an independent task force can pool knowledge and create a single point of reference. This can be initiated in start-ups as well as across companies. By drawing attention to carbon accounting through outreach campaigns, visibility is created. Through transparent and participative communication with educational elements, all stakeholders can be involved. Training can also take the form of external coaching with professionals if start-ups do not feel able to do it on their own.

From the **technical** side, databases must offer start-ups the possibility of obtaining documented product data and conversion factors free of charge and in an uncomplicated manner, so that data collection no longer represents an unmanageable problem. In addition, an open source version of CO2 calculation programs can make it easier for start-ups to get started.

It can be critically noted that differences in the importance of measure types depend on the progress made so far. In case of a rather low development of PCER in companies, information measures can be of highest importance to create a basic awareness in the first place. Depending on the technical development in companies and already established partnerships with data suppliers, technical measures can be excluded. National governments that have already made arrangements for legislation regarding PCER will have to adopt less structural recommendations. The relevance for the individual use case must be carefully analysed to select appropriate measures.

6. Conclusion, limitations and outlook

This paper aims to provide an overview of barriers, opportunities and measures in start-ups to assess PCF, as well as a permanent implementation of PCES. This addresses the question of why start-ups have so far hardly implemented a uniform reporting of product emission data. In the beginning, two RQ have been formulated, firstly regarding barriers and opportunities when assessing PCF, and secondly regarding crucial measures to drive start-ups to regularly capture PCF and implement PCES over the long term.

In conformity to the purpose of this work, it could be found out that main barriers are the high complexity of methods, the difficult traceability of SC processes, risk caused by emission and energy dependencies, the need to react to varying stakeholder demands, changes in internal management structure and technological processes. These are mutually dependent and vary according to the start-ups individual background. The dominating opportunities are market differentiation, visibility of actions for climate change mitigation and business improvements among others. Those can be understood as substantial opportunities that, if implemented correctly, can have a major impact.

The performed investigation contributes to current research by compiling four essential measure types to improve current implementation intentions in start-ups. Financial, informational, structural and technological actions such as regular internal workshops, low-emission product funding and the integration of a separate emission management are recommended. These results contribute to answering the second RQ, in so far as not only several suggestions were made during the interviews, but also the most important ones could be abstracted from the individual assessment and applied to start-ups in general.

Still, the present paper shows limitations e.g. a lack of access to adequate up-to-date documents and unavailability of first-hand data and previous PCF. Moreover, the conducted interviews were limited to German interview partners. The empirical study cannot sufficiently provide internationally applicable outcomes as the empirical results only cover the German start-up scene, the opinions and experiences of German founders or the business conditions of the German economy. Although it was possible to pick up multiple opinions on the topic, all interviewees are more or less part of the green industry. Start-ups without Sustainable Business Model could further enrich research. In addition, no large multinational companies were interviewed, which could have contributed to a better differentiation of barriers and opportunities of start-ups. The case study was limited to one single product so that differences between varying types of products have not been taken into account. Internal management structures within *truemorrow* could have influenced the process and expectations for results on PCF.

However findings and limitations can be used to identify future fields of research. Researchers can explore the optimal use of data and the design of PCEA programmes to support product assessments. Moreover, differences in PCES implementation under influence of company size, culture or state of development can be further investigated. Future research is needed to close mentioned research gaps and to implement PCES globally in all forms of business so that together climate change can be addressed and SCs remain performing and reliable in the future.

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Appendix

Interview guide

1. To which extent does your business model or certain values you promote reflect sustainability?
2. What is your overall perception of the importance of monitoring carbon emissions?
3. In how far carbon emission reporting could be interesting for you?
4. Have you ever performed a product carbon emission calculation?
    1. If so, how do you perform product carbon emission calculation? What is your guideline? Do you use a service, tool etc. like ClimatePartner or other?
    2. If not, what are the reasons?
5. What kind of benefits do you see by establishing carbon emission standards?
6. What hinders you in implementing these standards?
7. What would be necessary to (further) encourage you to introduce standards like GHG Protocol?
8. Which internal measures within start-ups and which external measures of the government or other parties could contribute to improve the implementation of product carbon emission standards?
9. In how far would you say that start-ups and large international firms have different problems in introducing and calculating product emissions?
10. What do you think about the following: The financial success of a start-up and sustainability efforts since the beginning of activity interfere with each other.
11. How would you start if you had to establish product carbon emission reporting?

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