Highlights of Sustainability

ISSN 2696-628X, A Peer-Reviewed Open Access Journal by Highlights of Science
https://www.hos.pub/ho/sustainability

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This article is part of the Special Issue
Capturing the Sustainable Impact of Early-Stage Business Models

Cite this Article

Diekel, F., Bach, V., & Finkbeiner, M. (2023). Assessing the Climate Performance Potential of Start-ups: Insights and Guidance on Environmental Sustainability Assessment of Young Ventures. *Highlights of Sustainability*, *2*(4), 207–223. https://doi.org/10.54175/hsustain2040015

Highlights of Science

Publisher of Peer-Reviewed Open Access Journals
https://www.hos.pub
Barcelona, Spain

Article

Assessing the Climate Performance Potential of Start-ups: Insights and Guidance on Environmental Sustainability Assessment of Young Ventures

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Abstract The role of early-stage venture capital (VC) investment in financing for ambitious climate action is often overlooked. In the developing field of climate-tech investment, one of the biggest challenges is to identify the start-ups and business models that contribute to climate change mitigation. The potential of a start-ups business model to reduce greenhouse gas emissions is defined as the start-ups climate performance potential (CPP). The assessment of a start-up's CPP could enable start-ups and VC investors to invest in a more informed way with greater precision, impact, and purpose. The objective of this paper can be expressed in two steps: First, to gain insights into and identify the potential for improvement in the environmental sustainability assessment practices of VC firms through an exploratory case study. Second, to provide life cycle-based guidance on environmental sustainability assessment of innovative products offered by start-ups to determine their CPP, by eliciting appropriate criteria and procedures for directionally sound assessment. For this, the assessment approach developed by the climate-tech VC firm World Fund was used for the exploratory case study. In a first step, the CPP assessment process was described, based on document review and observation. Next, the CPP carbon footprint method was compared with ISO standardizations of life cycle assessment (LCA) and carbon footprint (CF) along eight criteria. Development potential was identified and discussed for seven of the eight criteria, including, for example, the use of scenarios, the complexity of meta-analyses, and the need to avoid misleading incentives.

Keywords sustainable entrepreneurship; start-up; venture capital investment; climate-tech investment; start-up sustainability assessment; climate performance potential; life cycle assessment

1. Introduction

In their sixth Assessment Report on Mitigation and Climate Change, the Intergovernmental Panel on Climate Change (IPCC) [1], acknowledges that business solutions from early-stage companies in the impact investment sector can contribute positively to climate impact. Still, neither the urgent need nor the economic rationale for ambitious climate action is noticeable in the scale-up of climate finance, where soft costs for the regulatory environment and institutional capacity, upstream funding needs, research and development (R&D), and venture capital (VC) for the development of new technologies and business models are often overlooked [1]. At the same time, dominant logics in VC finance, including short-termism, predictability of the future, price efficiency, and risk-adjusted returns, are hindering the effective contribution of the financial market to climate change mitigation [2]. VC investors aim at maximizing shareholder value and are disinclined to invest in propositions that create positive externalities which do not create financial returns [2–4]. Diverting from these dominant logics, among others is the approach of climate tech investment, which is defined by PricewaterhouseCoopers (PwC) as investment in "technologies that are explicitly focused on reducing the greenhouse gas (GHG) emissions or addressing the impacts of climate change" [5]. The leading reasons for investors to divert from the dominant investment logics and get involved in sustainable business are according to Hegeman & Sørheim [6] practical idealism and disagreement with the status quo. Sustainable VC investors therefore want to identify start-ups that fit their investment thesis, which defines the intended sustainability impact and focus [6]. Lin [7], finds, that the identification of these companies and entrepreneurs

Open Access

Received: 20 June 2023
Accepted: 4 October 2023
Published: 6 October 2023

Academic Editor
Fausto Cavallaro, University of Molise, Italy

that adhere to the VC's sustainability goals while generating a positive profit is the biggest challenge for sustainable VC fund managers. The sustainable entrepreneurship literature has engaged with different performance factors of sustainable enterprises such as success factors, barriers, organizational structures, crowdfunding, and educational system as well as their influence on sustainability impact, socio-environmental impacts, and financial performance. Despite the existence of these performance factors, the key question remains how to measure the sustainability of start-ups [8].

Horne & Fichter [9] take a multi-level perspective on the impact of start-ups for the sustainable transformation. They suggest the measurement of the greenhouse gas (GHG) emissions of the start-ups as a good while still complex simplification. This simplification is in line with the concept of climate-tech investment, concentrating on the mitigation potential of start-ups. The potential of a start-ups business model to reduce greenhouse gas emissions is defined by Leendertse et al. [10] as the start-ups climate performance (potential). The term climate performance potential (CPP) is therefore adopted for this work, to describe the focus on environmental and more specifically GHG emission assessment. The ability to assess a start-up's CPP would reduce significant information asymmetries and allow start-ups to demonstrate their attractiveness while supporting key stakeholders such as VC investors to invest in a more informed way with greater precision, impact, and purpose [11].

On the side of sustainability assessment, of the many assessment methods and tools for determining environmental and sustainability performance that have been developed in recent decades, life cycle assessment (LCA) represents the most advanced state of the art in science and practice with respect to the environmental dimension of sustainability [12,13]. Life cycle thinking and LCA are considered essential elements of sustainability assessments and are increasingly cited as integral to comprehensive and holistic decision-making in both business and policy contexts [14]. LCA is standardized through the ISO 14040 [15] and ISO 14044 [16] as a method for assessing the potential environmental impact of a product, service, or process throughout its lifetime [15]. Product carbon footprinting as a single-issue LCA is standardized in the ISO 14067 [17]. Further standardization includes the Greenhouse Gas Protocol in the form of the Product Life Cycle Accounting and Reporting Standard [18].

Recent literature looks at the distinctive characteristics of start-ups and is able to derive start-up specific assessment challenges [11,19–21]. A core characteristic of a start-up is an informal and fast-moving work and management structure. This volatility in the management structure and therefore fast change in people and responsibilities makes it challenging to ensure continuity and replicability in the assessment [11]. Due to the usually small size of a start-up, it faces constraints in financial and human resources, which can affect the completion and proper documentation of an assessment [11,19,20]. Not only the working and management structure of a start-up is fast-moving but also the business model and value chains are highly volatile, as product and service designs, material choices, and supply chains are often still under development and therefore subject to rapid and substantial short term changes [11,20]. This requires a high level of flexibility and poses the challenge of dealing with high uncertainties and unforeseeable changes [11]. Another characteristic of a start-up is that it is young and new to the market, therefore lacking established value chains and historical performance data and results, which are otherwise used for assessments. A retrospective, experienced-based, ex-post evaluation which is used in established companies is therefore not possible posing the challenge for start-ups of conducting ex-ante evaluations relying on assumptions and plausible scenarios [11,20,21]. The nature of sustainability assessments requires a certain functional specialization and know-how, which is lacking in most start-ups [11,19]. It is therefore difficult to develop an efficient and simple assessment methodology, as the need for low formalization and high flexibility competes with the complexity of assessment methodologies and control systems [11].

While these listed characteristics pose challenges in the sustainability assessment of start-ups, they differ significantly from established companies and are in the majority of sustainability assessment approaches not considered as these focus on product sustainability assessments [11].

Part of the core challenge of assessing the sustainability of start-ups is shared in the developing field of prospective LCAs. Both face the challenge of assessing the environmental impacts of a new technology, since in both cases the core issue is to assess whether emerging technologies can lead to lower environmental impacts (compared to a potentially displaced mature technology). While the two approaches therefore share some challenges, including high uncertainties, data availability and quality, as well as the necessity for scenarios, they have not been connected directly in the literature. For environmental assessment, a first attempt of standardization has been made in the form of the recently developed DIN SPEC 90051-1 [20], which provides the basis for a qualitative sustainability assessment for start-ups. Although the DIN specification represents a first milestone in the standardization of the environmental sustainability assessment of start-ups and offers detailed methodological descriptions, it is a purely qualitative approach. The numbering DIN SPEC 90051-1 implies that a DIN SPEC 90051-2 will be developed to provide the appropriate quantitative approach based on the experience gained from working with qualitative assessment [20].

A limited number of approaches exist in the literature that deal with sustainability and start-up specific assessment, including the Sustainability Assessment Tool for Startups [22], the Sustainability Quick Check (SQC) model [23], the Lean Impact Measurement [24], the LCA clinic [25], The Positive Financial and Sustainability Case Calculation [26], the Standard for Social Return on Investment Analysis (SSROI) [27], the SPI-Framework [28], and the Triple-Bottom Line Impact Analysis Framework of Fintech Companies [29]. Other approaches were developed by third parties such as the Climate Impact Assessment for Early Stage Start-ups by PRIME Coalition and the New York State Energy Research and Development Authority (NYSERDA), which was later used as a basis for the free online open access, web-based software CRANE (Carbon Reduction Assessment for New Enterprises) [30]. CRANE was developed by Prime Coalition, a non-profit public charity and catalytic investor who manages and funds the tool [31]. The GHG & Impact Estimator Tool from ImpactNexus is another free tool, that allows start-ups to receive a quantified estimate of the GHG reduction potential of their products [32]. Apart from this, Venture Capital firms develop their own assessment approaches such as the Climate Performance Potential assessment developed by the VC firm World Fund [33].

The listed approaches remain mainly general and vary in scientific depth. For example, the approaches are published as master's theses, conference papers, and only in two cases as peer-reviewed articles. There is a lack of scientific contributions in this field that address the identified assessment problems and provide detailed guidelines for assessment in practice.

As addressed earlier, the assessment of a start-up's CPP could enable start-ups and VC investors to redirect their investments and business models to contribute to climate change mitigation. The research field of sustainable and climate-tech entrepreneurial investment at the research intersection of sustainable entrepreneurship and entrepreneurial finance is only recently starting to receive academic attention [3,4,7,34,35]. While some scholars focus on the motivation behind impact investing [6,36], the development of sustainable VC funds [7], or specifically on clean energy and technology investment [37–40], a central and under-researched issue is the assessment of environmental sustainability of start-ups [11]. This research gap is addressed in this study by developing life cycle-based guidance for the assessment of the CPP of start-ups. For this an existing assessment approach from practice, the CPP assessment from the VC firm World Fund is analyzed. The objective of this paper can be expressed in two steps: First, to gain insights into and identify the potential for improvement in the environmental sustainability assessment practices of VC firms through an exploratory case study. Second, to provide life cycle-based guidance on environmental sustainability assessment of innovative products offered by start-ups to determine their CPP, by eliciting appropriate criteria and procedures for directionally sound assessment. These objectives aim to answer the following research question: Which criteria and procedures are suitable for a directionally sound assessment of the climate performance potential of start-ups and what conclusions can be drawn from this for impact investment?

2. Materials and Methods

The research field of start-up sustainability assessment is still nascent; therefore, an exploratory qualitative research approach is carried out [41]. This entails a case study on the World Fund's CPP assessment (Section 2.1) to get a detailed presentation of an assessment approach developed and deployed in practice. The thereby described carbon footprint approach of the CPP assessment was then compared with the approach with ISO standardized LCA and carbon footprint method (Section 2.2).

2.1. Case Study Research Design

A case study approach is commonly used in the management and business research field for theory testing as well as theory generation [42–49]. The use of a single case study research design and methodology offers data for in-depth analysis, and understanding of issues in their natural life context, and can enhance the potential significance of the findings for practitioners [45]. In order to understand environmental sustainability assessments of start-ups from a VC firm's perspective in a real-life context, a case was selected based on the criteria of relevance, the potential to learn from the case, and the accessibility of data. The chosen case is the CPP assessment approach, developed by the climate-tech VC World Fund.

The World Fund is a €350M European climate-tech venture capital firm, which follows the investment thesis to invest in "tech that can save at least 100Mt of CO_2e emissions per year", which is assessed through their CPP assessment approach [33]. The CPP assessment therefore constitutes an environmental and start-up specific assessment approach developed and deployed in practice by a VC fund and is therefore a relevant case that holds the potential to gain an in-depth understanding of the assessment process, methodology, and its implementation in the investment process. It therefore meets the first two criteria for case selection—relevance and potential to learn from the case. The third criterion, of accessibility of data, was granted in consultation with the Head of Investor Relations and Impact of the World Fund for the period from October 2022 to the end of December 2022. The World Fund as a case was therefore selected as it fulfilled all three criteria for case selection.

The agreed time with the World Fund was used for a document review. Internal documents were gathered and reviewed, including an assessment template, a CPP Memo, and sector hypotheses as provided in the Supplementary Materials Document S1. Past assessments [50,51] and investor and external communication [52–54] were further considered. In addition, documents and information available online, such as the World Fund's website, press releases, and blog posts, were accessed. Each document provided an insight into how the overall approach works and how it is implemented in the VC firms' investment process.

The document analysis was further combined with an observation of the CPP assessment in the investment process. For this, the World Fund agreed to give partial access as an observer to the researcher for one investment process that was conducted during the cooperation time. The role of the researcher was therefore disclosed to all participants, allowing the researcher to actively participate in the assessment process. For the observation, an observation guide following Hancock & Algozzine [55] was developed in the form of a template listing features to be addressed during the observation. The observation notes can be found in the Supplementary Materials Table S1. The goal of the observation was to triangulate the CPP assessment process and framework as derived from the document review. The focus of the observation was therefore on how the CPP assessment was structured and implemented in the overall investment process.

2.2. Comparison with LCA and Carbon Footprint Method

In the next step, the CPP carbon footprint approach developed as a core part of the CPP assessment is compared to the ISO standardization of LCAs and carbon footprints [15,16,17]. The ISO standards were chosen as a useful reference for comparison, as they are among the most well-known and well-established assessment approaches for environmental impact assessment [14]. The ISO standards further provide a framework and fundamental principles of LCA that other standards, e.g., ILCD guideline, use as a reference [56]. The product standard was chosen instead of a standard addressing environmental impacts of companies, as the carbon footprint of products is assessed, not the one of companies. A company assessment includes additional elements such as employee commute, company laptops, water usage in the kitchens and toilets, etc., within the company's premises. While these aspects are important, they are not considered in the carbon footprint of products.

Comparing the CPP methodology, developed and deployed in practice, with the standardizations of LCA and carbon footprints enables the inclusion of well-developed knowledge and standardized assessment in the developed guideline for the CPP assessment of start-ups. With the aim of giving structure to the analysis, the approach developed by Arendt et al. [57] was adopted. In their paper, they established nine criteria for comparing ISO 14040/44 and ISO 14067 and, in their case, offset program methodologies. For the comparison of ISO 14040/44 and ISO 14067 with the CPP carbon footprint approach, the nine criteria were assessed for their relevance to this analysis. Eight of the nine criteria and the associated guiding questions, as shown in Table 1, were considered most relevant for the analysis. The criterion "Aggregation of biogenic and fossil carbon" was not included, because its relevancy for the research question is not given. According to existing standards, biogenic carbon should be monitored separately throughout the analysis. However, the results include both types of carbon flows and current characterization factors do not distinguish between biogenic and fossil carbon since both contribute to climate change equally. The eight criteria were applied for the comparison of the World Fund's CPP carbon footprint assessment with ISO 14040/44 and ISO 14067. From this comparison, challenges in the CPP carbon footprint approach were identified and discussed to develop life cycle-based guidance.

Table 1. Applied Criteria to compare CPP assessment with carbon footprint and LCA (adopted from [56]).

Criteria	Guiding Question
1. Analyzed system	Is the analyzed system a product or project?
2. Scenario analysis	Is scenario analysis obligatory?
3. Life cycle phases	Does the method usually include all life cycle phases?
4. Output	What is the studies' output? Information? A commodity?
5. Review	Is a review obligatory and how is it performed?
6. Data verification in review	How flexible is the data collection and how is it performed?
7. Flexibility in data collection and system boundaries	What are the system boundaries and how are they defined?
8. Treatment of shift of burden and impact categories	How many impact categories are considered? What is done to avoid shift of burden?

3. Results

In the following, the results are presented. First, the case description offers a detailed insight into the CPP assessment approach (Section 3.1). Next, an analysis of the CPP carbon footprint assessment is offered in Section 3.2.

3.1. Case Description Climate Performance Potential (CPP) Assessment

Based on the document review (see Supplementary Materials Document S1) and observation (see Supplementary Materials Table S1), the CPP assessment process, methodology, and its implementation in the World Fund's investment process as of December 2022 is presented. For this, first, the VC firm World Fund is introduced (Section 3.1.1), then their investment process is outlined (Section 3.1.2), followed by a description of the CPP-screening (Section 3.1.3) and ending with a detailed description of the CPP assessment process (Section 3.1.4), with a focus on the quantitative part of the assessment.

3.1.1. The World Fund

The World Fund is a VC fund was incubated by the search engine Ecosia in 2021. It is built around the belief that decarbonization is a key value driver for the future economy. The climate-tech VC intends to raise €350 million to back founders using technology solutions to tackle the climate crisis [58]. The most recent investment in the fund includes €50 million by the European Investment Fund, joining Ecosia, PwC Germany, the UK Environment Agency's pension fund, and more than 60 other limited partners (LPs) [58,59]. From the consideration that climate returns are an early indicator of financial returns, the World Fund deduces that the most valuable companies of the next decade will be those that enable a decarbonized world. The underlying approach to sustainability is therefore expressed in the World Fund's founding belief that decarbonization is the key value driver for the future. This approach can be classified as practical idealism, as sustainability is understood as a good business opportunity, with the conviction that business can be used as a force for good [6].

In order to identify the investments contributing to GHG reduction, the World Fund developed their own assessment approach as a necessary condition for an investment, the CPP assessment [58]. The key idea of the CPP assessment is to determine the difference between the emissions of a system with the new investment technology and without it. This difference needs to account for at least a 100Mt CO_2e emissions per year until 2040 to qualify for an investment [60]. Complementing their investment thesis, the World Fund concentrates on five industries which they identified to hold especially high mitigation potentials, based on the respective high contribution to GHG emissions: energy, food and agriculture, manufacturing, buildings, and transport. The World Fund currently holds seven portfolio companies from these industries that fulfill the investment thesis, namely Planet A Foods, Treecard, Juicy Marbles, Space Forge, Freshflow, IQM, and CUSTOMCELLS (per December 2022). The investment into RECUP was exited in 2022 [33].

3.1.2. The Investment Process

The World Fund's overall investment process is depicted in Figure 1. It consists of six steps with five decision points that decide over the progression, and in the end if an investment is made. From the first step, it takes on average 1.5 months to a term sheet and two to six months to close a deal. The process begins with a first assessment. Here, an initial understanding of the team, product, and traction, as well as first contact with the start-up decides whether the deal is passed, put on a watch list, or progresses to the next step, the follow-up assessment. During a follow-up assessment, the initial understanding is deepened through an analysis of company information including financial model, sales pipeline, and market technology using the support from the World Fund's scientific network. These first two steps also include a first screening for the CPP assessment, building on sector hypothesis, sector-specific co-investors, and a first "back-of-the-napkin" CPP calculation. At the end of the follow-up assessment, a decision is made again as to whether the deal will be accepted, placed on a watch list, or presented at the next deal flow meeting. The deal flow meeting provides the opportunity to discuss the investment rationale. If the rationale is considered convincing by the general partners (GPs) and it is decided to continue with the commercial due diligence (DD), a term sheet is created and a deal team is assigned with a senior team member as lead. Step four, the commercial DD, consists of multiple in-house DDs including market and competition DD, product DD, and tech DD with comprehensive reference calls with customers, as well as market and technology experts. Further, a founders' and core team members' DD, a financial DD, as well as a climate return DD in work with scientific advisors—which is the performance of the CPP assessment—is part of this step. After these commercials DDs, a decision if the deal is passed, or if an investment proposal with advisors' approval is made. At this point waitlisting the deal is no longer an option. The fifth phase is the investment decision itself, a simple majority decision by the investment committee including the General Partners. The last step consists of final term sheet negotiations, a third-party DD including legal, financial, and tech DD, and final shareholder agreement negotiations. This is followed either by a deal break and rejection of the investment, or a signing making the investment official. After an investment is made, the start-up becomes part of the VC's portfolio and its portfolio management.

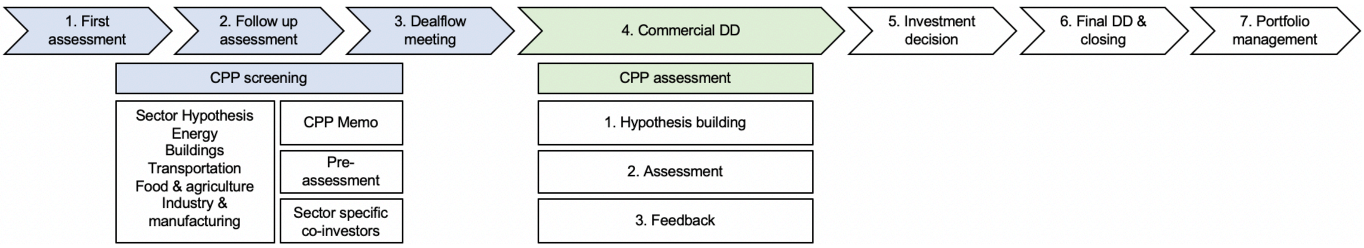

Figure 1. World Fund Investment Process and Positioning of Assessment.

3.1.3. The CPP Screening

As described above, for the CPP assessment, a pre-screening—the CPP screening—is conducted during the first steps of the investment process, while the actual assessment takes place during the commercial DD. The results of this CPP screening are included in the deal flow meeting discussions in step three and influence all related decisions. It builds on three elements: sector hypothesis, sector-specific co-investors, and a pre-assessment. The sector hypotheses were formulated for the five sectors targeted by the VC and are regularly updated to guide the first screening of CO_2e reduction potentials and business models. They include an overview of the sector's challenges, specific opportunities for investment, and CPP within the sector, as well as investment-specific background information such as investment gaps, previous relevant investments, and business models that are permanently or temporarily excluded from the investment scope. Their scope ranges from high-level hypotheses such as for the energy sector and food and agriculture sector to more specific sub-hypothesis as the one on clean aviation as part of the transport sector (compare Supplementary Materials Document S1). For the energy sector hypotheses, for example, two main high-level investment opportunities of energy storage and distributed energy resources were identified. The sector hypotheses therefore support the CPP screening by giving a first orientation where high CPP could be found, supporting the early decision to pass a deal, to put it on a watch list, or progresses in the investment process. The World Fund makes further use of syndication and signaling through co-investments, during the CPP screening. For this, they have identified sector-specific co-investors and make use of their respective expertise to estimate the general potential of a deal as well as the fit of the climate science into current trends and developments in the sector. The last element of the screening includes a simplified CPP calculation. In this simplified pre-assessment, a first hypothesis and a related baseline value are developed from the initial information available. This calculation follows the same logic as the calculation of the CPP carbon footprint, which is explained in detail in Section 3.1.4, but has no scientific basis at this point and is only based on the unproven initial hypotheses and estimated baseline. This is later used as a starting point for the in-depth CPP assessment. The results from this first screening are considered with the financial and market information on the deal in the deal flow meeting. During the case study period, a new step in the assessment was introduced at this point, a CPP memo. The CPP memo consists of a very brief overview of the climate potential, the climate performance, the CPP, as well as a justification of how the technology solves a bottleneck or accelerates development, and what baseline technology is chosen. It is therefore a summary of the CPP screening results which are presented in the deal flow meeting for discussion and need to be approved by the Head of Investor Relations and Impact. In case the deal is approved during the deal flow meeting, the actual CPP assessment is carried out as part of the commercial DD.

3.1.4. The CPP Assessment

The CPP assessment starts with a hypothesis building phase, followed by the actual assessment, and is concluded by a feedback phase, as shown in Figure 2. Throughout, the main responsibility for the assessment lies with the CPP assessment team, which is supported in the last step by other members of the deal team and a scientific advisor who offers feedback for the performed assessment. In the observed assessment, the CPP team consisted of the lead investment associate for the investment, head of investor relations and impact, and an analyst intern.

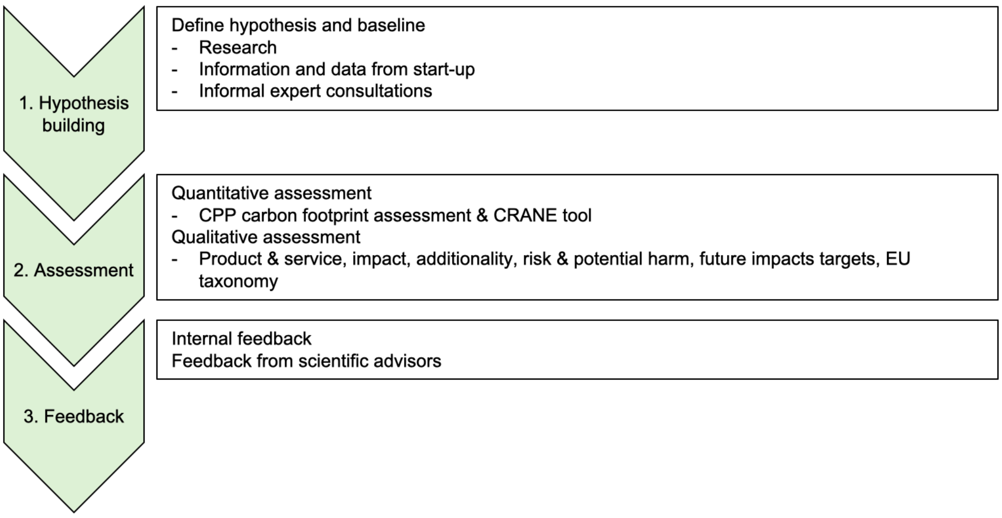

Figure 2. CPP Assessment Process.

The first assessment phase, hypothesis generation, builds on the CPP screening and puts the assessment team on the same page. It is mainly concerned with research, gathering information from the start-up, and informal expert consultations in order to generate a hypothesis and related baseline which is needed for the assessment. For the CPP assessment from the Planet A Foods investment [50], the hypothesis that the Planet A Foods technology will substitute cocoa butter was developed, making cocoa butter the baseline technology.

After the hypothesis building, the next step is the actual assessment. This part of the assessment follows the CPP assessment template, which provides structure, instructions, and descriptions of what is expected for each assessment part, as well as examples, possible pitfalls, and learnings gained during previous assessments. At the end of an assessment, the template is completed and thus becomes the investment-specific CPP assessment document. The content and structure of the template were adopted to provide an overview of the CPP assessment content (see Figure 3).

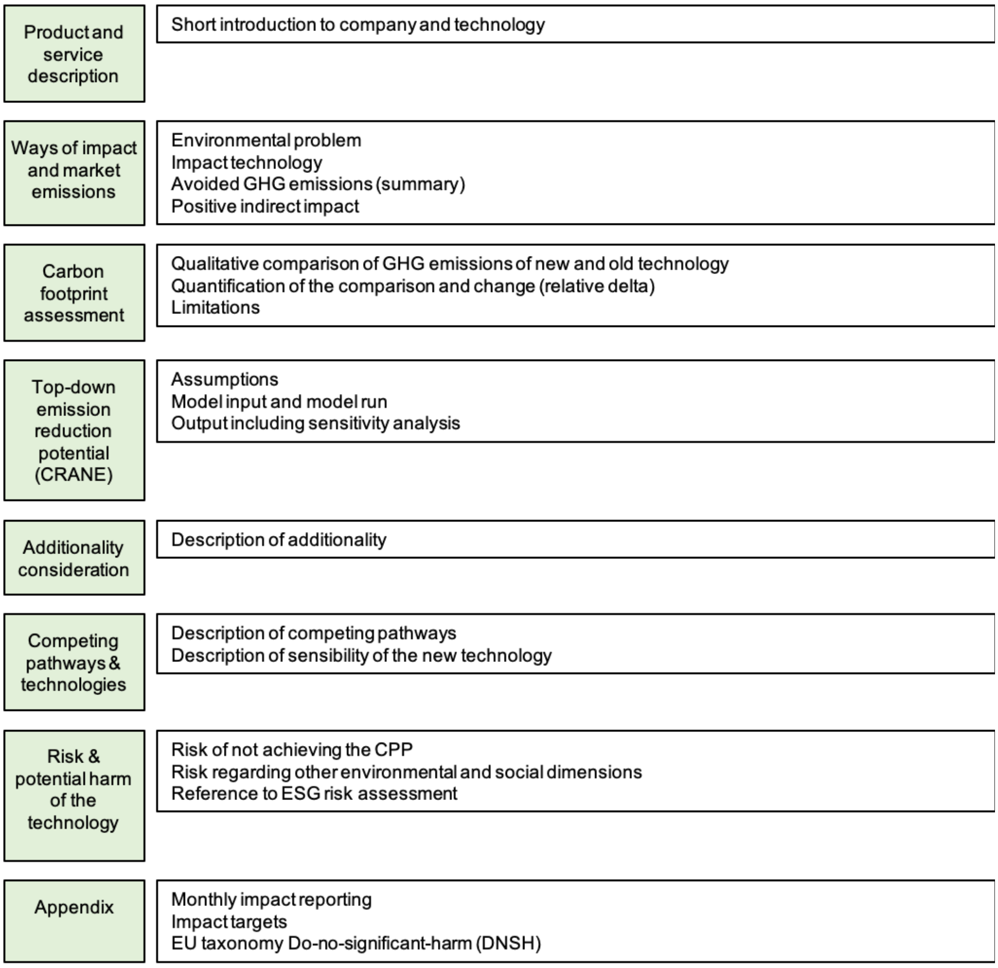

Figure 3. Overview of Structure and Content of a CPP Assessment.

At the core of this assessment phase is the quantification of the difference between a system's emission with the new investment technology and without it, as presented in steps 3 and 4 in Figure 3. This quantitative assessment is further embedded in a qualitative framing, presented in steps 1 to 3 and 6 to 8 in Figure 3. The qualitative part of the assessment is used to embed the outcome of the quantitative assessment and provide information that goes beyond the single focus on CO_2e emissions. This includes a description of the product and service, ways of impact and market emissions, additionality considerations, competing pathways and technologies, risk and potential harm of the technology, as well as setting future impact targets and monthly impact reporting. For this information, research, start-up contact, and informal expert consultation from the hypothesis building phase are used and if necessary supplemented even further.

The quantitative assessment includes two approaches, a bottom-up and a top-down approach. The bottom-up approach is referred to as carbon footprint assessment, where the carbon performance per unit for both the new technology and the baseline technology is calculated, based on existing LCA and carbon footprint studies. In a first step, the relevant life cycle stages are defined and for each stage, a qualitative description of the associated greenhouse gas emissions is offered in comparison between the new technology and the base technology. A life cycle phase is considered relevant if a delta in emissions between new and old technology can be identified. Next, the GHG emissions for each step are quantified. For this the recommendation is given to base the numbers on existing papers and LCA studies with a first preference for peer-reviewed studies but also linking to impact forecast (https://impact-forecast.com) as an extensive life cycle inventory (LCI) database. In the provided examples, LCA studies, LCA meta-studies, carbon and environmental footprints, as well as data from the International Energy Agency (IEA), and other publications were used. After this, a quantitative overview per life cycle stage per unit is provided, for both the new technology and the baseline technology. In case multiple studies are included, an average is used. In the next step a relative delta (Δ) is calculated, expressing the change in emissions. An example can be taken from the CPP assessment for the Juicy Marbles investment. Here, an average CO_2e footprint per kg of beef and plant-based beef was determined based on five LCA studies [61–65], and one meta-study [66]. Accounting for the additionality of the new Juicy Marbles technology providing whole cut plant-based meat, a conversion factor was determined to account for whole cuts as a bottleneck to reduce cows. The contribution of the cow to the beef carbon footprint was further considered. This resulted in an average of 7.2 kg CO_2e for the plant-based beef cut and 82.7 kg CO_2e for the beef cut (considering the cow contribution and whole cuts conversion), giving the delta of −91%. This delta constitutes the result of the bottom-up assessment.

In the next step, the World Fund makes use of an existing online tool, where the results from the bottom-up calculation are used as input for the top-down calculation. Here, the focus is shifted from a per-unit assessment to annual emissions. For this purpose, emissions are assessed at what the World Fund calls the technology level [60] using the web-based software CRANE (Carbon Reduction Assessment for New Enterprises) [31]. The technology level includes what is referred to as products, services, and processes in ISO 14040/44 and ISO 14067 (ISO) [15–17]. The CRANE software requires certain assumptions and input values, making the determination of these the first step of the bottom-up CPP calculation. The assumptions include the market and market size as well as efficiency improvements from today until 2040, and the CO_2e reduction potential, which is taken from the previous carbon footprint calculation. The CRANE tool assumes a technology adoption following an S-curve, as this is a common assumption, even though others suggest different diffusion dynamics for environmental product and service innovations [67]. Hence, a maximum value, a steepness value, and a half-time value need to be defined, as they describe the maximum penetration, the speed of penetration, and when 50% of penetration of the technology in the market is achieved. The CPP template offers the recommendation to set a maximum value of 100% for technologies that are expected to become a “no-brainer” in the future. No specific definition of a “no-brainer” technology is provided. Further assumptions define to what extent the new technology is a perfect substitute of the old technology, i.e., if it would lead to a 1:1 replacement. After running the CRANE tool, the assumptions and outputs including a sensitivity analysis are included in the CPP assessment document. The top-down CRANE calculation results in quantified annual avoidable emissions, the essential result for determining if the investment condition of 100Mt CO_2e emissions is met. An example of the graphic output of the annual reduction potential from the CPP assessment of the start-up QOA (now Planet A Foods) is shown in Figure 4.

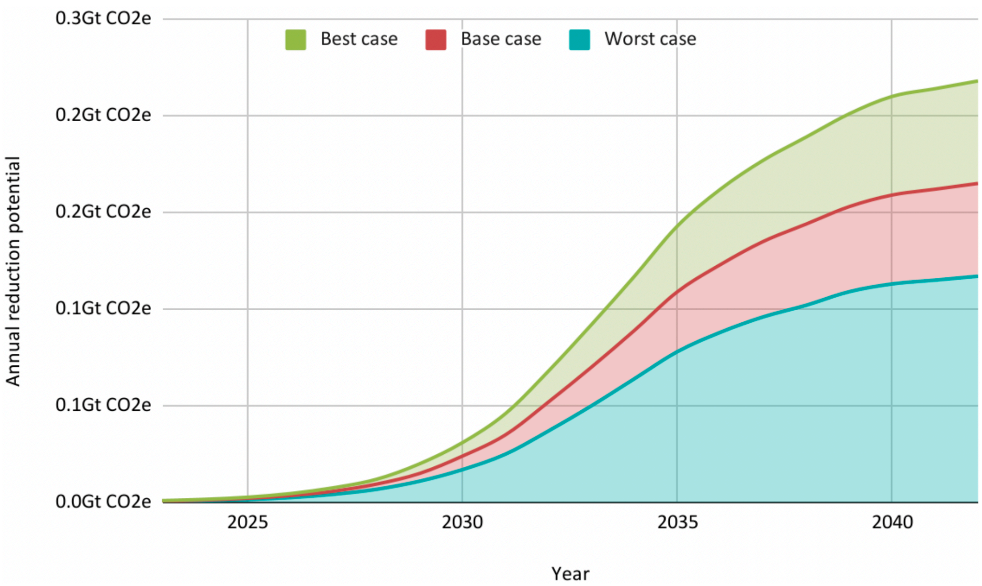

Figure 4. QOA CPP Assessment Annual Reduction Potential CRANE Output Example (adopted from World Fund [50]).

3.1.5. The Review

The last phase of the CPP assessment is the feedback phase. After the results are reported in the CPP assessment document, the document is first reviewed internally by other World Fund employees. After a revision, the document is sent to one of the scientific advisors whose final comments are worked into the CPP document. Should the assessment result after these revisions be at least 100 Mt CO_2e emission savings per year by 2040, the CPP condition required for the investment is considered to be met and will be taken into account as such in the subsequent investment decision.

3.2. Analysis of the CPP Assessment Carbon Footprint Method

An in-depth evaluation is carried out comparing the CPP carbon footprint method with the ISO standardized LCA and carbon footprint approaches [15–17]. The comparison is based on eight criteria derived from Arendt et al. [57]. The analysis shows potential for development in seven of the eight criteria. The results are detailed below for each criterion, the comparison is summarized in Table 2, while the resulting guidance for the development of the CPP assessment is summarized in Table 3.

Table 2. Comparison of LCA/Carbon Footprint and CPP Assessment (adopted from Arendt et al. [57]).

Criteria	LCA/Carbon Footprint	CPP Assessment
Analyzed system	According to a functional unit	Unit-based
Scenario analysis	Possible	Necessary
Life cycle phases	Complete life cycle, if not stated otherwise	All 'relevant' life cycle stages
Output	Information about potential environmental impacts of a product/process	CO2e reduction potential
Review	Critical review	Internal feedback and feedback from scientific advisors
Data verification in review	Data verification as part of the LCA not the review	Not provided
Data collection and system boundaries	Data collection, system boundary and cut-offs are defined in goal and scope, but are adapted in an iterative process during the study	Not provided
Treatment of shift of burden and impact categories	Consideration of multi-impacts to avoid shift of burden; carbon footprint single impact, but makes no claim regarding other impacts, includes further differentiation for GHG emissions and removals	Single impact: climate change, no further differentiation

Table 3. Summary of the Life Cycle-Based Guidance for the CPP Carbon Footprint Method.

Guidance for Further Development of the CPP Carbon Footprint Method
Analyzed System
Consider the development of additional functions when defining the functional unit and set up multiple functional units or ranges of functional units
Scenario Analysis
Development, use, and publication of cross-industry scenarios
Output
Identify and counteract possible incentives
Review
Feedback guideline
Data Verification in Review
Minimum requirement: diligent documentation of the data collection process and introduction of two-eye principle
Data Collection and System Boundaries
Standardized and transparent meta-analysis or shift to the use of individual studies
Treatment of Shift of Burden and Impact Categories
Minimum requirement: documentation of the decision and the decision rational not to differentiate further GHG emissions or removals

Analyzed System

LCA and carbon footprint studies usually quantify the performance of a product system for use as a functional unit [15–17]. The CPP carbon footprint assessment is similarly a unit-based quantification.

In Thonemann et al.'s [68] review on prospective LCAs, working with functional units in systems highly susceptible to change is described as a key challenge, as the dedicated function might not be fully known. This challenge is also applicable to the CPP assessment, as the specific use of the technology and therefore the reference unit might change in the future depending on the development of the technology and the start-up. This high volatility is mirrored in the start-up specific assessment challenge uncertainties and unforeseeable changes, as a result of volatile value chains and business models.

Solutions from the literature for this challenge include a focus on the strategic approach of the start-up which holds the potential for a change in the business model and a comparison of products or services with the most suitable alternative at present. Further, a renewed focus on transparency and good communication for stakeholders is proposed to reduce uncertainty and maintain trust and commitment [11]. Buure [22] additionally suggests to consider the long-term need for the business, while the DIN SPEC 90051-1 [20] more specifically suggests to consider vision, mission, and strategy with the business model and its scalability as central to the directional security and development of the business.

The CPP takes up these solutions, including benchmarking with the best available alternative as a core part of the assessment. Business model, scalability, and other key aspects central to the development of the business are already commonly assessed as part of a regular commercial DD of a VC, as they are central to an investment decision. Addressing the analyzed system more directly, these solutions can be extended by proposals from the prospective LCA challenges, suggesting to develop additional functions in the definition of the functional unit and to establish multiple functional units or ranges of functional units [68].

Scenario Analysis

Even though scenario analysis and LCA can be combined [69], for example as part of prospective LCAs [70,71] the ISO standards do not offer explicit guidance for the use of scenarios [15,16]. In the CPP assessment, on the other hand, the focus of the approach is on scenario analysis. This is necessary, as no historical performance data is available for the new technology and the assessment aims to determine future emissions.

The use of scenarios, as necessary in the CPP assessment, is also discussed as a solution for scaling technology in prospective LCA studies [72]. Further solutions from prospective LCAs include the use of shared scenarios [73] and the development of common databases [70,71]. The idea of shared scenarios can also be applied to the CPP approach where currently no overarching scenario assumptions or narratives apart from the industry guidelines exist. Formulating scenarios, which can be shared across the five investment industries would reduce the complexity of individual CPP assessments without reducing the quality of the assessment, as they provide fundamental assumptions across industries. This would further allow for more consistency in the assessments. For the development of the scenarios existing work could be used as orientation, such as the shared socioeconomic pathways (SSPs), which consider combined trends in social, economic, and environmental development [74]. Taking into account the assessment principle of transparency [75], the developed scenarios and possible updates should be made publicly available.

Life-cycle Phases

Both LCAs and carbon footprints based on the ISO standards usually include all life-cycle phases [15–17]. The CPP assessment approach claims to include all relevant life-cycle phases. A life cycle phase is counted as relevant, according to the CPP template, if a delta in emissions between new and old technology can be identified. In turn, if the difference in emissions is only minor, the stage is to be neglected, with an explicit explanation in the CPP document. Accordingly, all life cycle phases are considered, at least once, and no further guidance is needed here.

Output

The standard output of a LCA or carbon footprint study is information about potential environmental impacts of a product or process [15–17]. The result of the CPP carbon footprint assessment is a CO_2e reduction potential expressed as a relative delta, which is used as an input variable for the CRANE tool.

The incentive for GPs to paint a more positive picture of sustainability impacts than their portfolio companies actually achieve is described by Lin [7]. In addition to attracting more sustainability-friendly investors and highlighting the impact of their sustainability investments [7], standard VC compensation structures in the form of carries can provide an additional incentive for GPs to maximize shareholder value [39,76,77]. Although CPP assessment is a pre-investment assessment, it is a key variable in the investment decision and as such is potentially subject to the above incentives.

Review

While many LCA case studies are reviewed on a voluntary base, those who are used for comparative assertions must be reviewed by a review panel [15]. Instead of a review, the CPP includes a feedback phase where both internal (other World Fund employees) and external feedback (scientific advisors) are considered.

The quality and diligence of the feedback provided for the CPP assessment depends solely on the individual who provides the feedback and their expertise, as there are no standardized guidelines for reviewers and feedback. In comparison, for the critical review of an LCA, assessors can use ISO standards 14040 and 14044 as a guide and are often given certain requirements by the assessment scheme used. Here, the introduction of feedback guidelines for the CPP could ensure more consistent and coherent feedback.

Data Verification in Review

A critical review of an LCA focuses on the assumptions and chosen systems. ISO 14044 and ISO 14067 further provide data quality requirements, and a data validation step as part of the data collection process for both LCA and carbon footprints [16,17]. No data verification step is included in the CPP assessment. As discussed before the depth and diligence of the review is dependent on the individual person and their expertise. As a minimum requirement, diligent documentation of the data collection process and a two-eye principle could be introduced here.

Data Collection and System Boundaries

The scope of an LCA study is determined in an iterative process, allowing for the use of data and system boundaries in accordance with the study's goal [15]. This flexibility in the ISO 14040 is necessary as it enables LCA to function as a diverse tool. The CPP approach does not clearly state how the system boundaries are determined. Data is collected using existing LCA and carbon footprint studies.

The performance of a full LCA study or carbon footprint is a time-, energy-, and data-intensive process [78]. Conducting a full LCA or carbon footprint study is therefore conflicting with available resources and expertise, resulting in the meta-analysis approach of the CPP assessment. However, using results from multiple studies as a data source is not without challenges. The ISO 14040 states that "comparing the results of different LCA or LCI studies is only possible if the assumptions and context of each study are equivalent" [15]. The methodological problems of comparing different study results are further addressed in the LCA meta-study literature [79–81]. A major challenge in conducting LCA meta-analysis is the differences in methodological choices, including system boundaries, coproduct allocation, and impact assessment methods [79,81]. The requirements can be summarized under qualitative and quantitative input transparency, as well as quantitative output transparency. Qualitative input transparency is needed to assess the completeness of a study and record modeling parameters and assumptions. Quantitative input transparency describes whether the actual inputs for the evaluated systems are provided and at what level of detail. This information is necessary for the replicability and recalculation of the study. Quantitative output transparency describes the reporting granularity, and thus the extent to which the results enable or obstruct reinterpretation of the results [80]. The identification of relevant studies, for potential harmonization, requires a systematic review of the literature, offering a checklist to guide the review of LCA in a standardized format [80]. The checklist including nine steps would potentially improve the quality of the meta-analysis in the CPP assessment: 1. review title, keywords and abstract, 2. rationale for the review, 3. review question and objectives, 4. description of review protocol, 5. findings and features of the individual studies in the review, 6. assessment of bias, 7. synthesis methods (qualitative and quantitative), 8. limitations of the review, and 9. summary of findings and conclusions. While the application of this checklist in the CPP assessment would potentially improve the quality of the meta-analysis, some of the steps require in-depth analysis and understanding of the studies, which could conflict with available resources and expertise. An alternative approach for the data collection in the CPP assessment, would be to present an overview of existing and relevant LCA and carbon footprint studies, but to only base the calculations on one of those studies. Here, selection criteria such as choosing the most conservative, or the newest study could be applied, while accounting for a certain quality of the study. This would make it possible to provide an overview of the state of research and at the same time address the challenges associated with data harmonization.

Treatment of Shift of Burden and Impact Categories

An LCA case study considers several impact categories to identify shifts of environmental burden [15]. Carbon footprint studies, on the other hand, address only a single impact category: climate change, and provide guidance for the treatment of specific GHG emissions and removals, including fossil and biogenic carbon, biogenic carbon in products, electricity, and land use change [17]. The CPP carbon footprint assessment focuses on the same single impact, climate change, but with no further differentiation. Other environmental and social impacts are addressed in the qualitative part of the CPP assessment, under the chapter risks regarding other environmental and social dimensions. A shift of burden could further occur between life cycle stages, these were already discussed under criteria three life-cycle phases.

The focus of the CPP on the single impact category climate change, can be considered appropriate as the measurement of GHG emissions is considered a good while still complex simplification [9]. At the same time, the lack of further differentiation of the impact category, such as the one by the ISO standard, points to a risk of oversimplification. Here, a minimum requirement could be introduced to document the decision and the decision rational not to differentiate further GHG emissions and reduction in the assessment.

The resulting guidance is summarized in Table 3 and discussed in the next chapter.

4. Discussion

The comparison of the CPP carbon footprint assessment with the ISO standardization of LCAs and carbon footprints allowed to go beyond general guidance and to provide case-specific methodological insights. Apart from the comparison of the criteria life cycle phases, all other seven criteria show potential for development. While this developed life cycle-based guidance ought to improve the CPP assessment approach, the implementation of the guidance and further development of the approach are subject to the VC firm performing the assessment. No standard for such a quantitative assessment exists and as shown in the case description, the CPP assessment can easily be adjusted by the VC. This volatility of the assessment approach itself offers certain advantages, as it enables improvements to be implemented quickly. However, the volatility can only be considered positive if the changes to the assessment approach are developed through a rigorous and continuous analysis of the approach, considering further scientific development. Future developments on the standardization of CPP and on the environmental sustainability assessment of start-ups, e.g., in the form of a DIN SPEC 90051-2, as well as advancements in the field of prospective LCAs could be of interest here.

At the same time, the volatility of the approach also makes high transparency and effective communication especially important. This is further underlined by the limited methodological depth, which is related to challenges such as the lack of expert knowledge and the availability of resources, as described for the World Fund under Data collection and system boundaries (compare 3.2). This relates to one of the main challenges of start-up specific assessment approaches the lack of specific knowledge associated with the complexity of environmental sustainability assessments. Most approaches from the literature approach this challenge by simplifying the assessment [11,20,22,26]. This bears the risk of an oversimplification of the assessment approaches. Simplified (qualitative) assessment approaches could help in the initial introduction of a more sustainable mind-set in a start-up and thus justify such extreme simplification. However, it might be misleading to put simplified approaches in the same category as approaches aiming at more detailed (quantitative) assessments. An appropriate depth and diligence in the assessment is necessary to allow for a more informed investment decision.

An oversimplification of the methodology, as well as other risks, such as incentives for a particular assessment outcome, should therefore be addressed through a high degree of transparency. Adhering to the basic principles of sustainability assessment and measurement, including transparency, effective communication, and broad participation [75], therefore remains an imperative prerequisite for a good assessment. From a macro level perspective, continuous analysis and improvement of the approach as well as adhering to principles such as transparency, effective communication, and broad participation could then provide the opportunity to contribute to a standardization process.

Overall, the case-specific analysis of the CPP approach offered life cycle-based guidance for this assessment approach while considering specific assessment challenges. The approach constitutes an important first step in the formalization of the assessment of start-ups CPP. At the same time, it is important to emphasize that regardless of the existing challenges, a certain depth and diligence in the assessment must always be ensured to avoid greenwashing. Otherwise, the potential for redirecting investments and business models to contribute to climate protection cannot be realized.

5. Conclusions

The goal of this paper was to develop life cycle-based guidance for assessing the CPP of start-ups, through an exploratory case study which provided insights and identified potential for improvement in the environmental sustainability assessment practices of VC firms and was used to elicit appropriate criteria and procedures for directionally sound assessment. The case study provided a detailed insight into the CPP assessment approach developed and used by the climate tech VC firm World Fund. Here, the case study shows how the CPP assessment follows the investment process with a CPP screening in the first steps and the main CPP assessment as part of the commercial due diligence. The comparison of the specific CPP carbon footprint approach with the ISO standardization of LCA and carbon footprints along eight criteria provides detailed methodological insights and identifies a potential for improvement for seven of the eight criteria, thereby answering the research question. For these seven criteria, CPP-specific guidance for further development of the approach was developed discussing, for example, the use of scenarios, the complexity of meta-analyses, and the need to avoid misleading incentives. These contributions not only address the research gap of environmental sustainability assessment for start-ups in the venture capital context but also provide important insights for practitioners.

The developed guidance, as shown in the discussion, highlights the need for a high degree of transparency and adherence to basic principles of sustainability assessment, further including broad participation and effective communication. The challenges of CPP assessment, including high volatility, the balance between methodological depth and simplification of assessment, and potential incentives for certain assessment outcomes, require this additional layer of accountability. The same can be applied to other potential assessors, as all environmental sustainability assessment faces specific assessment challenges based on their specific technology, business model, and investment context. This calls for a high level of diligence and integrity from the assessors.

While the chosen case study approach allowed for an in-depth analysis of a single assessment approach, it is limited by the scope and time frame of the study. As the CPP assessment is implemented and used in practice by the World Fund, it is subject to rapid change and adaptations, based on the needs and insights from the VC firm. The case study is therefore only able to present the assessment approach as it was implemented during the time of analysis as of December 2022, and could not include an observation of an implementation of the suggested guidance. Future research should therefore consider long-term case studies, following the implementation of suggested solutions, as well as the study of multiple cases for theory generation, allowing the development of more differentiated guidance, and a more detailed analysis of the benefits and challenges of a VC firm as assessor. Another limitation of the case study was the selection of a young VC firm. While the World Fund meets the criteria for case selection—accessibility of data, relevance, and potential to learn from the case—other cases, such as older, more experienced assessment approaches, could provide additional or different insights.

A further limitation to the result is that due to the scope of this research, other standards and guidelines such as the Product Environmental Footprint [82] or the GHG protocol [18], social and environmental aspects of sustainability, and post-investment assessments and monitoring were not considered. Future research should therefore look more closely at how to strike a balance between simplification and the required depth of assessment, especially in regard to a sustainability assessment that encompasses all dimensions of sustainability. Further, approaches for post-investment monitoring and repeated assessments, and an inclusion of other LCA and carbon footprint standards could lead to additional insights.

Given the urgent need to mitigate climate change and the fact that VC investments are an underestimated tool for the diffusion of climate technologies, the need for start-up specific environmental assessment approaches becomes clear. Considering the nascent research field, the very early stages of standardization of these approaches, and at the same time VCs developing and implementing their own assessment approaches, a scientific guide for start-up assessment is needed to support and guide good assessment practice.

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

Supplementary Materials

The following supplementary materials are available at https://www.hos.pub/articles/hsustain2040015/s01

Document S1: Climate assessment report - #COMPANY#'s climate performance potential (CPP); Table S1: Observation Notes.

Acknowledgments

The authors would like to thank Daniel Valenzuela and the World Fund for the good cooperation and the provided insights.

Author Contributions

Conceptualization: F.D., & V.B.; Data curation: F.D.; Formal analysis: F.D.; Methodology: F.D.; Supervision: M.F.; Validation: V.B.; Visualization: F.D.; Writing – original draft: F.D.; Writing – review & editing: V.B., & M.F.

Conflicts of Interest

The authors have no conflict of interest to declare.

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