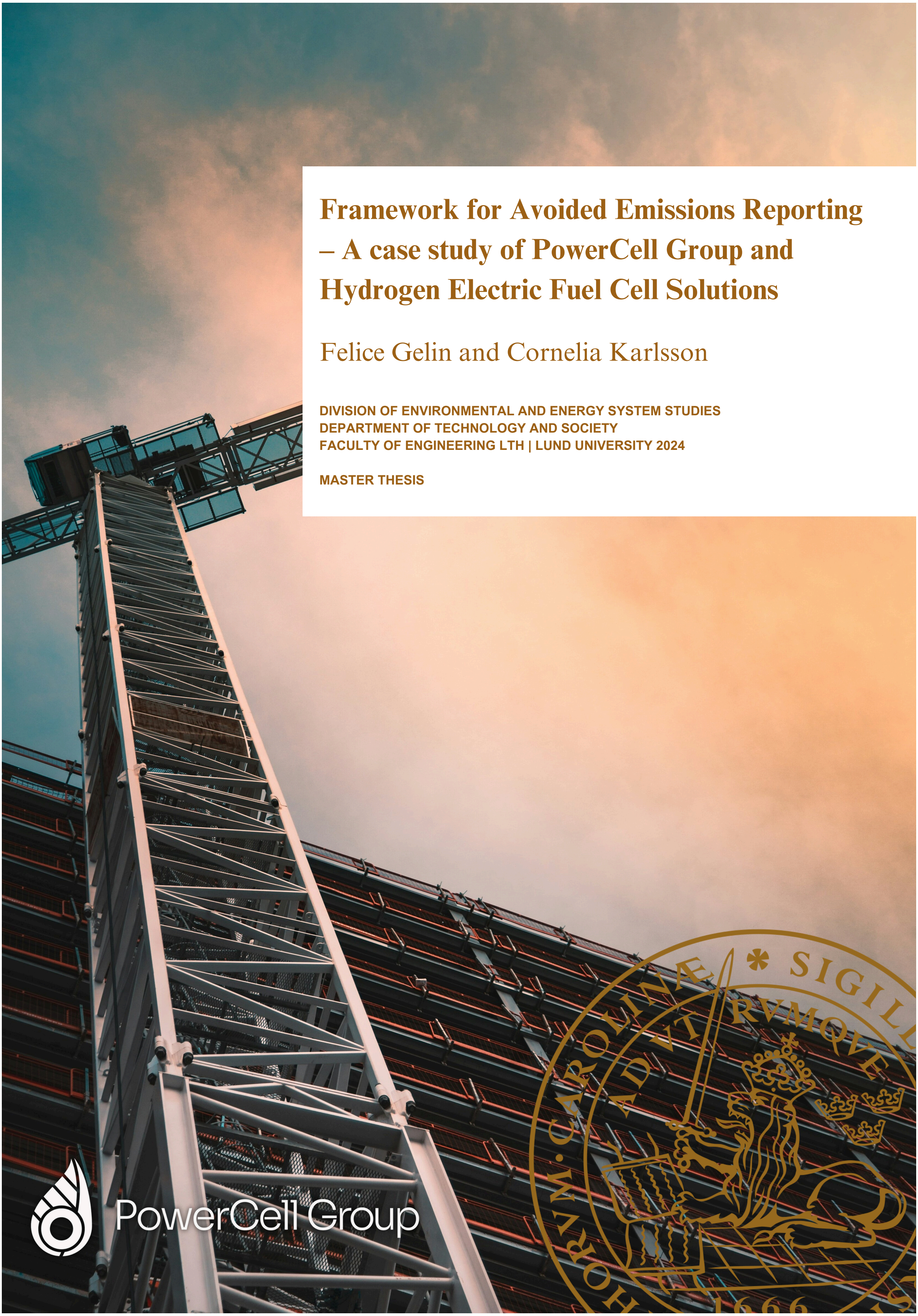

Framework for Avoided Emissions Reporting – A case study of PowerCell Group and Hydrogen Electric Fuel Cell Solutions

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DIVISION OF ENVIRONMENTAL AND ENERGY SYSTEM STUDIES
DEPARTMENT OF TECHNOLOGY AND SOCIETY
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY 2024

MASTER THESIS

PowerCell Group

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LUNDS UNIVERSITET

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Published by
Department of Technology and Society
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Avoided emissions (Scope 4)
Division: Division of Environmental and Energy System Studies
Supervisor: Pål Börjesson
Co-supervisor: Victor Åkerlund
Examiner: Max Åhman

Publication identifiers: ISSN 1102-3651
Report number: ISRN LUTFD2/TFEM—24/5211--SE + (1-131)

Acknowledgments

This master thesis has been written as the concluding assignment of the MSc in Industrial Engineering at Lund University, Faculty of Engineering, LTH. The thesis was written by Felice Gelin and Cornelia Karlsson, where both authors participated equally, between January and June 2024. It was conducted in collaboration with the company PowerCell Group and the Examiner of the thesis was Max Åhman at the department of Technology and Society, Environmental and Energy Systems Studies.

We want to express our deepest gratitude to our supervisor, Pål Börjesson, for his guidance and support throughout the writing process. His encouragement and belief in our capabilities provided us with the confidence we needed to get through this process. We especially appreciated his ability to understand and address our questions, regardless of how unstructured our thoughts may have appeared. His straightforward and insightful guidance and feedback was very important when shaping this thesis.

We also want to extend our thanks to Victor Åkerlund at PowerCell Group, for his encouragement and genuine interest in our work. His continuous feedback and contributions have provided us with critical insights and important perspectives that have helped us in our process. We always felt that Victor prioritised our weekly meetings and that our work mattered to PowerCell, which was highly motivating.

Last but not least, to our family and friends, thank you for your support during this spring and throughout our five years in Lund!

Lund, June 2024

Felice Gelin & Cornelia Karlsson

Sammanfattning

Denna rapport utforskar konceptet undvikna utsläpp, även kallat Scope 4-utsläpp, som en del av företags hållbarhetsrapportering- och kommunikation. Med fokus på PowerCell Group, en leverantör av vätgasdrivna bränsleceller, undersöker studien hur Scope 4-utsläpp kan integreras i hållbarhetsrapportering och vilka möjligheter och utmaningar detta innebär.

Undvikna utsläpp refererar till de minskningar av växthusgasutsläpp som indirekt uppnås genom användningen av produkter eller tjänster som ersätter mer utsläppsintensiva alternativ. Trots att Scope 4 har potential att spela en viktig roll för klimatlösningsföretag finns där ännu ingen standardiserad metodik för att rapportera undvikna utsläpp. Detta arbete syftar till att adressera denna brist genom att utveckla ett förslag på metodik för att kvantifiera och rapportera undvikna utsläpp, i linje med befintliga regelverk och standarder.

Genom en omfattande litteraturstudie, utveckling av ett konceptuellt ramverk och en fallstudie på PowerCell Group, ger avhandlingen insikter i det nuvarande rapporteringslandskapet för undvikna utsläpp. Den regulatoriska miljön diskuteras, och olika vägledande ramverk och företagsexempel granskas för att sedan utmynna i ett förslag på metod för Scope 4-rapportering.

Resultaten visar att även om rapportering av undvikna utsläpp erbjuder betydande möjligheter för företag att demonstrera sitt bidrag till en grön omställning, medför det också stora utmaningar. Dessa inkluderar risken för att anklagas för greenwashing och svårigheten i att ta fram trovärdiga och lagenliga gröna utlåtanden. Rapporten avslutas med rekommendationer för hur företag effektivt kan integrera Scope 4 utsläpp i sin hållbarhetsrapportering, och därigenom stödja den globala gröna omställningen.

Abstract

This thesis explores the concept of Scope 4 emissions, also known as avoided emissions, within corporate sustainability reporting. With a focus on PowerCell Group, a provider of hydrogen fuel cell solutions, this study investigates the integration of avoided emissions reporting, assessing both the potential benefits and the challenges associated with this practice.

Avoided emissions refer to reductions in greenhouse gas (GHG) emissions indirectly caused by the adoption of products or services that replace more emission-intensive alternatives. Despite their potential to significantly impact corporate environmental strategies, Scope 4 emissions are not yet widely recognised or standardised in corporate emissions reporting. This research aims to fill that gap by developing a robust methodology for quantifying and reporting avoided emissions, aligned with existing regulatory frameworks and standards.

Through a comprehensive literature review, development of a conceptual framework, and a detailed case study of the PowerCell Group, this thesis provides insights into the current landscape of avoided emissions reporting. It discusses the regulatory environment, and examines various guiding frameworks and company examples to propose a standardised approach for Scope 4 reporting.

The findings suggest that while reporting avoided emissions offers significant opportunities for companies to demonstrate their environmental impact, it also presents challenges such as potential accusations of greenwashing and the complexity of creating credible and compliant claims. The thesis concludes with recommendations for companies on how to effectively integrate Scope 4 emissions into their sustainability reporting practices, thereby supporting the global green transition.

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Abbreviations

BAU	business as usual
BOM	bill-of-materials
CSRD	Corporate Sustainability Reporting Directive
CO_2e	carbon dioxide equivalents
EPA	Environmental Protection Agency
ESG	environmental, social and governance
EU	European Union
GHG	greenhouse gas
GWh	gigawatt-hour
H_2	hydrogen
HVO	hydrotreated vegetable oil
IEA	International Energy Agency
ILCD	International Life Cycle Data system
ISO	International Organization of Standardisation
kWh	kilowatt-hour
LCA	life cycle assessment
LCI	life cycle inventory
Mg	megagram
MWh	megawatt-hour

NFRD	Non-Financial Reporting Directive
NZI	Net Zero Initiative
PEM	Proton exchange membrane
PPP	polluter pays principle
RED II	Renewable Energy Directive II
RISE	Research Institutes of Sweden
SBTi	Science-Based Targets initiative
SDG	Sustainable Development Goals
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute

Definitions

Life cycle assessment	Conducting a life cycle assessment (LCA) involves quantifying the environmental impact throughout different stages of a product's life cycle, from raw material acquisition to recycling and final disposal (Svenska institutet för standarder [SIS] 2006). It follows a clear methodology defined by ISO 14040/14044, see section 3.2.4.
Functional unit	When an LCA is carried out, a functional unit must be defined initially (Sveriges Lantbruksuniversitet (SLU) 2022). The functional unit describes the quantity and performance of the product or product system under assessment.
CO_2-equivalent	A metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide (Eurostat 2023).
Attributional approach	Using an attributional approach when conducting an LCA involves estimating the environmental burdens directly related to the product under assessment (Ekvall 2020). This approach uses average data and allocation is performed by assigning environmental burdens of a process to different parts of the life cycle.
Consequential approach	Using a consequential approach when conducting an LCA means that all direct and indirect environmental burdens resulting from the production and use of the product are taken into consideration (Ekvall 2020). This approach avoids allocation and instead uses system expansion.

Net Zero	Net zero emissions defines the state where GHG emissions due to human activities and removals of these gases are equal, meaning that the overall activity does not imply increased emissions in the carbon cycle (United Nations n.d.).
Climate solution	A climate solution must have a significantly lower carbon footprint per functional unit in comparison to the business-as-usual option it replaces (Falk, Wigg, Axelsson & Becker 2023). The solution's primary purpose is to enable others to reduce their emissions, and it must meet or exceed a credible threshold of emissions per functional unit, making it fit for a net zero world.
Carbon credits	Financial instrument where the buyer pays another company to take some action to reduce GHG emissions, which the buyer then can take credit from (UNFCCC 2021).
Rebound effects	Rebound effects can be described as the indirect emission increase due to the introduction of the climate solution (Stephens and Thieme 2020). For instance, the construction of new required infrastructure can be considered a rebound effect.
Enabling effects	The enabling effects of a solution or technology can be described as the carbon-saving mechanisms and are what causes the avoided emissions (Stephens and Thieme 2020). Enabling effects can be both primary and secondary. The distinction is that secondary enabling effects have an impact over a longer period of time and can therefore be more difficult to identify and calculate.
Brown hydrogen	In the hydrogen production context, "brown" hydrogen is the name of hydrogen produced with brown or black coal combustion (Swinburne University 2022).
Grey hydrogen	Grey hydrogen is produced by natural gas or methane using steam methane reformation (Swinburne University 2022).

Green hydrogen	As opposed to brown or grey hydrogen, “green” hydrogen is produced with electrolysis using only renewable sources of energy (Swinburne University 2022).
Blue hydrogen	Blue hydrogen is a common name for decarbonised hydrogen, which means that it has been produced just like grey hydrogen, but during manufacturing, carbon capturing and storage are performed (Swinburne University 2022).
Burden-free hydrogen	Burden-free hydrogen means that the hydrogen is produced from burden-free electricity (0 CO_2e/kWh). This expression is used in chapter 4.2 Case study.

1 Introduction

Since the late 1800s, the global average temperature has been steadily rising primarily due to the burning of fossil fuels (United Nations 2023). The impacts of global warming and climate change include extreme weather, like droughts, storms, wildfires, polar ice melting, water scarcity, and rising sea levels, all of which pose significant threats to life on Earth. In response, the international community has made efforts to address climate change. For example, with its establishment in 1992, The United Nations Framework Convention on Climate Change (UNFCCC) has facilitated global cooperation aimed at reducing greenhouse gas (GHG) emissions (UNFCCC n.d.). Another milestone is the Paris Agreement adopted in 2015, which is the latest legally binding international treaty signed by 196 parties. The main goal is to hold “the increase in global average temperature to well below 2℃ above pre-industrial levels” and “to try to limit the temperature increase to 1.5°C above pre-industrial levels”. As a result, all members of the European Union (EU), as parties to the UNFCCC, its Kyoto Protocol and the Paris Agreement, are obliged to report on their GHG emissions annually (European Commission n.d.).

To reduce GHG emissions and achieve the goals outlined in the Paris Agreement, one important step is to hold large companies accountable for their emissions (Science Based Targets n.d.). The GHG Protocol, created by the World Resource Institute (WRI), has played a key role in this effort by providing GHG accounting standards for companies (Position Green n.d.). The GHG Protocol, today the most widely used GHG accounting standard, introduced the concept of Scopes: a system aimed to help measure progress towards reducing emissions (Read & Shine 2022). Scope 1, 2 and 3 represent a way of categorising GHG emissions that a company produces, both in its own operations and its value chain (Deloitte n.d.). Scope 1 covers direct GHG emissions from sources under the company’s control, while Scope 2 includes indirect emissions from activities like electricity generation (GHG Protocol n.d.). Scope 3 encompasses all other indirect GHG emissions from the company’s value chain. Up until now (2024), emission reporting within scope 1, 2 and 3 have been voluntary, but as the global focus on climate change intensifies, so do regulations (Position Green n.d.). In the EU for instance, the Corporate Sustainability Reporting Directive (CSRD) mandates nearly 50,000 companies to disclose their emissions and reduction targets across all three scopes, with enforcement beginning in 2025.

Although regulations for sustainability compliance continue to evolve, a debate has arisen regarding whether these create additional challenges for sustainably oriented businesses to establish and expand (Stephens & Thieme 2020). Regulatory drivers have consistently focused on reducing absolute emissions at an operational level within organisations, rather than transforming and developing ideas that could reduce and avoid emissions on a system-wide level. Consequently, this creates a reporting standard that possibly makes organic growth and green claims contradictory. For example, a solar power company will always disclose increasing absolute emissions in their growth phase, due to factors such as increasing production volumes or new facilities. This can be set against an oil exploration company that has already finished its growth journey and thus possesses enough resources and emission reduction potential to always disclose an improvement in its sustainability reports. Although the solar power company arguably plays a more important role in the system-wide transition to achieve the goals outlined in the Paris Agreement, it is noteworthy that the oil company may present a more favourable image in their numbers. To accelerate the green transition, so-called climate solutions are needed, and their possibility to expand must be facilitated, not worked against (Falk et al. 2023). While many climate solutions are already available, the scaling and implementation are hindered by inadequate recognition and accountability mechanisms within current frameworks and legislation. This is where the inclusion of reporting on Scope 4 emissions becomes relevant.

The concept of Scope 4 emissions, which will be the central focus of this thesis, represents an incentive that could potentially target the issues described above and be leveraged by companies that provide climate solutions. Scope 4 emissions, also known as avoided emissions, refer to reductions in emissions indirectly caused by a product or service that can replace a, from a sustainability perspective, worse-performing product or service (Draucker 2013). This thesis aims to investigate whether companies providing these climate solutions should integrate Scope 4 emissions into their sustainability reporting and how they can accomplish this effectively while being compliant with current and future regulations and also avoiding accusations of greenwashing. Additionally, a case study on PowerCell Group will be performed. PowerCell Group offers hydrogen (H_2) fuel cells that can, for example, substitute diesel gensets, thus serving as a good example of a company that potentially would benefit from Scope 4 reporting.

1.1 What is Scope 4 emissions?

Scope 4 emissions, or avoided emissions, can be described in several different ways and the interpretation is not necessarily straightforward. As Draucker (2013) articulates it, Scope 4 emissions are “(...) emission reductions that occur outside a product’s life cycle or value chain but as a result of the use of that product”. Alternatively, one definition is that avoided emissions occur when a product “(...) enables the same function to be performed with significantly less GHG emissions” (Stephens & Thieme 2020). Examples of solutions that lead to avoided emissions include fuel-saving tyres, low-temperature detergents or energy-saving phone batteries (Draucker 2013). Other products that contribute to avoided emissions are less obvious. For example, the use of teleconferencing services has been argued to also lead to avoided emissions as it reduces the need for people to travel, thereby lowering GHG emissions. Figure 1.1 shows a graphical explanation of Scope 4 emissions.

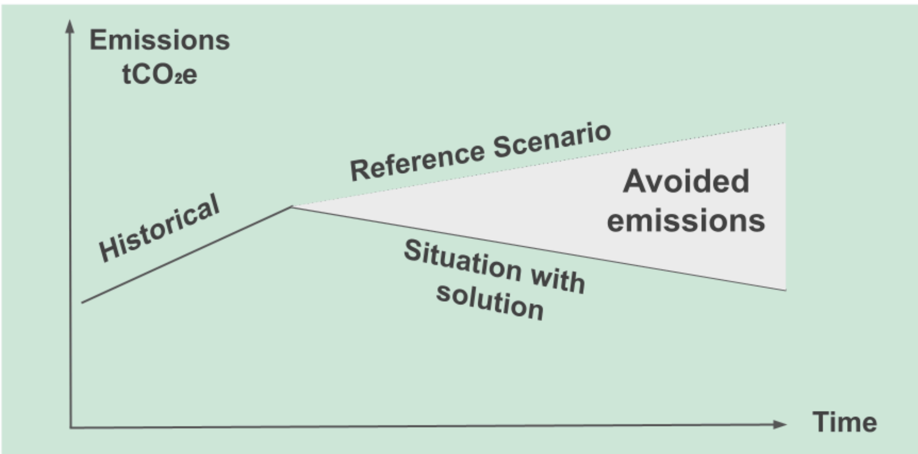

Figure 1.1 Graphical explanation of avoided emissions (WBSD & NZI 2023).

Scope 4 emissions differ from Scopes 1, 2, and 3 as it involves quantifying emissions that were never generated and always in relation to a reference scenario, while the other GHG inventory accounting (Scope 1, 2 and 3) is quantified from the company’s point of view (see Figure 1.2 for illustration). The reference scenario represents the product that would have been used if the solution enabling the emission reduction did not exist. Hereafter, the solution enabling the avoided emissions will be referred to as “the solution”.

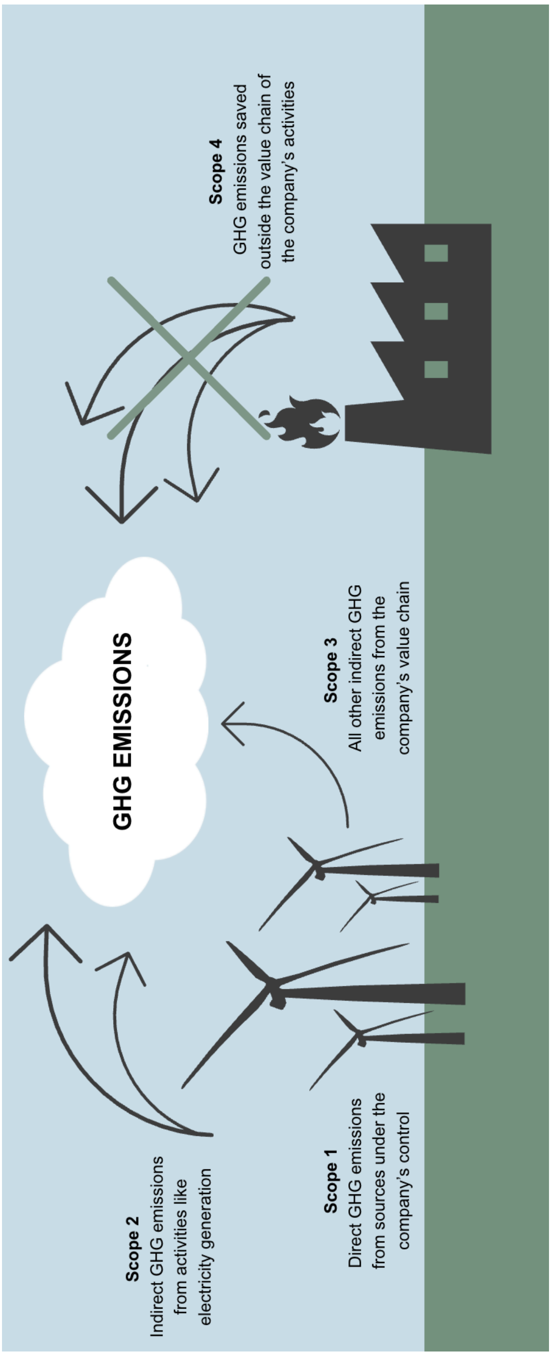

Figure 1.2 Illustration of the relationship between Scope 1-3 and Scope 4, wind power example.

The concept of avoided emissions was officially introduced in 2013 by the WRI through the GHG Protocol. Since then, several companies have incorporated this metric into their sustainability reporting. However, due to the lack of an international standard, this has resulted in inconsistent terminology and varying approaches to quantification, which diminishes the validity and integrity of avoided emissions claims.

1.2 The risk of green claims

A major risk in communicating avoided emissions and other green claims lies in being accused for greenwashing. This means that the company seeks to portray itself as "environmentally friendly" by emphasising selected environmentally conscious initiatives in its marketing campaigns. By cherry picking numbers that make the amount of Scope 4 emissions look favourable for the concerned company, it can be questioned whether allowing this kind of reporting methods will only result in deceptive and inconsistent statements.

A parallel can be drawn to claims about climate neutrality and climate compensation claims. These statements are based on calculations where companies can "subtract" negative impact generated from carbon sequestration initiatives, called offsets, from their own operational emissions (UNFCCC 2021). Such an example could be that the company invests in tree plantations or methane capturing through carbon credits. In 2023, this market was valued at USD 103.8 billion (Global Market Insight 2023). However, recent investigations reveal that the majority of these investments are "worthless", as companies often use exaggerated carbon-saving indices in their assessments. Additionally, only a fraction of the projects invested in are actually executed (The Guardian 2023). Not only has this shedded bad light on companies who use these carbon offsets in their reporting, but also raised the question whether offsets, "climate compensation" and "climate neutrality" are just new tools to buy oneself free from necessary technological- and behavioural changes (Naturskyddsföreningen 2021). This is a critical risk to address also when considering avoided emissions reporting, as consumers become more aware yet more sceptical of green claims after decades of unfulfilled corporate promises (Svanen 2022).

1.3 Case Study Company: PowerCell Group

To put Scope 4 reporting into an applicable perspective, a case study will be performed on PowerCell Group – a former spin-out from Volvo Group, providing hydrogen fuel cell stacks and fuel cell systems (see Figure 1.3 for example) that are fully exchangeable substitutes to numerous fossil-fueled technologies (PowerCell Group n.d.a). Fuel cell technology is based on electrochemical reactions between hydrogen and oxygen, which enables electricity generation causing no emissions of greenhouse gases and pollutants in its use phase. In addition, the hydrogen fuel cell system solves a key challenge of today's renewable energy system (Gandiglio et al. 2022), being the energy storage issue when there is an imbalance between renewable energy demand- and supply. The surplus of renewable energy, not needed for immediate consumption, can be stored with hydrogen as an energy carrier, and fuel cell systems then make it possible to use the hydrogen at a later stage to generate electricity (see Figure 1.4 for visualisation). PowerCell Group, hereafter only PowerCell, also states that their products are not limited to installation size and is more than twice as efficient as traditional combustion engine technology (PowerCell Group n.d.c). As of 2024, PowerCell's applications can be used within a wide range of industries, such as marine, on- and off-road, aviation and stationary off-grid power generation.

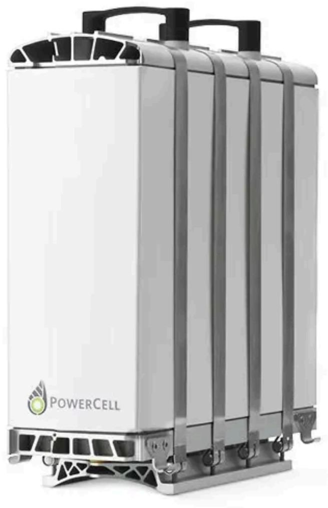

Figure 1.3 PowerCell Fuel Cell stack (PowerCell Group n.d.c).

The basic fuel cell consists of an electrolyte membrane where the reaction happens, a platinum catalyst, and bipolar plates where the hydrogen and oxygen molecules pass (PowerCell Group n.d.c). The specific technology that PowerCell adopts is called PEM (Proton Exchange Membrane), which is the most researched and dominating kind of hydrogen fuel cell on the market today. This may be explained by the fact that reactions are possible at temperatures as low as -40°C, and up to 120°C, but still generate high power density, making it excellent for portable applications. However, operating at low temperatures requires an expensive platinum catalyst, which causes costs to inflate. Apart from the major components, each fuel cell application also comes with its own set of complementary components for set-up and integration.

Although the fuel cell technology itself has passed the product development stage, its promise to provide green energy is highly dependent on the advancement of green hydrogen production and infrastructure. With the great majority of the hydrogen produced today being “grey”, meaning that it is produced from natural gas or methane, hydrogen accounts for a substantial bottleneck in the green energy transition (PwC 2024). To label hydrogen as “green”, it is required that it is produced using only biogas or electricity from renewable sources. This means that an additional bottleneck further down in the value chain is that of the availability of renewable energy. The emission intensity of hydrogen production, thus the emission intensity of fuel cell use, is fully determined by the electricity mix that is used (Yu, Wang & Vredenburg 2021). PowerCell addresses the limited availability of green hydrogen in today’s market landscape but also recognises the market’s uprise (Powercell Group n.d.c), which will be further discussed in the following section.

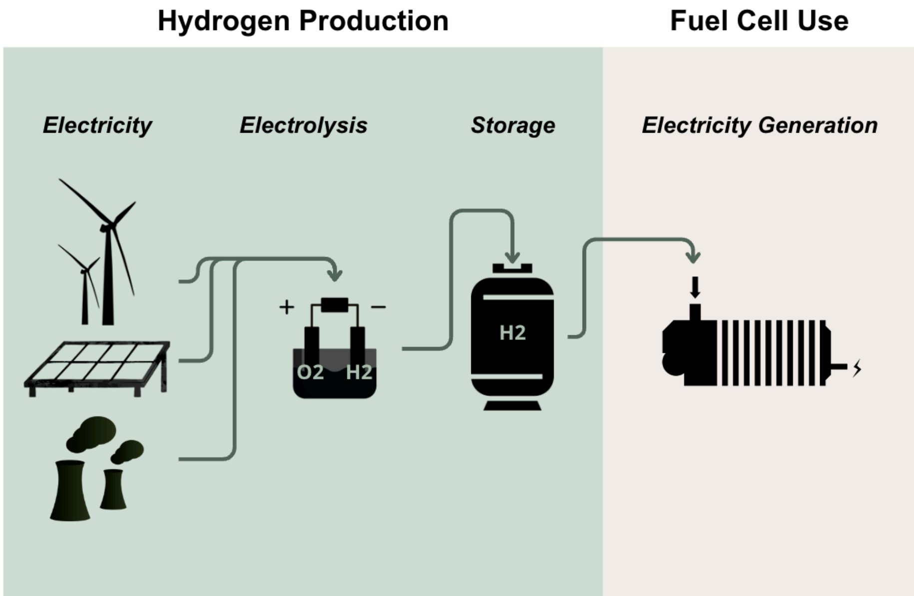

Figure 1.4 Conceptual illustration of hydrogen production and the general fuel cell application.

1.4 Hydrogen and the hydrogen market

Given its central role in fuel cell systems, it is important to acknowledge the current state of hydrogen and its function within the energy industry. Today, it constitutes a fundamental part of especially the modern refining sector due to its light, storable, energy-dense and low-emission features, although it has a history that reaches almost 200 years (International Energy Agency (IEA) 2019). Considering its clean element, that is, that it only produces water when consumed, hydrogen has also become an attractive fuel option for transportation and electricity generation applications (U.S Department of Energy n.d.) As a result, the global demand for hydrogen has increased more than threefold since 1975 (IEA 2019).

In theory, hydrogen can be produced both from fossil fuels, biomass, or even water. However, as of 2024, natural gas accounts for around 75% of the total annual production, which in turn accounts for about 6% of the global natural gas use. Energy cost is considered the major factor in this trend, with fuel costs being the sector's largest cost component. According to IEA (2019), this has resulted in annual CO_2 emissions from the hydrogen industry equivalent to that of the UK and Indonesia combined.

On the other hand, there is a growing consensus that the hydrogen market can become an important part of the clean energy transition. As of 2019, there were around fifty targets, mandates and policy incentives in place from numerous countries globally, to support the hydrogen industry (IEA 2019). Additionally, the spending on hydrogen research, development and demonstration is also increasing, especially on vehicle applications. Green hydrogen offers an alternative to grey hydrogen and is growing in interest also from a market perspective due to declining costs for renewable electricity. However, if all of today's hydrogen production were to be generated from electricity, it would result in an electricity demand equivalent to more than the total annual electricity generation of the EU. One hypothetically discussed future scenario is building electrolysers at locations that already have excellent renewable resource conditions, which could create strongly competitive low-cost options for today's hydrogen producers.

In a report from McKinsey (2024), it was projected that blue and green hydrogen demand will grow substantially by 2050, stating that after 2025, close to all new hydrogen production coming online is expected to be blue and green hydrogen. In their scenario analysis, all potential future scenarios show a clear rise in green and blue (grey hydrogen with carbon capture and storage) hydrogen, and a decrease in grey hydrogen. The industries driving this transition are expected to be existing industrial use initially, but later on the mobility sector.

Aligned with McKinsey's findings, the IEA (2023) has also released projections indicating a decrease in the emissions intensity of hydrogen production in the coming years. According to the IEA's "Net Zero by 2050"-scenario, by 2030, the average emissions intensity is expected to decrease to 6-7 kg CO_2e/kg H_2, and by 2050, it will be further reduced to less than 1 kg CO_2e/kg H_2. For context, in 2021, the average emissions intensity of global hydrogen production was 12-13 kg CO_2e/kg H_2. The EU is one of the actors driving the development with its Hydrogen Strategy (European Commission n.d.e). The strategy outlines a plan for increasing the production of green hydrogen by 2030 and includes several action points regarding investment support, increasing production and demand, establishing a hydrogen market and infrastructure, prioritising research, and fostering international cooperation. Among countries in the EU, Sweden is one of the countries where green hydrogen projects are expected to play a key role in the climate transition, and are set to reduce national emissions by 14% in 2045 (Fossilfritt Sverige n.d.). The Swedish hydrogen strategy states ambitious green hydrogen production targets for both 2030 and 2045. To summarise, these projections and trends outline a clear reduction roadmap for emissions in hydrogen production, indicating the importance of hydrogen as an energy carrier for a sustainable future.

1.5 Purpose and research questions

The purpose of this study is to explore the concept of Scope 4 emissions, examining it both in a broader context and specifically in the context of PowerCell. The terms Scope 4 and avoided emissions will be used interchangeably. Scope 4 has not received similar recognition and definition in literature as Scope 1, 2 and 3 since it is not standard, making it a less established concept. However, as outlined earlier, it could serve as a valuable tool for companies providing climate solutions, emphasising the need to understand and potentially implement the usage of Scope 4.

The purpose will be achieved by analysing and discussing the following questions:

Q1 What are the trends, challenges, and best practices in avoided emissions reporting as documented in current literature, including the regulatory context?

Q2 What methodology should be used to quantify avoided emissions, particularly in the context of PowerCell Group?

Q3 What are the possibilities and barriers associated with avoided emissions reporting?

2 Method

To fulfil the purpose of this thesis, a hybrid approach incorporating different methods has been employed. The overarching methodology is illustrated in Figure 2.1 and comprises four sequential parts. The initial phase involved a comprehensive literature review, which was then followed by the development of a conceptual Scope 4 framework, using the main insights from the preceding section. The third part entailed a case study on PowerCell Group, where the framework was applied in practice. Finally, the perspective was broadened with a general discussion and insights about Scope 4 reporting and its practical implications for the case study company. Each of the four parts is described in the following sections.

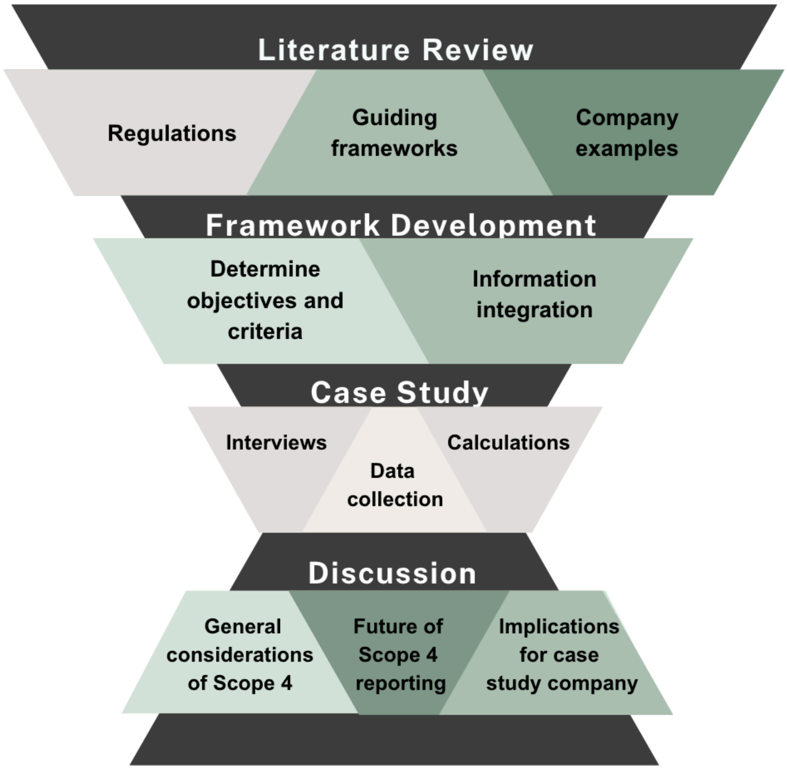

Figure 2.1 The overarching methodology is built up by four sequential steps.

2.1 Literature review

The literature review consisted of three different parts, each focusing on a specific category of literature. In the first part, a review of current legislation potentially impacting Scope 4 reporting was conducted. The second part consisted of reviewing current guiding framework publications on Scope 4. The final part involved mapping out examples of companies that are already utilising and communicating their avoided emissions today. For each of the three parts, a summary of the main findings followed.

To initially determine what literature to review, two selection criteria for each part of the review were established. Considering which regulations to incorporate, the criteria was that the regulations had to be geographically relevant to the case study company, ensuring applicability to its business environment. Secondly, the selected regulations had to impact sustainability reporting, thereby implying a potential influence on Scope 4 reporting as well.

Regarding the selection of guiding documents to review, the first criteria was that all literature had to be published after 2018 to ensure accuracy and relevance. Secondly, the literature should be written and published by well-known organisations or institutions, ensuring the reliability of the provided information.

Lastly, regarding the criteria for selecting the company examples, the company had to have publicly disclosed their avoided emissions as of March 2024. Secondly, the selected company should have some similarities with the case study company, including operating within comparable industries and being regarded as a potential climate solutions company. This to allow for easier comparison with the case study company. As part of the review of the company examples, to get a more comprehensive understanding of how the companies had quantified their avoided emissions, all selected companies were contacted and given the opportunity to participate in an interview. However, only one company accepted and therefore one interview was held with two people representing that company (see Table 2.2). All selection criteria are summarised in Table 2.1.

Table 2.1 Criteria for literature selection.

Literature review	*Selection criteria*
Review of regulations	● Geographically relevant to the case study company ● Will most likely affect Scope 4 reporting to some extent
Review of guiding frameworks	● Published after 2018 to ensure accuracy and relevance ● Published by established och recognized organisations and institutes
Review of company examples	● Currently (March 2024) communicating avoided emissions ● Potential climate solutions company operating within similar industry to that of the case study company

Table 2.2 Interview conducted as part of the literature review.

Interview person	*Date*
Eric Zinn, *Chief Sustainability Officer at Göteborg Energi* and David Holmström, *Environmental Engineer at Profu*	25th of March 2024

2.2 Framework development

When the literature review was completed, the main findings were used to develop a conceptual framework for Scope 4 reporting. This part of the study involved first determining the objectives and criteria for the framework; to decide what factors, aligned with the literature, that must be prioritised and considered when designing the approach to quantifying avoided emissions. When this part had been completed, the next part entailed synthesising and integrating the gathered information into chronological steps that also lived up to the established criteria. The final framework is described in section 4.1.

2.3 Case study

In the third part of this thesis, the Scope 4 framework was applied in a practical setting to the case study company. To execute the steps outlined in the framework, this section of the thesis included several activities. Firstly, interviews were conducted with representatives from the case study company or representatives who had worked with the company in question, see Table 2.3.

This was motivated by the need to get a comprehensive understanding of the company offering. Two interviews were held with Mats Zackrisson (Researcher at Research Institutes of Sweden (RISE)), who had conducted a life-cycle assessment (LCA) for the case study company, and Martin Pontén (Project Manager at PowerCell Group), who had also been involved in the life-cycle assessment. These interviews provided clarification on the methodology that had been employed when the LCA was performed. One final interview was held with Victer Åkerlund, Chief Analytics and Sustainability Officer at PowerCell, who provided information on PowerCell's current sustainability reporting procedures.

Table 2.3 Interviews conducted as part of the case study.

Interview person	***Date***
Mats Zackrisson, *Researcher at RISE*	6th of February 2024
Martin Pontén, *Project Manager at PowerCell*	22nd of February 2024
Victor Åkerlund, *Chief Analytics and Sustainability Officer at PowerCell*	16th of April 2024

In parallel with the interviews, necessary primary and secondary data was collected through both internal sources from the case study company and public sources. Lastly, data and insights from interviews were used to conduct all steps to derive the final calculations of avoided emissions. The case study is presented in section 4.2.

2.4 Discussion

Following the case study, Scope 4 reporting from a holistic perspective will be discussed. This discussion is structured into three key sections, initially addressing the most critical considerations for avoided emissions reporting that must be taken into account today. Additionally, the future of Scope 4 reporting is explored, examining future factors that will have a significant impact. Finally, the implications for the case study company will be summarised and discussed, outlining a strategic path forward for their Scope 4 reporting efforts.

3 Literature review

The following chapter will present the findings from the literature review, which is divided into three sections: a review of regulations, a review of guiding frameworks, and a review of company examples. Each section will conclude with a summary of the key findings.

3.2 Review of regulations

The next section will examine the main insights from the reviewed regulations. The regulations are the EU Taxonomy, Corporate Sustainability Reporting Directive and Green Claims Directive, as shown in Table 3.1.

Table 3.1 Reviewed regulations.

Regulations	***Legislative body***	***Year of implementation***
Taxonomy	European Union	2024–2026
Corporate Sustainability Reporting Directive (CSRD)	European Union	2023–2029
Green Claims Directive	European Union	2024–2027

3.2.1 EU Taxonomy

In 2020, the EU approved "The European Green Deal" – a set of policy initiatives with the common purpose of facilitating the path to a climate-neutral European Union in 2050 (European Commission n.d.g). To distinguish what companies and activities should be labelled as "sustainable" and thereby qualify for benefits such as investments towards sustainable projects, the deal includes a common classification system with predefined criteria (European Commission n.d.c). This system, named the "EU Taxonomy", is a sustainability–finance framework with an underlying aim to direct investments towards green activities, while also creating security for investors and protecting stakeholders from greenwashing. All organisations with more than 500 employees and of public interest – encompassing companies listed on the stock market, insurance firms, and other entities designated as such by member states – are impacted.

To qualify under the EU Taxonomy, there are six climate and environmental objectives of which the company in question needs to fulfil at least one. These are (1) climate change mitigation, (2) climate change adaptation, (3) sustainable use and protection of water and marine resources, (4) transition to a circular economy, (5) pollution prevention and control, and (6) protection and restoration of biodiversity and ecosystems, as seen in Figure 3.1.

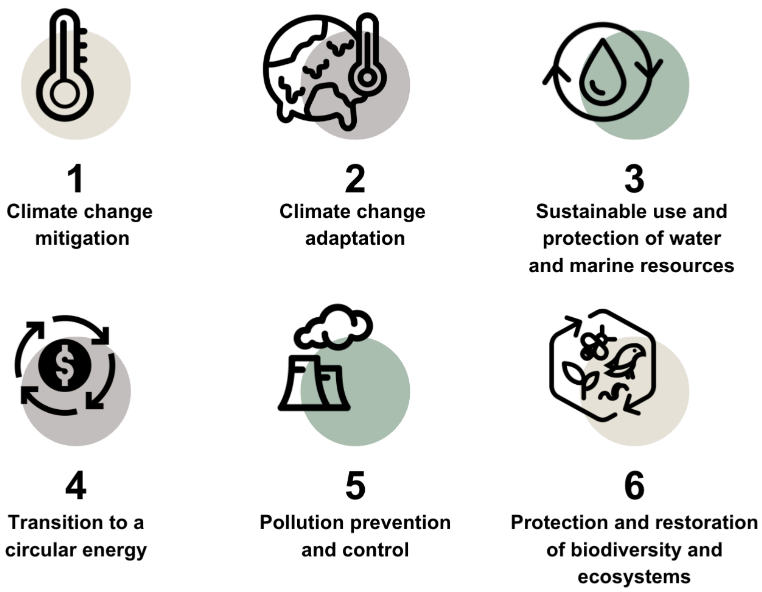

Figure 3.1 The six climate and environmental objectives (European Commission n.d.c).

In addition, the regulation includes four overarching conditions that must be met by the business's offer, to qualify as environmentally sustainable. These are: (1) Making a substantial contribution to at least one environmental objective, (2) Doing no significant harm to any of the other five environmental objectives, (3) Complying with minimum safeguards, and (4) Complying with the technical screening criteria set out in the *Taxonomy delegated act* (which will not be further covered in this report).

Apart from setting the qualification criteria for "sustainable firms", the Taxonomy also discloses obligations that affect all firms previously mentioned. These obligations are closely linked to the CSRD, which will be further covered in 3.2.2. The obligations specify the content, methodology and presentation of information to be made publicly available regarding the proportion of environmentally sustainable activities in all businesses that fall under the regulation (European Commission n.d.a). The full set of requirements will apply in January 2026.

3.2.2 Corporate Sustainability Reporting Directive

The Corporate Sustainability Reporting Directive (CSRD) was entered into force by the EU in 2023, aiming to modernise and strengthen the social- and environmental reporting practices within the union (European Commission n.d.a). Similar to the EU Taxonomy, CSRD is a part of the European Green Deal, but focuses on transparency and availability of information on corporate impact. While the EU Taxonomy is voluntary, CSRD is mandated by law and is a critical tool for preventing misleading sustainability claims in a landscape where such messages are called out impulsively. In addition, it creates awareness within companies about their own risks and opportunities linked to sustainability (Finansinspektionen 2024).

The directive includes a new set of rules and requirements for companies falling within its scope and also entails a great increase in the number of companies that will fall under these requirements. Compared to the Non-Financial Reporting Directive (NFRD), which is the predecessor of the CSRD, this new directive is expected to increase the number of organisations subject to the EU's reporting requirements from 11,700 to nearly 50,000 (KPMG n.d.).

The directive applies to all companies of public interest (which are the same as listed in 3.2.1) as well as all large companies where two out of three of the following criteria are met:

- More than 250 employees
- More than €49M turnover
- More than €20M in total assets

The requirements include annual reporting on several environmental, social and governance (ESG) areas including environmental protection, social responsibility and treatment of employees, respect for human rights, anti-corruption and bribery, and diversity on company boards. The reporting must align with other EU standards, such as the EU Taxonomy (3.2.1), and European Sustainability Reporting Standards, the last being a set of twelve standards that describes how to disclose metrics on climate change and resource use, among others. For entities already subject to the NFRD, the regulations will be applicable starting from the 2024 financial year, and those companies that are not will have to report on 2025 data. Lastly, for smaller companies of public interest, the rules will apply to data from 2026.

While CSRD does not include explicit rules on Scope 4 claims, it is an important pillar in the development of sustainability reporting regulations. Its overall purpose is to promote transparency and accountability in the reporting environment, resulting in increasing attention to assuring that disclosures are substantiated by evidence.

3.2.3 Green Claims Directive

To ensure that consumers within the EU are protected against illegitimate green claims from companies, the European Commission put forward a proposal called the Green Claims Directive in March 2023 (European Parliamentary Research Service (EPRS) 2024). The proposal was created in response to the comprehensive use of untrustworthy sustainability labels in the EU. In 2023, 230 sustainability labels were in use and only 50% of those labels were verified by external and independent parties. Furthermore, in 2020 the European Commission stated that 53% of environmental claims made by companies in the EU were considered “vague, misleading or unfounded” and 40% were communicated without any supporting evidence (European Commission 2023). Due to the lack of legislation regarding green claims, many companies have taken the opportunity to highlight, and often exaggerate, their positive impact by declaring that their products are for example “greener”, “eco-friendlier” or “more sustainable” than other products, without having to specify and prove what this means in practice (EPRS 2024). This development has led to a situation where consumer trust in sustainability labels is low, which undermines the entire purpose of using these labels, namely to give consumers the opportunity to make informed purchasing decisions.

In addition to giving consumers a false impression of environmental performance, the widespread use of misleading sustainability claims also creates an unjust situation for companies that provide a legitimate climate solution (European Commission n.d.d). The purpose of the Green Claims Directive is therefore to create a fairer environment for both companies and consumers. The legislation will limit and restrict the usage of green claims, thereby addressing the issues of green-washing that result from these claims.

The Green Claims directive seeks to establish a standardised approach for companies in the EU to make green claims reliable, comparable and verifiable (EPRS 2024). While the proposal does not suggest a single method, companies must be able to provide evidence for their claims, and the assessment must meet several predefined requirements. For instance, all claims must take the life-cycle perspective into account, meaning that life cycle assessments must first be carried out by the company behind the green claim. Furthermore, requirements also involve communicating whether the claim concerns the whole company or just one product in the portfolio. Additionally, all significant environmental aspects must be considered when performance is assessed, making it impossible for companies to cherry-pick positive impact. Claims should also be based on the latest climate science, adhere to international standards and not be equivalent to the performance that is mandated by law. For example, a company cannot highlight that their products are “toxic-free”, when it is already prohibited by law. Also, secondary data should only be used when it is not feasible to collect primary data.

Regarding comparative environmental claims (e.g. Scope 4 claims) the proposal suggests a number of additional requirements that must be met (EPRS 2024). Firstly, the same kind of assumptions and data should be used when assessing two scenarios that will be compared with each other. Secondly, the same life-cycle stages and environmental impacts must be taken into consideration. In other words, to be able to make a comparative claim, the two systems must be as equivalent as possible. A summary of all relevant requirements for Scope 4 reporting can be found in Table 3.2.

Even if all requirements are met, the directive will make generic environmental claims such as “environmentally friendly”, “climate neutral” or “eco” prohibited (European Parliament 2023). Additionally, only sustainability labels with certification will be approved and claims that state that a product has neutral, reduced or positive environmental impact due to the usage of emissions offsetting schemes will no longer be accepted. There are three remaining steps before the directive can be adopted, with the next step being the voting process in plenary. Once adopted, companies within the EU have 18 months to comply with the new directive.

Table 3.2 Selected relevant requirements for environmental claims and comparative environmental claims defined in Greens Claims Directive (EPRS 2024).

Requirements for environmental claims
• Specifying if the claim concerns the whole product or part of it, or if the claim concerns all activities of a company or only some of them • Basing claims on recognised scientific evidence, using accurate information and international standards • Taking a life-cycle perspective • Taking all the significant environmental aspects and impacts into account to assess the environmental performance • Demonstrating that the claim is not equivalent to requirements imposed by law • Providing information whether the productor company subject to the claim performs significantly better than in common practice • Checking that a positive achievement has no harmful impacts on climate change, resource consumption and circularity, sustainable use and protection of water and marine resources, pollution, biodiversity, animal welfare and ecosystems • Including primary information (directly measured or collected by the company) • Including secondary information (based on other sources than primary information, such as literature studies, engineering studies and patents), when no primary information is available.
Requirements for comparative environmental claims
• Use equivalent information and data for the assessment • Use data that is generated or sourced in an equivalent manner • Cover the same stages along the value chain • Cover the same environmental impacts, aspects or performances • Use the same assumptions

3.2.4 Summary of reviewed regulations

It is important to note that although the EU's Green Deal does not cover any explicit rules concerning Scope 4 reporting, it is an important pillar in the development of sustainability reporting regulations. The EU taxonomy and the CSRD both imply great challenges for companies that have not yet been affected by previous reporting regulations. This will necessitate a substantial upgrade in internal reporting capabilities, a focus on enhancing data quality, and a commitment to transparent reporting aligned with the emerging criteria. In addition, it can be speculated that stricter rules could apply to claims about Scope 4 in the future, as a natural extension to the Green Deal and current regulations.

An important part of the EU Taxonomy that becomes relevant regarding what companies may be authorised to report on Scope 4 is the criteria for “sustainable companies". It can be argued that the same criteria are relevant when determining if avoided emissions reporting is suitable for a specific company. Since a common risk with both sustainable labels and Scope 4 reporting is greenwashing accusations, satisfying the EU Taxonomy criteria before making Scope 4 claims may be one tool to mitigate such risks.

When discussing relevant regulations, the most crucial factor to consider is the progress of the EU's Green Claims Directive. This directive will play a central role in shaping how environmental claims are made and verified across all industries within the EU. In particular, the Green Claims Directive implies great challenges in communicating comparative claims, which becomes highly relevant when investigating avoided emissions reporting. Although this regulation is not yet fully implemented, it is clear that avoided emissions reporting requires assessments based on life cycle analysis, if companies wish to develop reporting processes that stay compliant long-term.

3.2 Review of Guiding Frameworks

This section will summarise and synthesise a selection of currently available guiding papers on Scope 4 reporting and other complementary topics. All reviewed papers have been selected based on the established criteria presented in "Chapter 2 Method". These include both conservative and progressive views on the topic, ensuring comprehensive coverage of the current debate and opinions. It should also be noted that no official standard has yet been established. The reviewed papers are "Estimating and Reporting the Comparative Emissions Impacts of Products", "Guidance on Avoided Emission", "The Avoided Emissions Framework", ISO 14040 and 14044, and "Climate Solutions Principles: defining and qualifying climate solutions and climate solutions companies", as presented in Table 3.3.

The inclusion of ISO 14040 and 14044 is motivated by the requirements outlined in the Green Claims Directive (see section 3.2.3 and Table 3.2). Specifically, one of the requirements is that environmental claims must include all significant environmental aspects and impacts. Consequently, while avoided emissions only focuses on GHG emissions, other environmental impacts should also be evaluated. This approach ensures that the company does not communicate avoided emissions while performing poorly in other environmental impact categories.

Table 3.3 Reviewed literature related to Scope 4.

Literature	*Publishing organisation*	*Year of publication*
Estimating and Reporting the Comparative Emissions Impacts of Products	World Resources Institute	2019
Guidance on Avoided Emissions	World Business Council for Sustainable Development and Net Zero Initiative	2023
The Avoided Emissions Framework	Mission Innovation	2020
ISO 14040 and 14044	International Organization for Standardization	2006[1]
Climate solutions principles: defining and qualifying climate solutions and climate solutions companies	The Exponential Roadmap Initiative and Oxford Net Zero	2023

3.2.1 Estimating and Reporting the Comparative Emissions Impacts of Products

In 2019, Stephen Russel (2019) through the WRI (primarily recognised for their publication of the *GHG Protocol*) published a guiding working paper on if and how to estimate and report Scope 4 emissions. Due to an observed increase in corporate interest in Scope 4, the paper aimed to offer a neutral framework to improve companies' credibility and consistency of their claims. More specifically, it highlights the accounting issues related to Scope 4 and how current practices lack trustworthiness due to phenomena such as cherry-picking and neglect of indirect market-mediated effects. Since its release, *Estimating and Reporting the Comparative Emissions Impacts of Products* (WRI 2019) is one of the more referenced papers within its field of study.

The paper immediately introduces the reader to two distinct concepts of Scope 4 measuring, labelled "the consequential approach" and "the attributional approach". The two approaches differ in that the attributional approach bases its calculations on LCAs of two comparable products, whereas the consequential

[1] ISO standards undergo a periodic review every five years to ensure they remain up to date and relevant.

approach includes the total, system-wide changes in emissions resulting from the product swap (see Figures 3.2 and 3.3 for illustrative descriptions).

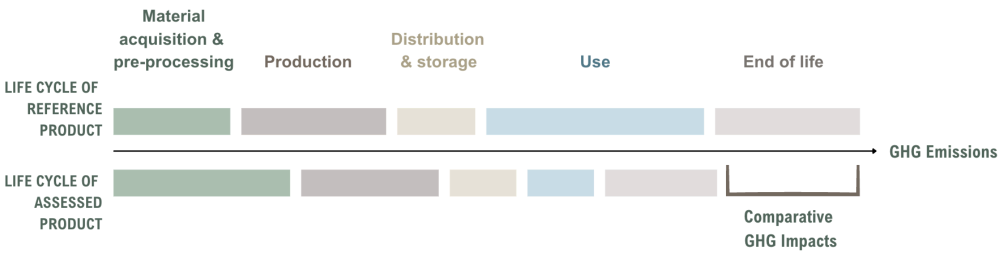

Figure 3.2 Avoided emissions using the attributional approach (WRI 2019).

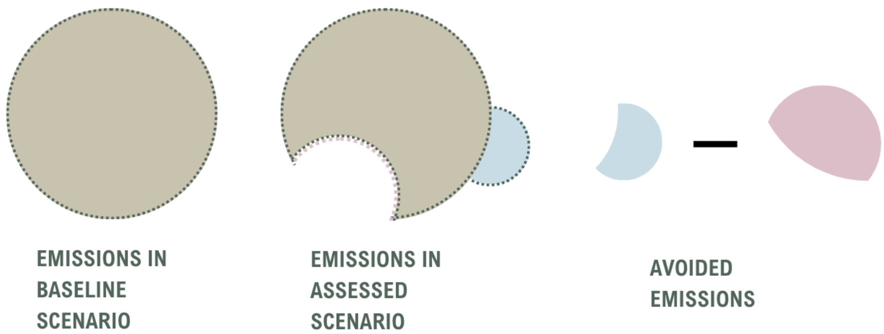

Figure 3.3 Interpretation of the consequential approach.

The consequential changes encompass various indirect effects, also called rebound effects, which can be described as the indirect emission changes due to the introduction of the solution. For instance, a rebound effect can be an increased demand for construction of new infrastructure. Consequently, all changes in consumption will always lead to an increase of GHG emissions to some extent. The consequential approach also covers effects such as carbon leakage and substitution effects, which might indirectly increase or decrease emissions on a systemic level. As a result, the consequential approach causes challenges in that the reporting company might have to analyse very large systems beyond the direct life cycle stages of the solution. On the other hand, the attributional approach focuses on numbers directly related to the life cycle stages of the solution, which may result in an omission of important indirect numbers. It is also noteworthy to state that although a company chooses to use the attributional approach, it is still recommended to include a discussion on potential rebound effects. Both methodologies are conceptually explained in equations (1) and (2).

$$\textit{GHG Impact}^{2} = \textit{Life cycle emissions of reference product} - \textit{Life cycle emissions of assessed product} \quad (1)$$

$$\textit{GHG Impact}^{3} = \textit{Emissions in the baseline scenario} - \textit{Emissions in the policy scenario} \quad (2)$$

It is early stated that the consequential approach is recommended if the company plans to make public claims from their calculations. However, a major issue in following the consequential approach is the current limitations in data availability. System-wide calculations would require full sets of consequential LCAs and other complementary consequential data for the baseline- and policy scenario, which today are close to nonexistent. The paper proposes that this might explain why most other published guiding documents follow the attributional approach. The WRI also states that these methodological issues are the main factors influencing current publications on Scope 4 estimates, but also recognizes that the attributional approach can be used as an interim solution until consequential data is available. Due to these acknowledged preconditions, only the attributional approach will be covered in the next sections.

Suggested Approach

To ensure credibility and consistency in Scope 4 claims, the paper suggests five criteria that the comparative assessments must fulfil: relevance, completeness, consistency, transparency and accuracy. In short, the practical implications are that all life-cycle GHG emissions must be included in the calculations, that data needs to be up-to-date, that uncertainties must be reduced as far as possible and that all results must be traceable back to the primary source. In addition, all GHG inventories must conform to the GHG Protocol requirements, and include both negative and positive impacts. It is important that the company in question is

[2] Attributional approach
[3] Consequential approach

already transparent in their Scope 1, 2, and 3 emissions, before assessing their Scope 4 emissions.

When it comes to what product or service to build the reference scenario on, it is stated in the paper that numerous variants have been observed from different companies and organisations. These include the “average” emissions of the existing market, the product with the highest market share, the most conventional product, the best available technology, and previous versions of the same product from the company. The WRI highlights that the choice of reference product can highly influence the final results, strongly impacting the relevance and credibility of the claim. In their conclusions, the WRI proposes that the reference product should be what is most likely to be purchased on the market if the assessed product did not exist. This is supported by the fact that customers would probably choose this alternative product if the assessed product was unavailable. To exemplify, a customer who needs a new power solution would probably not choose between a wind turbine and coal combustion, but between wind and solar power. The paper advises against using a market average or any first-best alternative to the assessed product.

Recommendations are also made regarding the LCAs that the avoided emissions calculations are based on. To begin with, it is required that the same functional unit is used when two products are compared. The functional unit serves as the reference unit and is used to quantify the performance of the studied system. The paper exemplifies this by comparing the operation of a medium-sized automobile for 200 000 km using an electric engine versus a gasoline engine, where both applications would use CO_2-equivalents per kilowatt-hour (CO_2-e/kWh) as the functional unit in their respective LCA. All GHG emissions throughout both products’ lifespans must be included in the assessment, as opposed to what WRI has observed from corporate reports to date: numerous organisations only consider the use phase when publishing their claims, leading to both irrelevant and misleading conclusions. On the same topic, the issue of uncertainty in the LCAs is discussed thoroughly. Especially for long-lived products, the paper problematizes that the calculations may depend dramatically on policy- and non-policy drivers. This includes both user behaviour and product care, but also future changes in the energy mix, regulatory policies, market conditions and recycling practices. On this basis, the WRI recommends all comparisons on long-lived products incorporate rebound effects from relevant and identifiable drivers that might significantly affect the calculations over the assessed period.

Such an example can be found in Figure 3.4. If this is not possible, the assessment's time frame should not be longer than one year. In general, uncertainty in the data should always be considered and discussed when doing any comparative assessments.

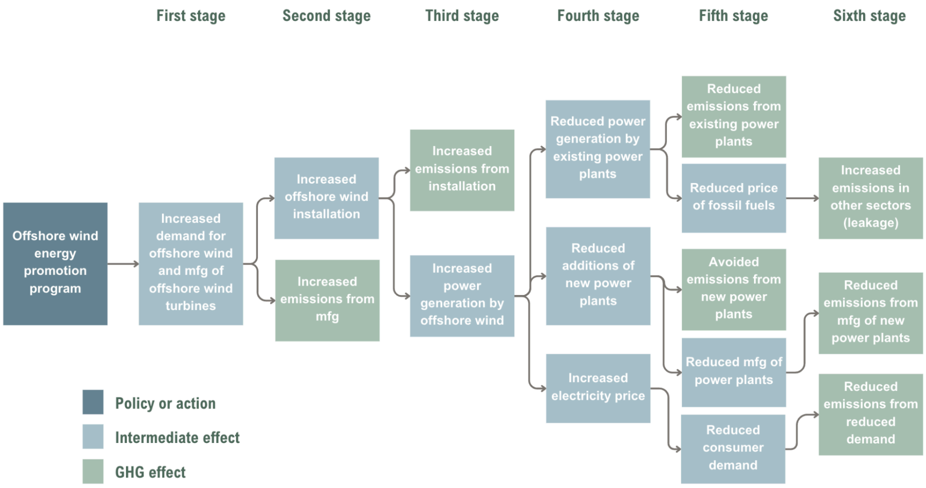

Figure 3.4 Visualization of rebound effects. Example on how future scenarios cause both negative and positive impacts (WRI 2019).

Furthermore, recommendations are formulated regarding portioning. Since there may be numerous actors within the value chain of the assessed product wanting to claim the avoided emissions, there is a high risk of double-counting. The advice is thus to attribute agreed-upon percentages of the result to partners who have been an active part of the assessment. These partners could be providers of raw materials, retailers, lenders and customers. If no partners exist, it should at least be communicated that the impact reflects a collective effort throughout the entire value chain.

Lastly, it is suggested that all companies who make any claims based on substitutions, that is, numbers that are only valid if one product is swapped to the assessed one, should estimate how many units are actually removed thanks to their product, and how many are sold in addition. Not all units sold will replace another product, which means that not all units will result in avoided emissions. For example, although a smart pad (assumed to have a lower environmental impact than a standard computer) can perfectly replace a computer, not all customers will buy a smart pad instead of the computer, but in addition to it. It is thus recommended that the reporting company estimates how many (current and future) reference products that may be replaced, and that the final result is adjusted to that number.

Risks and Uncertainty

Although the paper proposes rather conservative boundaries for companies who wish to report on Scope 4 emissions, emphasis is still placed on the remaining risks associated with avoided emissions claims, even when following all recommendations mentioned. The WRI explains this by stating that out of all corporate Scope 4 claims they had reviewed to date, none was approved in terms of credibility. A common mistake found in all cases was that companies only present their positive impact, whereas, in reality, consumption will always result in a negative impact to some extent. Another common behaviour that the WRI observed was that the positive impact that companies claimed was linearly dependent on growth in sales volumes. This means that no further analysis had been made about, for example, actual replacements, demand in infrastructure etcetera.

As previously highlighted, the main issue with the attributional approach and Scope 4 reporting is that market-mediated effects are seldom taken into account. This means that all calculations are based on the assumption that two products are perfect substitutes. The paper highlights that this assumption is unlikely to be true for any product system, thus being one of the front drivers for greenwashing accusations. Another issue in using the attributional approach lies in data quality. This takes shape both in ensuring the quality of internal data, but also in ensuring fairness between internal data and data on the reference product. Most probably, data on the assessed product will be more accurate and precise than that on the reference product. As the data on the assessed product is typically controlled by the reporting company, this may result in unfair comparisons, thus reducing the accuracy of the calculations and claims.

To summarise, *Estimating and Reporting the Comparative Emissions Impacts of Products* asks all companies that are interested in reporting their avoided emissions to be cautious. The paper repeatedly states that a consequential approach is recommended, especially if the intention is to make public claims. Although confirming that some companies and products can help to avoid GHG emissions, the WRI underscores that accurately measuring impact is a very challenging task.

3.2.2 Guidance on Avoided Emissions

Guidance on Avoided Emissions, published in 2023, was written by the World Business Council for Sustainable Development (WBCSD) in collaboration with the Net Zero Initiative (NZI), and the document explains if and how companies can claim and report avoided emissions. WBCSD is a global, CEO-led, community consisting of 225 businesses working to speed up the transition toward a more sustainable world (WBCSD n.d.). NZI is supported by the French Agency for Ecological Transition and the French Ministry of Ecological Transition and is an initiative founded by Carbone 4, a consulting firm specialising in low-carbon strategies (NZI n.d.).

One of the key drivers behind the creation of the guide is the *Net Zero Emissions by 2050 Scenario*, which is "(...) a normative scenario that shows a pathway for the global energy sector to achieve net zero CO_2 by 2050…" (IEA n.d.). The authors of the guide highlight that avoided emissions reporting has the potential to accelerate the adoption and implementation of new environmentally adapted products, services, projects, and technologies, thereby supporting the global Net Zero goal. More specifically, the report presents three ways through which companies can leverage avoided emissions reporting, including innovation, scaling, and accountability. In terms of innovation, avoided emissions can be used as a guiding tool to support the development of products with the largest decarbonisation potential. It can then be further used for prioritisation purposes when it comes to deciding on which solutions to scale. Reporting avoided emissions can also strengthen accountability since it allows companies to show stakeholders their contributions to a 1.5°C-aligned society.

Avoided emissions eligibility

To begin with, the guide emphasises that reporting of GHG inventory – Scope 1, 2 and 3 that is – must be separated from avoided emissions reporting. Thus, avoided emissions should not be used to compensate for negative impacts or improve the GHG inventory. Furthermore, a reduction across Scope 1-3 should not be interpreted as avoided emissions. Three use cases are presented to clarify situations where a company is – or is not – eligible to claim avoided emissions. In the first scenario, a company switches to plant-based protein instead of animal protein in their products, while also working to decrease their overall GHG inventory This change leads to reduced meat consumption among their customers, allowing the company to claim avoided emissions. In the second example, a company experiences a growing sales volume of solar panels. While they can claim avoided emissions, the company's GHG inventory increases simultaneously. In the third example, a company selling energy drinks reduces their Scope 3 emissions, but energy drinks do not contribute to global decarbonisation. Therefore, the company cannot claim that emissions were avoided in this scenario. The examples underscore the complexities involved in determining which Scope 4 claims are eligible. The examples are illustrated in Figure 3.5.

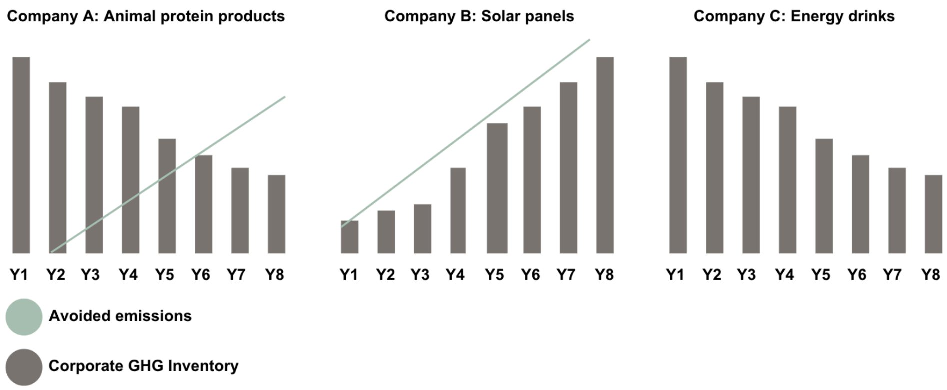

Figure 3.5 Three different examples of when companies may or may not claim avoided emissions (WBCSD & NZI 2023).

To simplify the process for companies to determine if they are eligible for avoided emissions reporting, the guide presents three eligibility criteria. The first criterion requires the company to demonstrate its credibility in climate action by reporting its GHG reduction targets, and measures undertaken to achieve these targets. For this purpose, the guide recommends the adoption of Science-Based Targets. The Science Based Targets initiative (SBTi) assists businesses globally in establishing GHG reduction targets aligned with the latest climate science and the goals of the Paris Agreement (Science Based Targets n.d.). The second criterion is about alignment of the company's offering with the most recent climate science. It mandates that the product must not be associated with activities involving fossil fuels and should demonstrate mitigation potential according to established sources. Two recognised sources for aligning with the latest climate science are, according to the framework, the IPCC Sixth Assessment Report and the EU Taxonomy.

The third criterion requires the product to have a significant decarbonisation impact, where there are three qualifying solution types: end-use solutions (e.g. bikes, trains, car-sharing apps), intermediary solutions (e.g. batteries in electric vehicles and low-carbon building materials) and solutions that optimise systems (e.g. reflective roofing solutions that reduce the energy demand or traffic optimisation systems). Consequently, a company providing a conventional product that is a component in an environmentally friendly solution cannot claim avoided emissions, since their product does not hold the decarbonisation impact. However, the framework also states that each avoided emissions claim does not have to be unique. If two different companies are producing products that jointly contribute to avoided emissions (e.g. an electric vehicle manufacturer and an electric-vehicle battery manufacturer), both companies may claim the avoided emissions, which consequently leads to double counting.

Suggested approach
The guide provides a five-step approach to how companies should calculate their avoided emissions, once they have passed the three eligibility criteria (see Figure 3.6). The first step entails deciding the time frame, where two different options are presented: either calculate avoided emissions from a forward-looking perspective or on a year-on-year basis. In both cases, avoided emissions should be calculated for the entire lifecycle of the product, including emissions that occur during production, the use phase, and end-of-life. The key distinction lies in whether the total amount of emissions that have been avoided during the entire lifespan of the solution is reported (first option) or if that number is divided by the lifetime (second option), thus giving a number that provides the yearly avoidance of emissions.

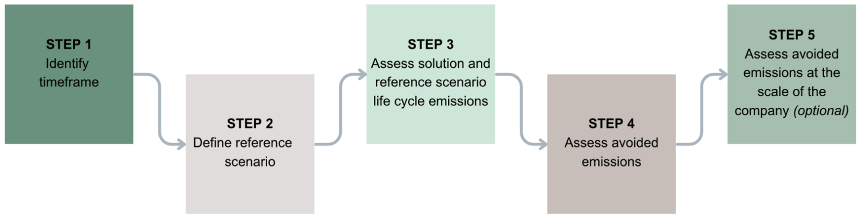

Figure 3.6 Overview of the suggested approach (WBCSD & NZI 2023).

In the second step, when the time frame has been determined, the reference scenario should be defined (see Figure 3.7). The reference scenario, as previously outlined, serves as a benchmark against which the solution is compared and should reflect the most probable scenario. The guide recommends that it should be based on the most widely used solutions, accounting for approximately the top 25% market share. Thus, the reference scenario must not necessarily be *one* solution, but can represent a mix of solutions. Defining the average reference scenario is not always straightforward since it depends on the context in which the solution is being used. For example, if a bicycle replaces a car, the car becomes the reference scenario, allowing for avoided emissions reporting. Conversely, if the bicycle replaces another bicycle, the old bicycle serves as the reference scenario and no Scope 4 emissions can be reported.

It can be especially difficult to define the reference scenario if the solution meets a new demand and no previous solution exists. Then the reference scenario is defined as the product that would be most expected to be used to fulfil the same purpose. Additionally, regulations must be considered when defining the reference scenario. A reference scenario cannot be legally prohibited – it should be an average solution that aligns with current and new regulations.

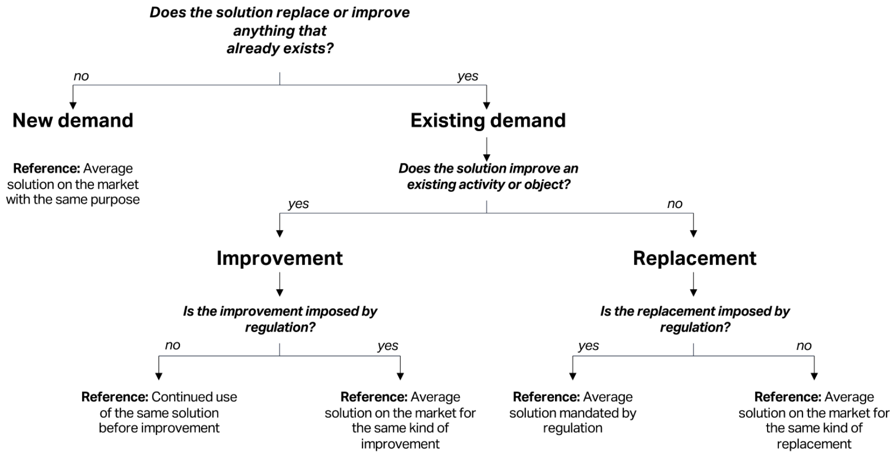

Figure 3.7 Different options for the reference scenario (WBCSD & NZI 2023).

The third step in the guide involves assessing the life cycle emissions of both the solution and the reference scenario where an LCA approach should be employed. The guide highlights two different approaches when conducting an LCA: the consequential approach and the attributional approach (see section 3.2.1). While the guide does not explicitly recommend one approach over the other, it emphasises the importance of justifying the selected approach. Regardless of the chosen approach, it is crucial to evaluate both the solution and the reference scenario within comparable systems and contexts, utilising the same functional units. Moreover, it is also essential to assess all life cycle stages and not only the use-phase. In other words, a cradle-to-grave approach should always be used when assessing avoided emissions.

The fourth step involves calculating the actual avoided emissions, which is the difference between GHG emissions released from the solution and those from the reference scenario. It is important to consider that the emission intensity of both the solution and the reference scenario can change over time which affects avoided emissions. If a forward-looking time frame is applied, the guidance recommends considering different energy scenarios, such as how the decarbonisation of the energy sector will impact the avoided emissions assessment. The fifth and final step, which is optional, involves aggregating avoided emissions to a company level by adding together avoided emissions for all products sold. However, in cases where a company offers multiple solutions that target the same emissions, it is important to avoid double counting these avoided emissions. Instead, the company should only count the total emission reduction compared to the reference scenario(s).

The guide also addresses the challenge of obtaining relevant data for calculating Scope 4 emissions. It acknowledges the challenge of accessing precise data for specific solutions and reference scenarios, suggesting that this difficulty can be addressed by reducing the level of specificity during data collection. The guide outlines three levels of specificity, as can be seen in Figure 3.8, with the highest level involving calculations based on the exact life cycle GHG emissions for a specific solution and reference scenario. This level requires determining the GHG emissions for each customer using the product, thus taking into account relevant situational factors. However, this process is highly complex and time-consuming. If this level of specificity is not feasible, the medium level can be utilised. This approach involves calculating the average life cycle GHG emissions for the solution and comparing it with the average reference scenario. The lowest level of specificity mentioned is estimating the GHG emissions of the solution within a given market, without focusing on individual companies. The guide emphasises the importance of communicating the level of specificity, highlighting that low specificity does not necessarily imply a lack of quality.

		Solution		
	Specificity level	Solution specific	Company specific	Statistical
Reference scenario	Solution specific	Very high	High	Medium-high
	Company specific	High	Medium	Medium-low
	Statistical	Medium-high	Medium-low	Low

Figure 3.8 Different specificity levels mentioned in the guidance (WBCSD & NZI 2023).

In summary, *Guidance on Avoided Emissions* underscores the potential significance of Scope 4 reporting for future sustainability efforts. It can serve as a valuable tool for companies that pass the eligibility criteria, helping them in questions related to innovation, scaling and accountability. The suggested five-step approach highlights the many considerations involved in quantifying Scope 4 emissions, revealing the complexities of the process. Key takeaways include the eligibility criteria and how to determine appropriate time frames and reference scenarios. Furthermore, the guidance emphasises that data limitations do not necessarily hinder avoided emissions reporting. Instead, reducing the specificity level can facilitate the process.

3.2.3 Avoided Emissions Framework

The *Avoided Emissions Framework* (AEF), with primary authors Stephens and Thieme (2020), was created by Mission Innovation, a global initiative aimed at accelerating progress aligned with the ambitions of the Paris Agreement. Comprising 23 countries and the European Commission, the initiative is supported by actors such as the International Energy Agency (IEA) and the World Economic Forum (Mission Innovation n.d.). The AEF was produced to support solutions that are part of a net-zero development, by providing tools for measuring and reporting, so that the solution providers can demonstrate their positive impact. Additionally, the purpose of the framework was to create a resource that can be used to validate which solutions are compatible with a net-zero society. The authors underscore the need for a shift in mindset – transitioning to a more sustainable society requires not only minimising harm but also actively striving to generate positive impacts, where they argue avoided emissions reporting can help in driving this shift.

The AEF emphasises that the assessment of avoided emissions must adhere to the general principles of relevance, completeness, consistency, transparency, and accuracy, as defined in the GHG Protocol. This entails providing comprehensive documentation with the avoided emissions claim, ensuring that another party could replicate the calculations and reach the same conclusion. Additionally, the AEF underscores the importance of reporting emissions across Scopes 1–3 as well as establishing Science-Based Targets before claiming avoided emissions. Companies with significant emissions across Scopes 1-3 should prioritise reducing these emissions rather than focusing on assessing avoided emissions. Furthermore, the framework emphasises that companies must consider their entire product portfolio when claiming avoided emissions to avoid accusations of cherry-picking positive impacts.

Suggested approach

The AEF introduces an initial calculation methodology for companies to consider when evaluating their Scope 4 emissions. The framework suggests two alternative ways of calculating avoided emissions, as seen in Equation 3 and 4 below.

$$\textit{Net avoided emissions} = \textit{Enabling avoided emissions} - \textit{Direct solution emissions} - \textit{Rebound emissions} \quad (3)$$

$$\textit{Net avoided emissions}^{4} = \textit{Business as usual (BAU) baseline emissions} - \textit{Emissions of the solution-enabled scenario} \quad (4)$$

In Equation 3, *enabling avoided emissions* represent the emissions avoided due to activities prevented by utilising the solution, *direct solution emissions* are the life cycle emissions of the solution, and *rebound emissions* refers to emissions generated as a consequence of implementing the new solution. In Equation 4, *BAU baseline emissions* stands for the emissions produced by the reference product, i.e., the product that would have been used if the solution had not existed.

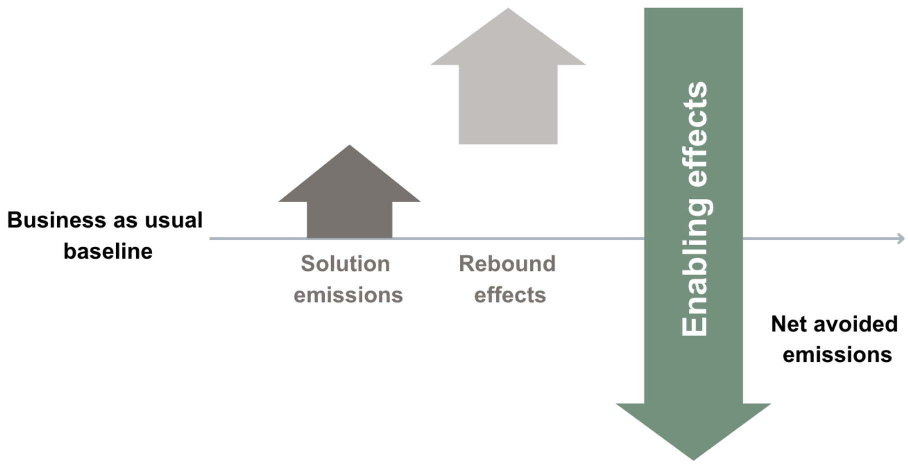

Figure 3.9 Net avoided emissions according to the Avoided Emissions Framework (Stephens & Thieme 2020).

[4] Avoided emissions defined in relation to the baseline scenario

To perform the calculations presented above, the framework presents an eight-step approach that companies should adhere to. The first step of the process is to identify the solutions that should be examined and decide whether the solutions hold enough decarbonization potential to justify a more detailed assessment. In the second step, the framework states that the carbon saving mechanisms or the *enabling effects* should be identified. The enabling effects of a solution or technology are what causes the avoided emissions and can be both primary and secondary. The distinction is that secondary enabling effects have an impact over a longer time and can therefore be more difficult to identify and calculate. To illustrate the difference, the AEF provides an example: a primary enabling effect could be the reduction in business travel resulting from the introduction of video-conferencing services. On the other hand, a secondary enabling effect could be the potential long-term decrease in the production of aircraft due to the shift towards video-conferencing and reduced business trips. It is highlighted in the framework that secondary enabling effects are sometimes left out due to the uncertainty related to them.

The second step involves determining the functional unit, direct solution emissions, the system boundary and the BAU baseline. The functional unit should define the quantity, time and quality of the solution. The framework recommends setting the time frame of one year, as it facilitates comparativeness. The direct emissions from the solution should be assessed by using an LCA approach. More specifically, emissions from all life stages should be considered. When establishing the system boundaries, it is important to incorporate both enabling effects and rebound effects. Rebound effects are, like secondary enabling effects, hard to quantify and relate to the indirect emission increase due to the introduction of the solution. In other words, the AEF states that enabling effects and rebound effects go opposite ways; the first increases avoided emissions and the second decreases avoided emissions. The AEF points out that rebound effects are often excluded when quantifying avoided emissions, although its importance has been highlighted in the literature. The inclusion of rebound effects in the assessment is crucial to ensure that the overall positive impact of the solution outweighs any negative effects caused by the rebound effects. In essence, rebound effects should be considered within the system boundary unless they are assumed to be negligible.

When defining the baseline, the framework emphasises the importance of making a careful decision, as an inaccurate baseline can result in both an overestimation and an underestimation of avoided emissions. Bearing this in mind, the baseline should represent "the most appropriate widely used alternative", and should answer the question "What would have happened without the new solution?". The framework suggests that it can be advantageous to use various baseline scenarios depending on whether there are different technologies or geographic factors that are relevant to consider.

The third and fourth steps involve documenting decisions, assumptions and identified uncertainties, and then have it reviewed by internal or external parties to ensure credibility and feasibility. During this phase, required data should also be identified, and the AEF addresses the issue of data quality. It acknowledges the inherent uncertainty in calculating Scope 4 emissions due to the inclusion of various data sources, the necessity of making assumptions, and the limited availability of data. Given these preconditions, the AEF emphasises the importance of maintaining both transparency and credibility by providing evidence for assumptions and prioritising the use of primary data over secondary- and modelled data.

The fifth step involves searching for academic studies that can provide a quantitative basis for the calculation of the carbon abatement factor. This factor reflects the avoided emissions per unit sold of the solution and serves as a normalised metric that makes comparing different Scope 4 assessments possible. However, the framework acknowledges that calculating the carbon abatement factor can be a complex task that must rely on existing academic or industry studies. Furthermore, the abatement factor can vary regionally when the solution is used in different contexts. For example, if the solution reduces electricity consumption, the abatement factor must reflect the local electricity grid.

Moving on to the sixth and seventh steps, these involve collecting all necessary data to calculate the abatement factor and then determining the total abatement by multiplying the factor by the volume (i.e. number of solutions used). The AEF provides a specific example by calculating the carbon abatement factor for a car-sharing service. In the example, three primary enabling effects that lead to avoided emissions were identified: reduced annual mileage, utilisation of more efficient cars compared to the average private car fleet, and avoided private car purchases. The framework then calculates the avoided emissions and direct emissions for each enabling effect, followed by determining the carbon abatement factor for each specific enabling effect through the calculations below.

The following equations were carried out to define the avoided emissions for reduced mileage:

$$\textit{Total Primary Avoided Emissions Reduced Mileage} = \textit{Weighted average avoided distance per user (km)} * \textit{National average emissions factors (kg } CO_2\textit{/km)} \quad (5)$$

$$\textit{Total Direct Emissions Reduced Mileage}^5 = \textit{Total avoided car travel per user (km)} * \textit{Model share} * \textit{Emission factor} \quad (6)$$

$$\textit{Carbon Abatement Factor (kg } CO_2 \textit{ per user) Reduced Mileage} = \textit{Primary avoided emissions} - \textit{Direct solution emissions} \quad (7)$$

To give some clarification to the example above, it illustrates a scenario where a solution is both inherently better from an environmental point of view than the market average, but also changes the behaviour of the user leading to further avoided emissions. The first equation takes the avoided emissions caused by the reduced mileage into account. The second equation is based on the conservative assumption that no journeys were actually avoided; the users instead used other modes of transport (bus, train etc.). The second equation also uses an emission factor, which is analogous to the carbon abatement factor but instead stands for product emissions. The total carbon abatement, and the total avoided emissions, is then calculated through multiplying the factor for each enabling effect with the volume and then adding them together. Once this process has been finalised, the eighth and final step includes validation of the process and finalising the documentation. Finally, the guide recommends that the results should be independently verified.

The guide addresses the issue of double counting in Scope 4 reporting and its implications. Double counting occurs when multiple companies claim the same avoided emissions due to their products being components of the same solution. Double counting presents credibility challenges when companies with minor roles in a climate solution claim avoided emissions, potentially exaggerating their impact. Furthermore, when companies report avoided emissions on a portfolio level, double counting can become very misleading since it is likely that overlapping emission savings exist within the company portfolio. The guide acknowledges that allocating avoided emissions among products has not been

[5] Calculated for each mode of transport (bus, train etc.)

attempted due to its complexity but suggests it would provide a fairer representation of each company's impact. A proposed solution is to allocate all avoided emissions to the fundamental solution provider(s), ensuring only the company providing the core technology claims these emissions (see Figure 3.10). In other words, the product without which the overall solution would not work is only eligible to claim the avoided emissions. However, this is not possible in all cases when multiple technologies are used simultaneously. If this is the case, the guide recommends to allocate equally between all different elements, as seen in Figure 3.10. In general, the guidance recommends that double counting should be avoided.

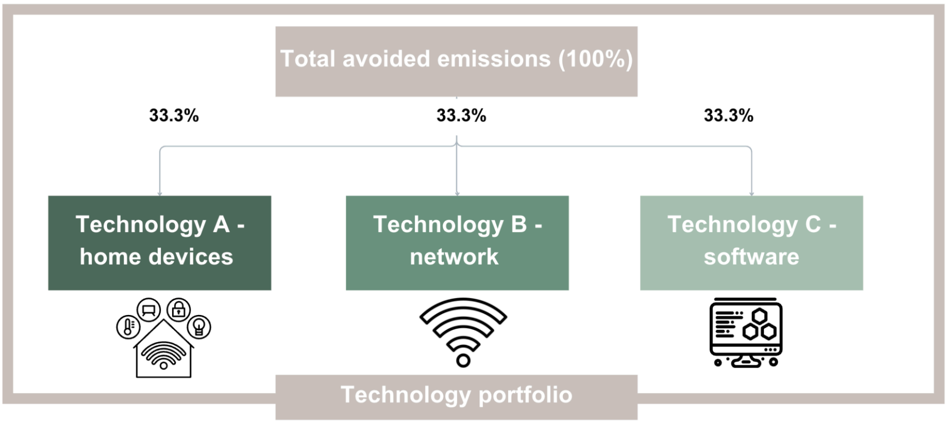

Figure 3.10 Allocation of avoided emissions (Stephens & Thieme 2020).

In summary, the *Avoided Emissions Framework* contributes to the discussion by introducing primary and secondary enabling effects, carbon abatement factors, and further elaborating on rebound effects. Unlike previous frameworks that rely on LCA approaches, the AEF proposes an alternative calculation method based on behavioural changes that can be translated into avoided emissions by using carbon abatement factors and emissions factors. The framework recommends avoiding double counting, using various reference scenarios based on technology and geography, and emphasises the significance of data transparency.

3.2.4 ISO 14040 and 14044

In 2006, the International Organization for Standardization (ISO) published ISO 14040 and ISO 14044 as part of their 14000-series on environmental management. The 14040 standard covers the life cycle assessment framework called “cradle to grave”, which includes principles and guidance on LCA studies and life cycle inventory (LCI) studies in general (ISO 2006). As a complement, 14044 was written for practitioners and explains more in detail how the assessment process is to be executed (Svenska institutet för standarder [SIS] 2006). Simply put, the standards explain how to quantify the environmental impact generated by a product, process or service throughout its life cycle, hence the name “cradle to grave”.

Furthermore, when discussing Scope 4 and avoided emissions, the ISO 14040 and 14044 standards become highly relevant concerning quantification and comparison between products. In particular, clause 3.6 in the standard: “(...) environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function”, states that if the purpose is to compare one product to another, two LCA’s cannot be put against each other. Instead, a comparative LCA must be conducted assessing both products, to ensure that equivalent methodologies are used. Other requirements when conducting a comparative analysis include ensuring that the data quality of both products is equal, and if the results are intended to be disclosed to the public, the LCA needs to be verified. The verification process can be carried out either by an accredited certification body or an approved individual verifier (EPD International n.d.). The main purpose of the verification is to secure accuracy and to decrease the likelihood of negative effects on the reference company. Lastly, any discovered sensitivity or uncertainty in the data must be disclosed.

3.2.5 Climate solutions principles: defining and qualifying climate solutions and climate solutions companies

In 2023, The Exponential Roadmap Initiative and Oxford Net Zero published their discussion paper *Climate solutions principles: defining and qualifying climate solutions and climate solutions companies* (Falk et al. 2023), to highlight the need for frameworks and standards that motivate companies to drive the development of climate solutions forward. To enable decarbonisation, the authors state that low-emission technologies need to be scaled rapidly, but that the current reporting landscape hinders these companies from growing. As a result, a proposal on how to identify and define climate solutions- and climate solutions companies is provided, as a way of differentiating those organisations and facilitating their recognition and future financing. Although it does not provide a suggestion on how to report on avoided emissions, the paper is considered an important voice in the Scope 4 context.

It is early stated that no climate solutions company can keep their label only by existing. Instead, a company that wishes to achieve this title needs to sustain their relevance through one out of two strategies: *growing green* or *brown to green.* The first strategy is relevant for companies that already provide climate solutions. The issue is that when these companies want to grow, so will the volume of their emissions. With current frameworks, mainly focusing on how well a company reduces its carbon footprint, this means that the climate solutions company will be penalised rather than rewarded for wanting to spread their solution out on the market. *Brown to green* instead defines when companies want to *become* climate solutions providers. Although acknowledging the importance of providing incentives for companies to always aim for GHG reductions, the paper underscores that every company also needs to push for more green solutions on the market. No current standardised guidelines on how a company can make this transition and shift their product portfolios from brown to green exist today.

Defining a climate solution

The framework that is presented aims to define under what conditions a product can be called a climate solution, and thereby, under what conditions a company can be called a climate solution company. Again, this label is stated to be an important tool to enable recognition and financing for decarbonisation enablers.

A lot of criteria are based on comparisons with BAU. This means that the label is dynamic and that requirements will increase as time passes and BAU changes. For achieving the climate solution label, the following criteria are proposed, where one or more must be fulfilled:

- The solution must significantly lower the carbon footprint per functional unit – at least 50% lower (preferably 90% or more) than the BAU option being replaced.
- The solution's primary purpose is to enable others to reduce their emissions.

- The solution meets or exceeds a credible threshold of emissions per functional unit, making it fit for a net zero world. The thresholds must be science-based and determined for global 1.5°C alignment.

In addition to the criteria, the paper also suggests that several underlying requirements should be fulfilled, including full transparency on the quantifications of emissions both on the solution and its reference solution. These calculations should contain the entire lifecycle and follow relevant standards and not be older than two years. No "net" reduction claims from carbon credits can be included in these numbers. They must also satisfy a set of safeguard requirements, namely that the solution is scalable to the whole world's population within the global carbon budget, not enable any further virgin use of fossil fuels, it must fulfil some kind of human need and be aligned with the UN Sustainable Development Goals (SDGs). A last requirement is that the solution does not have any negative impacts on nature apart from GHG emissions, for example harming the biodiversity in oceans. The full set of prerequisites can be found in Figure 3.11.

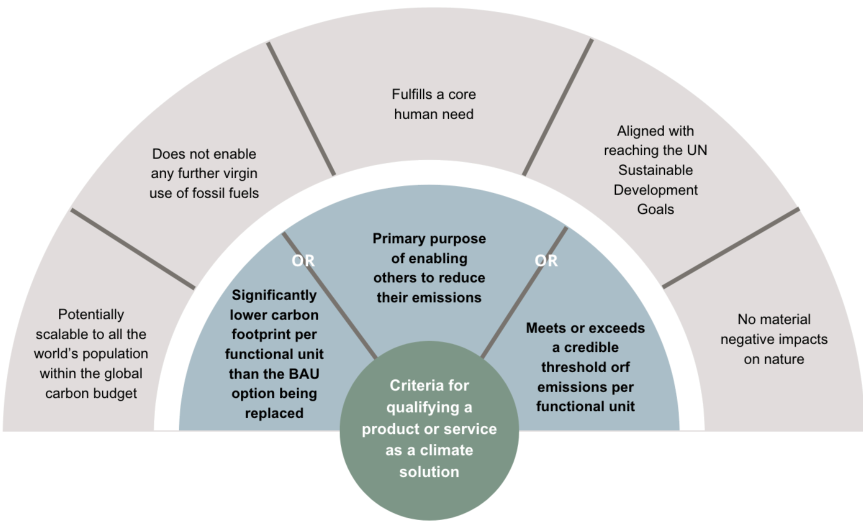

Figure 3.11 Prerequisites for a climate solution (Falk et al. 2023).

The paper continuously repeats that this label is never guaranteed forever after it has been achieved. Following the "Carbon Law", a carbon roadmap that suggests how to meet the UN's Paris Agreement by 2050 by halving global emissions every decade, a climate solution must always follow a trajectory of at least 50%.

As the gap narrows, the solution must thereby increase its efficiency and lower its impact further for it to keep the label.

Defining a Climate Solutions Company

Even if a company is offering a solution that meets all requirements to label itself as a climate solution, that does not necessarily mean that the company can call itself a climate solutions company. This has to do with the assurance that companies cannot add a climate solution to their product portfolio and give themselves this label, only to have their main sales volume consisting of something else. The paper suggests the following criteria for companies who wish to be climate solutions companies:

- More than 90% of the company's revenue must come from sales of climate solutions.
- The company must have public interim and net zero climate targets, a published transition plan and an annual report on progress.
- The company must work broadly to transform its sector.

These criteria will not be fulfilled statically, but for a fixed period meaning that new assessments will need to be made over time.

In summary, this paper sheds light on the importance of allowing climate solutions and climate solutions companies to present their potential positive impact on the environment. This is both to reward new solutions that wish to grow green, and also to give incentives to companies who could transform their product portfolios from brown to green. As a first step in building the guidelines for this new possible way of reporting impact, the paper suggests that a company must primarily fulfil a number of criteria to be labelled as a climate solutions company. Furthermore, the solution must meet the criteria for being considered a climate solution, with these requirements becoming progressively stringent as substitutes also improve in their sustainability measurements.

3.3.3 Summary of reviewed guiding frameworks

The documents presented are all connected to Scope 4 reporting in some way, focusing on different aspects. The first three documents provide guiding principles, collectively offering a nuanced picture of the current Scope 4 landscape. The ISO standard and the paper on climate solutions contribute fundamental ideas that relate to avoided emissions reporting. To summarise the main takeaways, the following sections aim to clarify the primary similarities and differences among the reviewed documents and conclude on recommendations.

One important observation is the emphasis placed on determining which companies are eligible to report their avoided emissions. Scope 4 reporting is relevant only for companies with solutions that have a substantial decarbonizing impact and result in lower GHG emissions compared to the reference scenario. To provide further clarity on which products or services that qualify, the concept of climate solutions, described in the last paper, can be used as a guiding tool. In order to qualify for Scope 4 reporting, products and services must qualify as climate solutions. As previously outlined (see section 3.2.5), a climate solution is a solution designed primarily to enable others to reduce their emissions. It must have a significantly lower carbon footprint per functional unit and meet or exceed a threshold of emissions per functional unit, making it suitable for a net-zero emissions world.

Furthermore, also relating to Scope 4 eligibility and mentioned in the first three documents, is the requirement that the company already reports on Scope 1-3 emissions and has established reduction targets across these scopes, for instance according to SBTi. While being straightforward for companies that can decrease Scope 1-3 emissions while increasing Scope 4, this aspect can also introduce complexity into the process. For instance, it may seem contradictory for a company with increasing Scope 1-3 emissions to report on Scope 4 emissions. However, if this increase stems from rising sales volumes of climate solutions or expansion into new markets, consequently leading to an increase in Scope 4 emissions, the rise across Scope 1-3 may be necessary. Moreover, it could potentially be more challenging for a climate solutions company to set ambitious reduction targets across Scope 1-3 compared to a company with historically high emissions. This is because the climate solution company probably already operates with lower emissions. The reviewed documents do not offer explicit solutions to this situation, however, it can be argued that Scope 4 reporting, in itself, aims to address this disparity.

Another observation concerns the recommended methodology for assessing Scope 4. While the first two frameworks advocate for employing an LCA approach, the third document suggests a blend of methodologies. Utilising an LCA approach in the Scope 4 context entails conducting a comparative LCA according to ISO 14040 and 14044 for the solution and the reference scenario, encompassing all life stages from cradle to grave. Using this methodology ensures that the solution contributes to decarbonization and not solely operates with lower emissions during the use-phase. The third document, the *Avoided Emissions Framework*, differs in its recommended methodology. While it involves conducting an LCA over the direct emissions of the solution, its key aspect is identifying and quantifying the enabling effects. This approach entails translating changes in behaviour, caused by the solution, into avoided emissions. For instance, the guide mentions a video conferencing service, arguing that it reduces work-related trips and thus leads to avoided emissions. However, this method introduces greater uncertainty compared to only using the LCA approach since proving a reduction in trips due to the use of video conferencing services can be difficult, if not impossible. These differences in suggested methodologies raises a crucial question regarding which products and services that should be relevant for Scope 4 reporting. Is it sufficient if a solution induces a potential "emissions reducing change in behaviour" or must avoided emissions be quantified through an LCA approach? By taking a conservative approach, and given the traceability requirements from the Green Claims Directive, the LCA approach may be considered the more appropriate approach. This method is considered having less uncertainty, which is crucial as Scope 4 reporting has yet to receive an international standard.

Adopting either a consequential or an attributional approach has also been described as an important decision when assessing Scope 4 in the first two documents. WRI recommends using the consequential approach but acknowledges the challenging task of conducting consequential LCAs. The attributional approach can be considered more feasible. In the *Guidance on Avoided Emissions*, it is stated that no matter the method of choice, it must be motivated and justified. Although using the attributional approach, analysing potential rebound effects remains an important step. This step relates to the discussion in the previous paragraph, namely if and in what way the system-wide changes (e.g. all identified rebound and enabling effects) should be taken into account when assessing Scope 4 emissions. Again, applying a conservative and feasible approach, rebound effects should be analysed but from a qualitative perspective, since quantification would require consequential data which can be difficult to access and collect.

Other important themes involve selecting an appropriate time frame and reference scenario and decisions regarding portioning or allocation. When it comes to selecting a time frame, the literature review presents mainly two different options. The first option entails reporting the total amount of avoided emissions during the solution’s entire lifespan, taking all life stages into account. This option involves uncertainty since the market can change: a new solution with even lower GHG emissions makes the Scope 4 claim invalid. The second option involves assessing avoided emissions annually, by dividing the total life cycle emissions by the lifetime. The second option is thus less uncertain since it involves using a shorter time frame.

When deciding on an appropriate reference scenario for Scope 4 reporting, various opinions exist in the literature, offering different options. Three distinct approaches are presented: utilising the market average as the reference scenario , selecting the product with the largest market share, or identifying the product most likely to be used if the assessed product did not exist. While these options can lead to the same reference scenario, this must not necessarily be the case. For instance, similar to the example mentioned in section 3.2.1, the solution with the largest market share might be “the worst case scenario”, while the product that is most likely to be used in the absence of the assessed product is another climate solution. However, when considering the fundamental purpose behind companies reporting their avoided emissions— to demonstrate that their solution results in lower GHG emissions—it appears more logical to use the product with the largest market share as the reference scenario, rather than comparing two climate solutions against each other. The AEF further adds to the discussion by highlighting that it can be beneficial to use multiple reference scenarios since that allows to take different technologies and geographies into account. It also provides a more nuanced picture: that depending on the reference scenario Scope 4 emissions will vary.

When it comes to portioning or allocation, it is either recommended to attribute percentages of the result to the different partners who have been an active part of the assessment or to allow double-counting of avoided emissions. Lastly, the importance of high data quality and also assessing the quality of data is another common denominator in the literature review. The quality of the data that has been used must be communicated, as well as any uncertainties when reporting avoided emissions. In Table 3.4, the main takeaways from the reviewed documents have been summarised.

Table 3.4 Summary of reviewed guiding frameworks.

Guiding frameworks	*Eligibility criteria*	*Methodology*			*Limitations*
		System definition	***Time frame***	***Data requirements***	
Estimating and Reporting the Comparative Emissions Impacts of Products	The company must first report on Scope 1-3 emissions and have established reduction targets.	Include all rebound effects according to a consequential approach. Compare with the second best alternative.	One year if future scenarios are not discussed.	LCA approach. Data with high traceability is required.	For long-lived products, claims can only be made on a one-year basis.
Guidance on Avoided Emissions	The company must pass three eligibility criteria that involve that the product has a substantial decarbonising impact.	Discuss rebound effects. Mix attributional and consequential approach. Compare with the most widely used alternative.	Forward-looking perspective *or* year-on-year.	LCA approach. Address specificity of data.	Communicate the specificity level. Justify the selected consequential or attributional approach.
The Avoided Emissions Framework	The company must first report on Scope 1-3 emissions and have established reduction targets.	Discuss all rebound and enabling effects, including behaviour change. Multiple reference scenarios if applicable.	One year	Combined approach: LCA, carbon abatement- and emission factors.	Avoid double counting. Assess the whole product portfolio.
Climate solutions principles: defining and qualifying climate solutions and climate solutions companies	Fulfil criteria to qualify as a climate solution and a climate solutions company.	Not covered	Not covered	LCA approach. "Netting" is not allowed. Include all types of impact. Data should not be older than two years.	Performance is relative. Aim for continuous improvement.
ISO 14040/14044	Not covered	System expansion or cut-off approach.	Not covered	LCA approach. Specific requirements for comparative LCA. Analysis of data sensitivity and uncertainty must be included.	Interested parties must be offered to conduct a critical review of the results if results are intended to be disclosed to the public.

3.3 Review of company examples

The next section will examine the four examples of companies currently utilising Scope 4 reporting. The companies that will be reviewed are Ceres, Vestas Wind Systems A/S, Einride and Göteborg Energi with Profu, see Table 3.5 for further details. The section includes screenshots from the company websites from March 2024.

Table 3.5 Reviewed company examples.

Reviewed document	***Company***	***Industry***	***Product or service***
Carbon saving calculator	Ceres	Energy	Fuel cells
Sustainability report 2023	Vestas Wind Systems A/S	Energy	Wind systems
Tool for estimated savings, CO_2e emissions	Einride	Transportation	Electric and autonomous vehicles
Climate statements 2022	Göteborg Energi via Profu	Energy	District heating

3.3.1 Ceres

Ceres is a British provider of hydrogen fuel cells and electrolysis for green hydrogen production. They call themselves a "leader of clean energy technology" (Ceres n.d.b), and provide an ambitious tool for visitors to get an estimate on Ceres' carbon saving potential, called "the carbon saving calculator" (Ceres n.d.a). Ceres discloses some sources but does not show how the exact calculations have been made, other than their fundamental assumptions and structure.

The user must first choose between five specified applications where the hydrogen fuel cell can serve as a suitable substitute for the current business as usual. These are "EV supercharging", "peak power providence during an NFL game", "providing energy for a data centre in Ireland", a "power station for home heating", and "systems required to power Montenegro". The next step is to determine the reference scenario, which is limited to grid power energy mixes in different countries. Finally, the user can choose on what fuel the fuel cell is running on, either hydrogen or natural gas, after which a compilation of the carbon-saving potential is displayed. An example can be found in Figure 3.12.

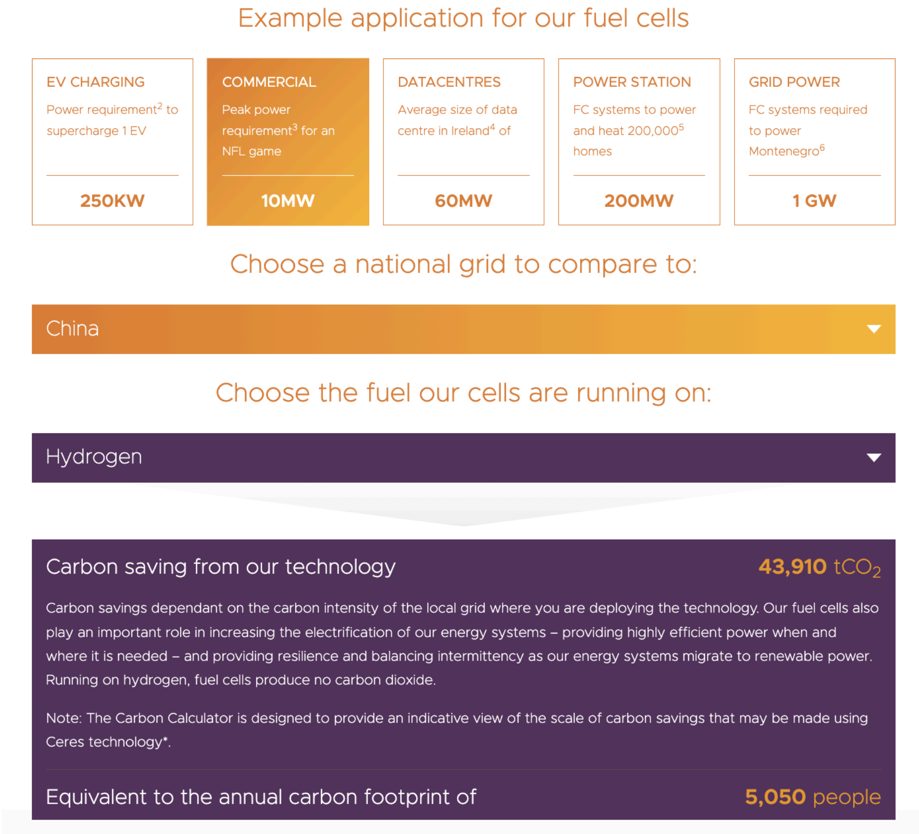

Figure 3.12 Ceres' carbon saving calculator (Ceres n.d.a).

Ceres adds a disclaimer that the numbers shown should not isolatedly be used to determine any technological decisions, that Ceres takes no responsibility for the results generated and that the tool is only meant to serve as a guide. Some notable observations regarding the methodology and communication choices evident in this example are as follows: firstly, only sources related to the application scenarios (power requirements and energy mixes) are disclosed; secondly, the tool assumes that the fuel cells will solely operate on green hydrogen; finally, there are no comments on the time frame, product lifetime, indirect emissions, and what parts of the lifecycle is included in the generated number.

3.3.2 Vestas Wind Systems A/S

Vestas Wind Systems is a Danish company that provides wind energy solutions on a global scale (Vestas n.d.). Describing themselves as "a global leader in sustainable energy solutions", Vestas is the oldest and largest wind manufacturer in the world. They contribute to reducing GHG emissions within the global energy system since one wind turbine generates 30-50 times more energy throughout its lifecycle than it consumes (Vestas 2023). In their 2023 Sustainability Report, Vestas provided details on their avoided emissions. They communicated two figures: the anticipated annual emissions avoided by their entire aggregated fleet installed between 1981 and 2023 (213 million tonnes CO_2e), and the expected emissions avoided over the lifespan of the capacity produced and shipped during 2023 (396 million tonnes CO_2e). However, the report only included details about how the second number had been quantified. The calculation methodology can be seen below, in equation (5).

$$\textit{Expected } CO_2e \textit{ avoided (M tonnes)} = \textit{Turbines produced and shipped (MWh)} * \textit{Capacity factor (\%)} * \textit{Expected lifetime of the turbine (years)} * \textit{Emissions intensity of electricity (g } CO_2e/kWh\textit{)} \quad (5)$$

To provide clarification on the calculation above, Vestas quantified the first factor by converting the megawatts (MW) of turbines installed into megawatt-hours (MWh). Subsequently, this figure was multiplied by the average capacity factor for wind farms serviced by Vestas and the expected lifespan of the turbines. Finally, the global average emissions intensity of electricity, quantified by IEA in 2023, was utilised to complete the calculation.

In connection to communicating their avoided emissions, Vestas has also disclosed their emissions across Scope 1-3 which can be traced back to 2019. The company has set clear targets across Scopes 1-3, which have been validated by the Science Based Targets initiative (SBTi). The figures across Scopes 1-3 are compared to equivalent numbers from 2022, indicating an increase in emissions across these scopes. Despite the total Scope 3 emissions increasing in 2023 compared to 2022, the emissions per megawatt-hour (MWh) generated have decreased. This trend, that emissions Scope 1-3 increase, could be attributed to higher sales in 2023 compared to 2022. Consequently, the total amount of avoided emissions in 2023 would be higher than in the previous year. However, contrary to expectations, Scope 4 emissions decreased from 408 million tonnes in 2022 to 396 million tonnes in 2023, which is left unaddressed.

3.3.3 Einride

Einride, a Swedish transportation company, specialises in digital, electric and autonomous shipping technology (Einride n.d.). Founded in 2016, the company has since then aspired to decarbonise the freight industry through its intelligent freight mobility solutions. In 2019 it was the first company in the world to deploy an autonomous vehicle on a public road (World Economic Forum n.d.). According to information available on the company's website, transitioning from diesel-based freight to shipping with Einride can result in an average CO_2e reduction of 95% (Einride n.d.). Additionally, while Einride does not explicitly use the terms "avoided emissions" or "Scope 4 emissions", the company provides a tool that allows users to estimate the potential CO_2 emissions savings compared to a reference scenario through the utilisation of their services. By simply adding information about goods type (Industrial, Retail, Grocery Retail or Other), the geographic location, daily shipping volumes and whether or not Einride should manage the electricity capacity, an estimate of potential CO_2e savings is generated.

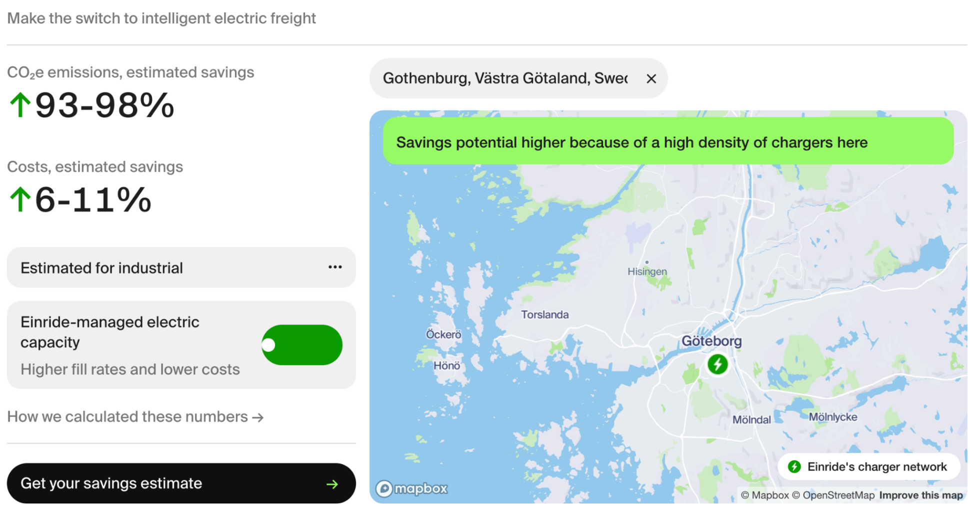

Figure 3.13 Tool that estimates CO_2e emissions savings (Einride n.d.).

A short description of how the estimate is calculated is provided. It is stated that "Operational emissions are evaluated based on a pre-operational methodology that's based on simulated energy consumption values.". In practice, this means that Einride has simulated the electric truck's energy consumption by using their "in-house vehicle models" that takes current operating conditions into account, for example, factors such as loads, speed profiles and road geometric properties. This energy consumption estimate, representing the use phase of the electric vehicle in the selected geographic region, is then used to calculate the emissions by using electricity emissions factors for the specific region. Einride states that either data from the IEA or, for the US market, data from the Environmental Protection Agency (EPA) is being used.

3.3.4 Göteborg Energi and Profu

Göteborg Energi is a municipal company providing energy and energy solutions in Gothenburg city and adjacent areas. Their comprehensive offer includes a range of services, spanning electricity, vehicle charging stations, district heating, solar energy, fibre optics, and gas. Each segment is underpinned by a commitment to facilitating a seamless transition towards a sustainable urban landscape, communicated for example through consumer campaigns, energy-saving tips and an overall vision of building a sustainable Gothenburg (Göteborg Energi n.d.).

Figure 3.14 Göteborg Energi Campaign "How little can you do for the climate?" (Göteborg Energi n.d.).

On their website, it is easy to access the latest sustainability report, which includes a disclosure of their KPIs and measurements, but also something that they call their climate statements (*Swedish: Klimatbokslut*). This is an annual climate accounting report established in collaboration with consultancy firm Profu (Göteborg Energi n.d.). The purpose of the climate statements is to provide a comprehensive picture of Göteborg Energi's impact on a system-wide level (Göteborg Energi 2022). According to the company, it has been developed following the Greenhouse Gas Protocol (see 3.2.1).

The climate statements from 2022 starts with an overview of Göteborg Energi's climate impact over the year of assessment, claiming that the sum of their added and avoided emissions is -394 300 tonnes CO_2e (Profu 2023). Furthermore, from thoroughly analysing a scenario where Göteborg Energi does not exist with one where it does, Profu argues that 994 767 tonnes of CO_2e have been avoided (see Figure 3.15).

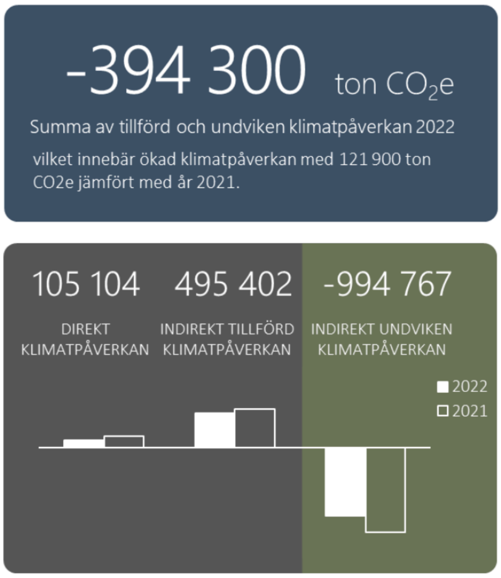

Figure 3.15 Claimed sum of Göteborg Energi's impact (blue), with breakdown numbers (grey/green) (Göteborg Energi & Profu 2022).

The results have been calculated using both internal numbers from Göteborg Energi's own Scope 1 and 2 measures, official key figures from Värmemarknadskommittén, and numbers on alternative scenarios from Profu's "experience models". The report provides a thorough illustration of the suggested impact drivers, accompanied by explanations of the supporting data. In addition, an in-depth report about Profu's methodology has been assessed, where deviations from the GHG Protocol framework are disclosed. In this report, it becomes clear that Profu views the attributional approach as solely an allocation method, whereas the consequential approach allows for a broader perspective to avoided emissions reporting. However, the report does not comment on the requirements for consequential data and LCAs that the GHG Protocol framework lists, why it is interpreted that this is one of the deviations that Profu makes. The choice of offsetting their avoided emissions from their added in Scope 1 and 2 (see Figure 3.16) is another such deviation from the GHG Protocol.

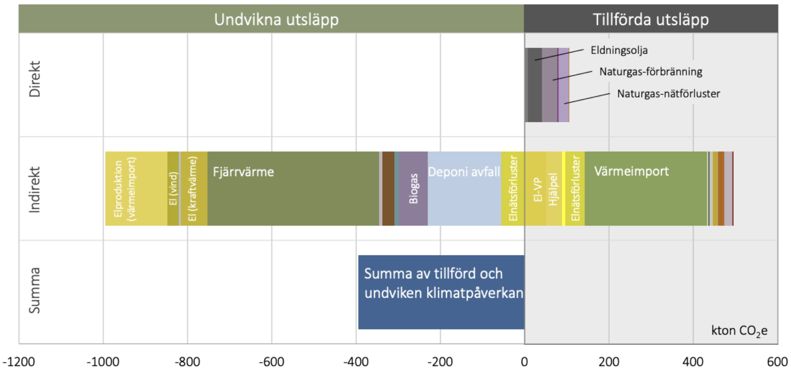

Figure 3.16 Breakdown of avoided and added emissions (Göteborg Energi & Profu 2022).

In an interview, David Holmström[6], Environmental Engineer at Profu, clarifies that the calculation method they follow is an interpretation of the consequential approach, but that some adjustments have been made to fit the energy market, the reporting objectives and the data that is available today. For example, no LCAs have been carried out or used in their estimates. Instead, their numbers are mainly based on reasonings around margins, and public- and internal data. Especially when assessing a company within the energy market, Holmström explains that Gothenburg and Sweden are part of the northern European power grid system and that the reference scenario hence must be analysed in detail to understand what specific numbers should be used. For example, only using a reference scenario that represents the Swedish electricity grid would not be sufficient, since the Swedish energy market is only a subsystem and cannot be viewed in isolation.

The importance of using a system-wide approach is something that Holmström and Eric Zinn, Chief Sustainability Officer at Göteborg Energi, emphasises thoroughly during the same interview. They state that this approach explains the substantial numbers presented in their “indirect impact”. As an example, the

[6]Eric Zinn, Chief Sustainability Officer, Göteborg Energi and David Holmström, Environmental Engineer, Profu. Interview 25th of March 2024.

reason why so much emissions are reduced from "landfill avoidance" (light blue bar in Figure 3.16), is due to a domino effect where Gothenburg would import less waste in the scenario where Göteborg Energi did not exist. As a consequence, less waste from Europe would be imported for combustion, leaving this amount of waste in landfills and leading to added emissions in the shape of methane leakage. According to Holmström, incorporating this aspect is crucial when assessing a company's environmental footprint, while Zinn emphasises its significance as a vital tool for forward-looking analysis of the market as a whole.

When discussing the issue of greenwashing from presenting avoided emissions claims, Zinn says that the report is not meant to be a communication tool for customers, but more about getting a holistic view of Göteborg Energi's impact. He also confirms that with the global green transition, their relative impact will become smaller and smaller with every year of assessment, but that this is positive. On the other hand, in terms of reliability, Holmström admits that all numbers are based on their own estimations and choices of reference scenarios and that the quantified data inputs are difficult to prove. When asked about the new Green Claims Directive and how it will affect Profu's methodology, Holmström says that discussions have been initialised but that they will have to evaluate further if modifications are necessary.

3.3.6 Summary of reviewed company examples

After reviewing four examples of companies that currently perform Scope 4 reporting, it is evident that each company diverges from the existing guidelines in some manner. First and foremost, there is inconsistency in terminology: Vestas and Göteborg Energi are the only companies explicitly using the terms "avoided emissions" and "Scope 4". On the other hand, Ceres and Einride communicate their avoided emissions by providing tools that estimate CO_2e savings when using their products. Since these estimations are still based on comparing their products with a reference scenario, they fall under the concept of avoided emissions.

Besides inconsistent terminology, a few observations have been made both in terms of common denominators and factors that separate the examples from each other. A common factor among all examples is the absence of utilising an LCA approach. For example, Vestas has solely used their total amount of generated megawatt-hours and translated those into emissions using emissions factors, leaving it unclear how the environmental impact from the manufacturing process and all other life stages have been accounted for. Furthermore, the approach that Einride uses when providing their CO_2e-savings estimates only relies on the use phase, meaning that an LCA approach is not being employed. The environmental impact during all other life stages is not presented, making a holistic comparison between Einride's electric vehicle and a diesel truck, which constitutes the reference scenario, impossible. Additionally, no specifics are provided regarding the timeframe in which the truck should be operated to achieve the projected CO_2e savings. Next in order is Göteborg Energi, who claims that the GHG protocol's consequential approach has been used, but does not utilise any consequential LCAs to base their calculations on.

Not using an LCA approach when reporting Scope 4 emissions heavily reduces the credibility of the claim, since it cannot be certain that the environmental impact from the use phase outperforms the impact from the other life stages. Instead, it allows companies to develop methodologies that prioritise areas where their metrics appear most favourable, potentially leading to numbers that consumers struggle to comprehend or compare.

Another common denominator between Vestas and Einride is the low specificity of the claim. Both companies rely on emission factors when quantifying their avoided emissions, thus using a very general approach. Vestas utilises an average global emission factor which means that their reference scenario represents a general estimation that does not consider specific technologies in isolation or geographical differences. In addition, Vestas uses a "capacity factor" without providing sufficient contextual information, making it unclear what is accounted for in that factor. Einride takes a slightly more detailed approach by using regional emission factors that represent the local electricity grid.

The lack of transparency is another observation that can be seen in all examples. For example, Einride only offers a short description of the calculations they have performed and refers to the usage of "inhouse-models". The same goes for the estimates provided by Ceres. This lack of transparency leaves users with limited insight into the calculations behind the assessed technology, particularly in instances where they may vary based on specific applications. Low transparency creates the impression that the statement could be fabricated, even though considerable effort may have been invested in assessing Scope 4 emissions. Clear evidence supporting the claim must be provided to establish trustworthiness.

The examples provided by Ceres also appear to be based on overly optimistic assumptions, particularly regarding the current hydrogen market. It seems that Ceres may have assumed that the hydrogen used in their analysis is entirely green, without acknowledging the variations in hydrogen sourcing. Ideally, the tool should offer the flexibility to choose different types of hydrogen sources for a more comprehensive analysis. Alternatively, Ceres should have provided clarification regarding their assumptions.

Another observation that applies to all company examples is a general lack of discussion regarding uncertainty. Although Ceres adds a disclaimer in their calculator saying that they take no responsibility for the generated results, it is desired that they disclose what possible uncertainties could affect the results. Not only does this improve the trustworthiness of the numbers, but it is also required in the guiding frameworks reviewed in this paper. The same applies to Göteborg Energi, where although a substantial amount of background information is provided, it is never discussed whether other possible scenarios could influence the result presented. Since their claim on avoided emissions is almost ten times the size of their direct emissions, it is important to highlight that these numbers are based on theoretical scenarios with inherent high uncertainty. Such recognition would underscore the potential for significant variations in output if alternative scenarios were chosen, adding a necessary dose of humility to the analysis. On the same topic, it can be argued that it is deceptive by Göteborg Energi to present their suggested avoided emissions next to their direct, actual emissions since this means that they mix verified, internal numbers with possible and theoretical ones. Mixing different levels of uncertainty into a quantified result generates, again, a number that is very hard to comprehend or compare. It is also not in line with the GHG Protocol as Profu and Göteborg Energi claim. In addition, although Göteborg Energi says that this report is not intended to be presented to possible customers, the result is both presented in their sustainability report, and the statement's introduction also states that these numbers are of interest to "all customers and other stakeholders".

4 Scope 4 Framework

In this chapter, a suggestion on how a company can report on Scope 4 emissions is presented. The framework, that will be called the "Scope 4 Framework", entails a seven-step approach to avoided emissions reporting and has been established using input from all parts of the literature review, and with a focus on mitigating the risk of greenwashing.

4.1 Description of the Scope 4 Framework

Based on the literature review and interviews, a practical framework for Scope 4 reporting has been developed. This framework aims to function as a guiding tool for organisations that are considering initiating the process of Scope 4 reporting and describes how to proceed from ideation through to implementation. By following this seven-step approach, the objective is to provide a procedure that is comprehensive, compliant with relevant regulations and feasible without excessive resources. The framework is presented in Figure 4.1.

With every practical step comes an attribute that is considered crucial to avoid accusations of greenwashing (portrayed by arrows in Figure 4.1). These are compliance, accuracy, credibility, relevance and transparency. Also, feasibility has been included to ensure that executing the tasks within the framework is not overly complex and can be completed within a reasonable time frame. The attributes serve as the main criteria when designing the framework and its correlating steps and procedures. The steps will be presented chronologically in the following sections.

In terms of its content and recommendations, the framework includes selected takeaways from the literature review that go in line with the established criteria. Where opinions differed, the framework either uses the method that is considered the most feasible, or presents two options.. It is important to note that the framework is designed for current and relevant future regulations and guidelines as of 2024. Hence, adopters are urged to always follow current regulations and update themselves accordingly.

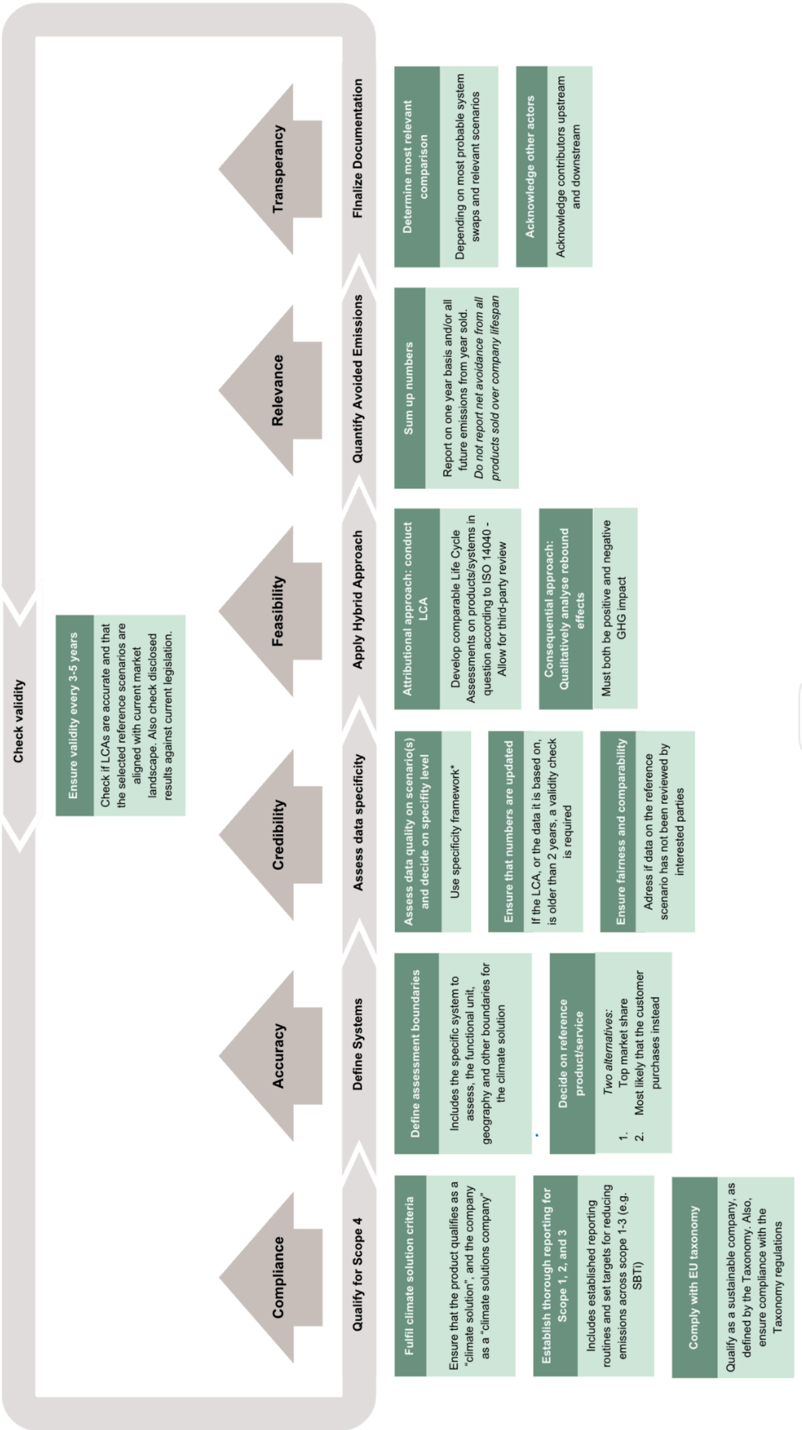

Figure 4.1 The Scope 4 Framework.

4.1.1 Qualify for Scope 4

Since a major part of the European Green Deal revolves around distinguishing sustainable activities and companies from others, the Scope 4 Framework integrates procedures in fulfilling some sustainability criteria in its primary step. This can be further strengthened by the arguments discussed in 3.3.6, around what kind of companies are eligible to claim praise for avoided emissions. By incorporating the EU Taxonomy's criteria for qualifying as a sustainable company, the framework quickly filters out companies whose offer's main cause is not to provide a more sustainable solution to the current status quo. This means that the company at interest must first provide proof that it qualifies as a "sustainable" company by the EU's definition, before proceeding with the next steps.

Since sustainability and sustainability superiorness are relative measurements, as pointed out in *Climate solutions principles: defining and qualifying climate solutions and climate solutions companies*, the first step in the Scope 4 Framework also incorporates the criteria from the same working paper. These criteria on what a climate solution and what a climate solutions company is defined by will always be relative to the current time and global sustainability level. Thus, the first step of the Scope 4 Framework will have to be iterated and re-tried as time passes and other technologies evolve. One important criterion from this paper is that the company that wishes to disclose their avoided emissions must first also ensure that their offer does not come with other harmful impacts on the environment, such as overfertilisation or acidification. Doing so prevents potential cherry-picking accusations. Lastly, the qualification step also includes ensuring compliance with the requirements from the EU Taxonomy and the CSRD, which ensures that an established ground for sustainability reporting is in place before initiating any Scope 4 reporting process. This includes defined Scope 1 to 3 data collecting- and reporting routines and trained personnel. Since the comparative calculations must be based on ISO-compliant LCAs (presented in 4.1.4), these routines are crucial to be able to calculate valid and transparent results.

By incorporating these criteria, the first step of the framework aims to ensure compliance with relevant legislation as well as to secure validity in that the reporting company can prove an actual reduction in emissions. Note that these criteria naturally exclude companies whose solutions solely generate avoided emissions due to potentially changed behaviour. For companies not complying with the criteria, it is thus recommended to not incorporate Scope 4 as part of their communication and reporting practices.

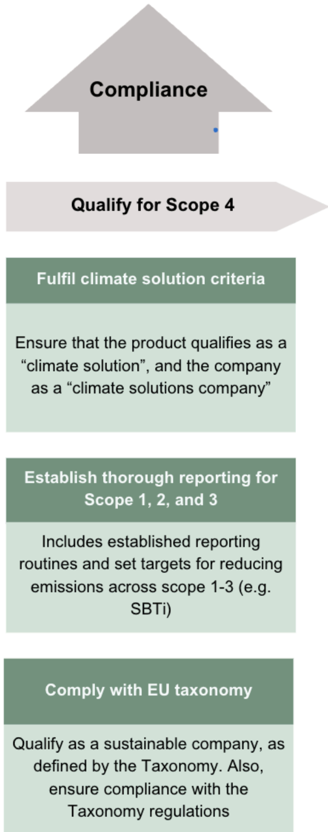

Figure 4.2 Step 1 Qualify for Scope 4.

4.1.2 Define systems

The second step involves defining the systems for comparison. This entails selecting the climate solution to be evaluated and establishing the reference scenario(s). Initially, the company must specify the climate solution and its assessment context, and then define the functional unit and system boundaries. When deciding on the assessment context, factors such as geography should be taken into consideration. The climate solution and the reference scenario must be assessed in contexts that are as similar as possible, meaning that they can be used as perfect substitutes within the specified context, which was particularly highlighted by Mats Zackrisson[7], Researcher at RISE, in an interview.

When determining reference scenarios, the Scope 4 Framework recommends using two different scenarios (potentially more than two depending on the situation). One scenario should reflect the product or service that would likely have been chosen in the absence of the solution, while the other should represent the market-leading option, being the product or service with the highest market share. Using different reference scenarios will provide a more comprehensive and nuanced perspective and will then further increase the credibility of the claim, instead of only comparing with the "worst-case scenario". However, as discussed in section 3.3.6, these scenarios may converge into one since both options can lead to the same product or service. Where circumstances speak for only comparing the assessed system with one reference scenario, this recommendation can be overlooked, however, users are urged to do so with caution.

To ensure accuracy in the Scope 4 claim, it is crucial to carefully consider the second step since it will have a great influence on the magnitude of the avoided emissions claim. It will further determine the complexity of the calculation process since the system boundaries decide what factors will be included. When establishing the system boundaries, it is a balance between maintaining the feasibility of quantifying avoided emissions, while also striving to use a system that accurately reflects reality.

[7]Mats Zackrisson. Researcher, RISE. Interview 6th of February 2024.

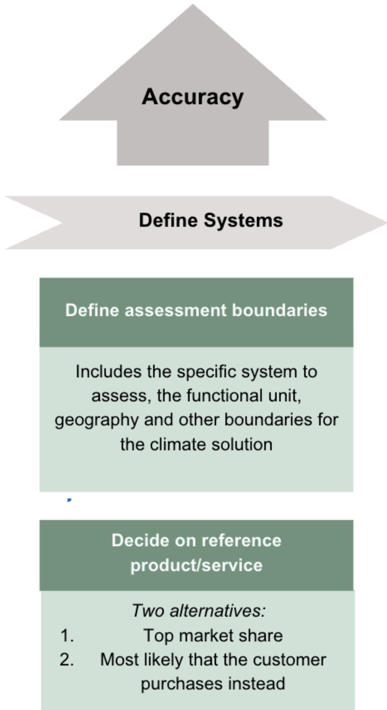

Figure 4.3 Step 2 Define systems.

4.1.3 Assess data specificity

The third step of the Scope 4 Framework involves collecting data and assessing the specificity of collected data that will be used in the coming steps, to achieve high credibility of the avoided emissions claim. Addressing the specificity entails using the specificity framework (see Figure 4.4) and determining the specificity level. Evaluating the specificity involves clearly stating, both for the climate solution and the reference scenario(s), whether the data is solution-specific, company-specific or statistical. If the data is solution- or company-specific it is primary data, while statistical data can be considered as secondary data.

	Solution			
Reference scenario	**Specificity level**	Solution specific	Company specific	Statistical
	Solution specific	Very high	High	Medium-high
	Company specific	High	Medium	Medium-low
	Statistical	Medium-high	Medium-low	Low

Figure 4.4 Specificity framework to be used in the third step of the Scope 4 Framework.

In the specificity framework (see Figure 4.4), the highest level of specificity, labelled "Very high", is the most desirable. This level involves the least amount of uncertainty as the avoided emissions claim is based on data collected from specific products. However, a low specificity level does not inherently indicate a poor quality claim, but it does entail more uncertainty due to the lack of specific data. Acknowledging and addressing the specificity of the avoided emissions claim is important since it ensures clarity for the recipient regarding the data underlying the avoided emissions claim. Also, it strengthens the credibility of the claim. Consequently, information on data specificity should accompany the avoided emissions claim.

In terms of what data is required, this is determined by the system that was defined in the previous step. For the climate solution, the goal should be to collect solution or company-specific primary data, which should be feasible since the climate solution is part of the product portfolio of the company performing the assessment. While it is advised to collect primary data for the reference scenario as well, this task is likely to be more challenging. In such cases, statistical secondary data may be the only viable option. This secondary data can be obtained by sourcing publicly available data from companies providing the reference product. Utilising statistical data from databases, which would represent the average reference scenario on the market, is another option. It is highly recommended that the collected data should not be older than two years. If such data is not available, a validity check must be conducted.

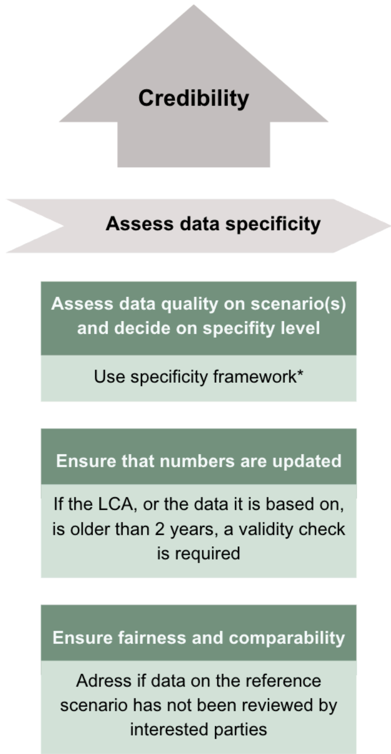

Figure 4.5 Step 3 Assess data specificity.

4.1.4 Apply hybrid approach

The fourth criterion that this framework aims to fulfil is feasibility, which does not necessarily relate to the mitigation of greenwashing. However, it is an important factor to ensure for the reporting company. With the comprehensive recommendations and regulations that have been reviewed in previous sections, a major criterion for the subsequent recommended procedures is that it must be possible to use without excessive resources or expert knowledge. As a result, the "hybrid approach" was developed.

The hybrid approach consists of two steps: conducting an attributional and comparative LCA for the climate solution and reference scenario(s), followed by an analysis of potential rebound effects. The approach intends to incorporate the LCA based method for calculations that would both ensure compliance with the reviewed regulations and that also align with the recommendations observed in the guiding documents. However, it differentiates from the reviewed literature in that it requires a complementary, qualitative discussion about the rebound effects of the system swap. This decision is based on the recommendation from the WRI framework (3.2.1) in using a consequential approach but solves the issue that such data is not available today. By using the hybrid approach and providing analysis and acknowledgement that a system swap will always lead to increased emissions in certain ways, the ambition is that this will increase reliability and transparency for customers and other stakeholders.

When performing the quantitative analysis, it is recommended that a supplementary uncertainty analysis is added as part of the calculations. This means that an uncertainty interval should be added to the collected input data, in turn creating a continuous interval that represents the final potential avoided, or added, emissions. The interval provides an argument for which comparative numbers to communicate, and where uncertainty is too high. The uncertainty factor for the input data should be between 20–50%, depending on its evaluated uncertainty.

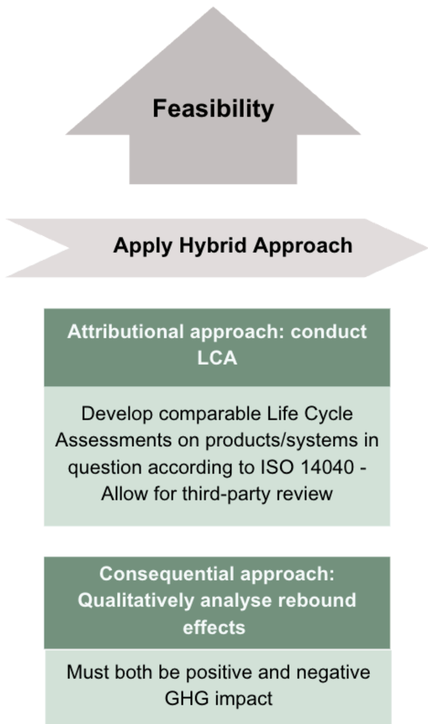

Figure 4.6 Step 4 Apply the hybrid approach.

4.1.5 Quantify avoided emissions

Once the hybrid approach has been executed in the fourth step and the GHG emissions per functional unit for the climate solution and the reference scenario are known, the fifth step entails quantifying the avoided emissions and arriving at a final figure. In other words, the fifth step entails using the results from the LCA to calculate the avoided emissions over an appropriate time frame to enhance the relevance of the avoided emissions claim.

The Scope 4 Framework recommends utilising two different yet complementary time frames for reporting avoided emissions: annually and over the entire lifespan of the climate solution. These time frames, cited in the literature, provide a comprehensive and relevant view of Scope 4 emissions. The annual figure offers greater certainty, as the market will fluctuate less within a single year compared to the entire lifespan of the solution. However, the figure representing the total avoided emissions over the lifespan still contributes to the overall picture. It is crucial to explicitly state that this number remains valid only with the current market dynamics. In practice, the equations below show what calculations to perform to get the final figures, if for example the functional unit is defined as one delivered kWh. Note that *GHG emissions/kWh* represents the result from the LCA completed in the previous step.

*Total GHG emissions for climate solution = GHG emissions/kWh * number of kilowatt hours for climate solution* (6)

*Total GHG emissions for reference scenario = GHG emissions/kWh * number of kilowatt hours for climate solution* (7)

Total avoided emissions of climate solution = Total GHG emissions for reference scenario - Total GHG emissions for climate solution (8)

Yearly avoided emissions of climate solution = Total avoided emissions of climate solution/lifespan [years] (9)

These figures can be multiplied by the number of products sold to calculate the total avoided emissions on a company level for each specific product. Additionally, the total avoided emissions for different products in the portfolio can be aggregated to obtain a number representing the total avoided emissions on a company level. Thus, using the time frames above offers flexibility and ensures the relevance of the avoided emission claims within the given context.

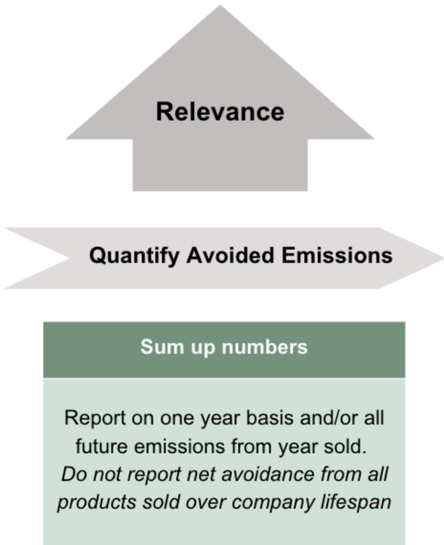

Figure 4.7 Step 5 Quantify avoided emissions.

4.1.6 Finalise documentation

The sixth step of the Scope 4 Framework involves conducting a relevance analysis. If multiple reference scenarios have been used and compared to the climate solution this step entails selecting which of the scenarios hold the highest relevance. This is an important step when deciding which results to communicate. When assessing which results are the most relevant, system-wide factors should be considered, for example identified rebound effects and the development of supporting technologies.

Furthermore, the sixth step also involves acknowledging that the accomplishment of a solution is possible thanks to all actors involved in the company's value chain. This step aims to further strengthen the transparency of the result disclosed, but it also adds humility to the claim. Furthermore, this kind of addressing mitigates the observed issue of double-counting: if, for example, a provider of EV batteries discloses their avoided emissions, but a purchaser of these batteries does so as well, there is a high probability that the same avoided emissions have been disclosed twice. Since the technical methodology has no intuitive tool to solve this, coordinated acknowledgements of one another will at least let the recipient understand that all avoided emissions reported are not exclusive. Thus, acknowledging other actors does not directly fix the double counting issue, but it is a good substitute for portioning the avoided emissions among all stakeholders. This other option would add yet another complex calculation step that decreases the feasibility of the framework. In conclusion, the Scope 4 Framework allows for double-counting, but awareness of this issue should be understood internally and communicated with all stakeholders.

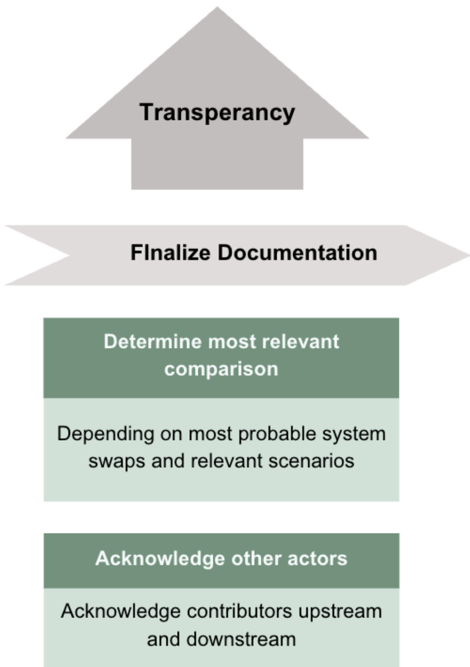

Figure 4.8 Step 6 Finalise documentation.

4.1.7 Check validity

To ensure that the results presented are continuously relevant, it is recommended to do a validity check every three to five years. This validity period is aligned with those of other documents of quantified environmental information, such as EPDs (The International EPD System n.d.). To perform the validity check, a three-step methodology is proposed: first, the reference systems must be verified in terms of their relevance, that is, that they still qualify as either the top market share, or the alternative that a potential customer would most likely purchase instead of the climate solution. If the market landscape is different from the one that the LCAs mirror, it is highly recommended to re-execute the framework's process steps to mitigate any obsolescence. Second, it must also be verified that the data used in the LCAs still are valid, both considering the climate solution and the reference systems. Again, if the analysis says otherwise, the results should be considered outdated and a new assessment should be conducted.

Third, apart from previously mentioned verifications, this iterative process step also includes checking the disclosed results, especially with a focus on the performed methodology, against the regulatory landscape. This includes ensuring that no new directives on how comparative assessments should be performed have been implemented and that the regulatory framework for reporting and publishing numbers on Scope 4 emissions has not changed. Presumably, the most relevant directive to scrutinise on this topic is the Green Claims Directive and its current timeline towards full implementation.

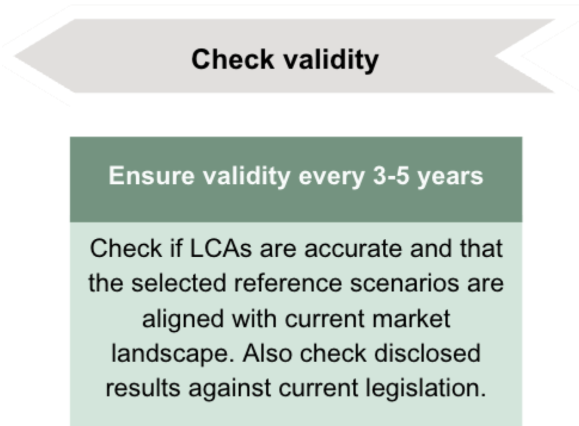

Figure 4.9 Step 7 Check validity.

4.2 Case Study: PowerCell Group

In the following section, the Scope 4 Framework will be used in the context of PowerCell and applied to their fuel cell system, P System 100 (described in 4.2.2), to estimate the associated avoided emissions in comparison to multiple different reference scenarios. Before initiating the process of executing the steps within the framework, it is crucial to acknowledge that within the timeframe of this thesis, it is not feasible to perform all steps as thoroughly as needed. Consequently, a few disclaimers are necessary. These are outlined below.

- A life cycle assessment already carried out by Mats Zackrisson at RISE on behalf of PowerCell in September 2022 will be used in the fourth step. The LCA is performed in accordance with ISO 14040 and 14044 and compares a fuel cell with a diesel genset. The described system in this LCA will therefore decide the system in the second step of the Scope 4 Framework.
- One of the reference scenarios is a stationary battery and an LCA carried out by Öivind Andersson and Pål Börjesson (2021) that represents a battery used in an electric vehicle will be utilised. Since this LCA does not represent the same system as the LCA on fuel cells, this is a deviation from the recommendation in the Scope 4 Framework. Thus, the results from the comparison with a stationary battery cannot be publicly disclosed by PowerCell.
- To fulfil the requirements of a comparative LCA outlined in the ISO standard, third-party verification is necessary (see 3.2.4). This will not be completed as part of the following assessment but is a step that should be performed by PowerCell, to be able to disclose the results.
- The seventh step of the framework, *Check validity,* will not be performed as part of this case study. This is only recommended every 3-5 years and it is thus a step that PowerCell will have to carry out in the future.
- When communicating the results of avoided emissions, the explicit numbers should never be presented in isolation. The philosophy underpinning the Scope 4 Framework is that once all steps have been executed, comprehensive information regarding each step should accompany the avoided emissions claim. This is to ensure compliance, accuracy, credibility and transparency.

4.2.1 Qualify for Scope 4

For PowerCell to be determined as a company eligible for Scope 4 reporting, the assessed product needs to fulfil the criteria of being a climate solution, and the organisation itself needs to fulfil the criteria of a climate solutions company. Furthermore, PowerCell's offer needs to be aligned with one of the criteria from the EU Taxonomy's definition of a sustainable company. The result from the specific list of criteria is presented below.

Table 4.1 Results from the eligibility matrix of PowerCell and P System 100.

EU Taxonomy vs PowerCell		
The company works towards one of the following main objectives: climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems.		Yes, but the official document is in progress
Climate Solution vs P System 100		
Does the solution significantly lower the carbon footprint per functional unit than the BAU?		Yes
Is the solution's primary purpose to enable others to reduce their emissions?	(Must fulfil at least one)	Yes
Does the solution meet a credible threshold of emissions per functional unit?		Yes
Are the calculations life-cycle based?		Yes
Does the result not rely on net reduction from carbon credits?		Yes
Is the solution scalable to the whole world's population, while not enabling any further virgin use of fossil fuels?		Yes, with comment
Does it fulfil a basic human need?		Yes
Is it aligned with the UN's SGDs?		Yes
Does it not have any other harmful impact on the environment?		Yes, but the official document is in progress

“Climate solutions company” vs PowerCell	
Does more than 90% of the company’s revenue come from sales of climate solutions?	Yes
Does the company have public interim and net zero climate targets, a published transition plan and an annual progress report?	Yes, in progress
Does the company work broadly to transform its sector?	Yes
Other criteria	
Does the company have established routines for Scope 1 to 3 reporting?	Yes
Is the company compliant with the EU Taxonomy?	Yes, but official documents in progress
Does the company report on their impact in line with the CSRD?	Applicable in 2025

All criteria have been discussed and analysed together with Chief Analytics and Sustainability Officer at PowerCell, Victor Åkerlund[8], in an interview. Since the criteria from the guiding papers do not come with specific definitions on when they are fulfilled, qualitative reasoning has been permitted to assess their fulfilment. For example, on the question if “the solution is scalable to the whole world’s population, while not enabling any further virgin use of fossil fuels”, a best case scenario would include actual numbers and analysis on the product’s scalability, potential bottlenecks and a consequence analysis in terms of virgin fossil fuel use. However, as of 2024, no such evidence exists within PowerCell internally. Instead, Åkerlund explains that the concept of hydrogen fuel cells without doubt could work globally as a substitute for conventional engines. “In theory, it only requires a solar panel, an electrolysis system and a fuel cell system”, Åkerlund states, but also adds that a large-scale demand for fuel cells would require investigation in, for example, raw material supply and other bottlenecks (further discussed in 4.2.4). Regardless, the criteria is considered fulfilled, since the solution is not dependent on a specific location or geography.

[8] Victor Åkerlund, Chief Analytics and Sustainability Officer, PowerCell Group. Interview 16th April of 2024.

A criterion that can be found both in the legislative requirements and in the guiding papers is that the company must work towards a sustainability objective, without harming the environment in any other way. These criteria are also considered fulfilled, but Åkerlund[9] mentions that the EU Taxonomy requires a full set of evidence material that must be performed according to a specific methodology. These documents are in progress, and Åkerlund hopes that full compliance with the EU Taxonomy will be achieved in 2025.

Finally, Åkerlund explains that the CSRD does not yet apply to PowerCell, and will do so in either 2025 or 2026, depending on their future growth. The practical implications of the CSRD are nevertheless already in progress. Thus, this criterion will not affect the eligibility of PowerCell's qualification for Scope 4 reporting.

4.2.2 Define systems

The climate solution that will be considered in the Scope 4 Framework is the PowerCell P System 100 fuel cell, specifically used in a construction site application. In essence, this application is used before grid electricity is available at a construction site (Zackrisson 2022). The full system consists of both the P System 100 and container components essential for the application. The P System 100 further consists of different parts: a fuel cell stack, a hydrogen subsystem, a cooling system, an air subsystem, a fuel cell safety system and a fuel cell control system. Furthermore, the P System 100 has an operational lifetime of 20 000 hours, an estimated lifetime of approximately 10 years (See Appendix B for estimation), and a power output of 100 kW. Assuming a 50% efficiency rate, the system can deliver 1.0 GWh.

The reason for selecting the P System 100 in a construction site application is because it is the system that has been assessed in the LCA conducted by RISE. The same functional unit and system boundaries that were used in this LCA will be used in the Scope 4 assessment. Consequently, the functional unit that will be employed is one delivered kWh of electricity. Furthermore, the LCA employs a cradle-to-grave perspective and uses the polluter pays principle (PPP). In essence, this principle is similar to a cut-off approach where recycled materials

[9] Victor Åkerlund, Chief Analytics and Sustainability Officer, PowerCell Group. Interview 16th April of 2024.

are accounted for as input materials only if actual recycled materials are utilised instead of virgin materials. No credits are included for materials that are recycled after the end of the use phase. This approach is justified due to the difficulty in verifying that materials are actually being recycled. Thus, a rather conservative approach was utilised when the LCA was performed, which aligns with the conservative nature of the Scope 4 Framework and ISO 14044.

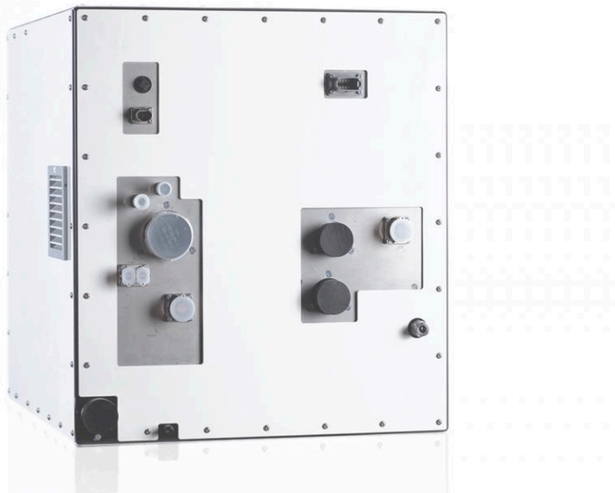

Figure 4.10 Power Generation System 100 (PowerCell Group n.d.b)

Since the level of GHG emissions generated by a fuel cell system highly depends on the electricity used to produce hydrogen, multiple scenarios using different types of H_2 generation will be considered. The different scenarios take Swedish mix, European mix and solar electricity into account. Additionally, one scenario will be based on using hydrogen generated from burden-free electricity, meaning that no GHG emissions were emitted during the electricity generation. Another scenario will represent a future fuel cell where burden-free hydrogen and less platinum (34 g instead of 92 g) are used in the fuel cell stack. It must be addressed that these burden-free scenarios are purely hypothetical, since burden-free electricity does not exist. However, it has been included to highlight the GHG impact of the fuel cell alone.

All of the mentioned scenarios were included in the LCA by Zackrisson (2022). In an interview with Martin Pontén[10], Project Manager at PowerCell, he stated

[10] Martin Pontén, Project Manager, PowerCell Group. Interview 6th of February 2024.

that if PowerCell were to perform another LCA today, the future base case would be based on a fuel cell stack with 40 g platinum. Consequently, the future base case employed in this case study is based on a slightly more optimistic scenario.

Furthermore, one final fuel cell scenario that was not included in the LCA by RISE will be considered. This scenario will be based on using a fuel cell that runs on grey hydrogen, since it is considered highly relevant due to the fact that the majority of the hydrogen produced today is grey (see section 1.3 and 1.4).

In terms of reference scenarios, multiple will be employed. The first reference scenario to be used is a diesel genset, which was also included in the LCA conducted by Zackrisson (2022). The reason for choosing a diesel genset as one of the reference scenarios is because it can be assumed to be the most widely used solution and market-leading option, since fossil fuels (coal, gas and oil) make up 82% of the global energy mix (S&P Global 2023). The second reference scenario that will be employed is a diesel genset fuelled on HVO100 (Hydrotreated Vegetable Oil). HVO100 is a type of biofuel that leads to a reduction in GHG emissions in comparison to conventional fuels (Lantmännen 2023). HVO can therefore be assumed to reflect the option that would likely have been chosen in the absence of the climate solution if the objective is to swap to a system with less climate impact. Since HVO has similar chemical properties as diesel, it can be used as a substitute for diesel in a genset. It can be used either as pure HVO100 or blended with regular fossil diesel.

A scenario based on 42.5% HVO and 57.5% diesel will also be considered. This is motivated by the binding renewable energy target of at least 42.5% by 2030 in the EU (Directive 2023/2413). This scenario can thus serve as a potential future scenario.

The final reference scenario that will be considered is a stationary battery, which could also serve as a direct substitute for the fuel cell system in a construction site application. Selecting a stationary battery as a reference scenario is motivated by the fact that, similar to the option of using HVO, it could potentially have been chosen in the absence of the climate solution. By incorporating both the usage of HVO and a battery as reference scenarios, a more nuanced picture of the avoided emissions claims is provided, as alternatives beyond the worst-case scenario of using diesel are considered. However, due to the previously mentioned limitations, an appropriate LCA has not been conducted for a battery in a construction site system. Instead, an LCA for a battery-electric vehicle will be used (Andersson & Börjesson 2021). Thus, this last reference scenario involves a significant amount of uncertainty and deviates from the recommended approach in the Scope 4 Framework. The different scenarios (both versions of the climate solution and the different reference scenarios) that will be considered are listed in Tables 4.2 and 4.3.

Table 4.2 Summary of assessed climate solution scenarios.

Climate solution scenario	***Assessed system***
P System 100, Burden-free hydrogen (0 g CO_2e /kWh)	Construction site application
P System 100, Swedish electricity mix (44 g CO_2e /kWh)	Construction site application
P System 100, European electricity mix (373 g CO_2e /kWh)	Construction site application
P System 100, Solar power (77 g CO_2e /kWh)	Construction site application
P System 100, Future scenario (Burden-free hydrogen and 34 g Pt)	Construction site application
P System 100, Grey hydrogen (12 kg CO_2e/kg H_2)	Construction site application

Table 4.3 Summary of assessed reference scenarios.

Reference scenario	***Assessed system***
Genset, Diesel	Construction site application
Genset, HVO100	Construction site application
Genset, 42.5% HVO/57.5% Diesel	Construction site application
Stationary battery, Swedish electricity mix (44 g CO_2e /kWh)	Battery-electric vehicle application
Stationary battery, European electricity mix (373 g CO_2e /kWh)	Battery-electric vehicle application
Stationary battery, Solar power (77 g CO_2e /kWh)	Battery-electric vehicle application

4.2.3 Assess data specificity

In the subsequent section, the specificity of the data utilised in the Scope 4 assessment will be addressed. Firstly, the LCA forming the foundation of this assessment integrates both primary and secondary data sources. Input data for the P System 100 is collected from a bill-of-materials (BOM), the RISE database, and the commercial database Ecoinvent (Zackrisson 2022). Essentially, this means that primary and company-specific data has been used to calculate the GHG emissions generated by the P System 100.

The input data for the diesel genset is secondary and statistical: it does not reflect data from a genset of a specific brand. Similarly, data for HVO is also statistical and has been sourced from the EU Renewable Energy Directive II (RED II), where an average of different European HVO blends has been calculated (Directive 2018/2001) (see Appendix A). Consequently, comparing the P System 100 with the genset results in a medium-low specificity level in the specificity levels matrix, see Figure 4.11. In other words, this means that the avoided emissions claim is prone to uncertainty, primarily due to the usage of secondary data for the genset. The uncertainty could be reduced by using company-specific data for the genset as well, thereby achieving a medium level of specificity instead in the framework below.

		Solution		
	Specificity level	Solution specific	Company specific	Statistical
Reference scenario	Solution specific	Very high	High	Medium-high
	Company specific	High	Medium	Medium-low
	Statistical	Medium-high	**Medium-low**	Low

Figure 4.11 The specificity level for the avoided emissions claim for a P System 100 and a genset.

As previously mentioned, due to the unavailability of a specific LCA for a stationary battery in a construction site application, an LCA for a battery electric vehicle will be utilised instead. It is important to note that this approach deviates from the suggested methodology outlined in the Scope 4 Framework, which recommends using solutions that are perfect substitutes for each other and are employed in the same context. In order to accurately communicate avoided emissions when comparing the fuel cell with a stationary battery, an additional LCA would need to be conducted. However, the battery scenario has been included nonetheless as it is considered an important reference scenario that is aligned with the recommendations in the Scope 4 Framework. Due to mentioned limitations, the comparison with a battery will not be assessed in the specificity level matrix.

4.2.4 Apply hybrid approach

This step of the Scope 4 assessment entails conducting the LCA(s), however, in this case, the previously conducted LCA by RISE will be used. The LCA was performed in accordance with ISO 14044 (and 14040) and the ILCD (International Life Cycle Data system) Handbook, with calculations conducted with SimaPro 9.3.0.3 and Excel. The result qualifies as attributional, since no calculations on rebound effects are included. All results from the LCA can be found in Table 4.4 and further on in 4.2.5.

In Tables 4.5, 4.6 and 4.7, the results from the scenarios not covered in the LCA can be found. These include the fuel cell using grey hydrogen as well as all reference scenarios, and are presented separately to emphasise that they come from other sources than the LCA by RISE. The scenarios involving grey hydrogen and HVO have been quantified through both using data from the LCA by RISE and statistical input data from IEA and RED II. All battery scenarios use data from the LCA by Andersson and Börjesson previously mentioned. Further details on the calculations are available in Appendix A.

In addition, an uncertainty interval has been calculated for each result (not included in the LCA by RISE), as can be seen in the tables below. For Tables 4.4 and 4.5, the associated interval is ±20%, while an interval of ±50% has been used for the battery results, see Table 4.6. This is supported by the fact that the battery scenarios include significantly more uncertainty than the other scenarios, since the results represent a battery used in an electric vehicle instead of a construction site application.

Table 4.4 GHG emissions per functional unit for P System 100 where different energy sources have been used in the H_2 production. Includes numbers of a diesel genset. "FC" denotes fuel cell.

	FC Burden-free H_2	*FC Swedish electricity mix*	*FC Solar electricity*	*FC European electricity mix*	*FC Future scenario Burden-free H_2 and less Pt*	*Genset, Diesel*
kg CO_2e /kWh	0.073	0.248	0.380	1.570	0.069	0.523
***Uncertainty intervals** (±20%)*	[0.058, 0.088]	[0.198, 0.298]	[0.304, 0.456]	[1.25], 1.88]	[0.055, 0.083]	[0.418, 0.628]

Table 4.5 GHG emissions per functional unit for P System 100 fuelled on grey hydrogen.

	FC Grey H_2
kg CO_2e /kWh	0.889
***Uncertainty intervals** (±20%)*	[0.712, 1.067]

Table 4.6 GHG emissions per functional unit for HVO scenarios. The input data for HVO represents an European average.

	Genset, HVO100	*Genset, 42.5% HVO, 57.5% Diesel*
kg CO_2e /kWh	0.136	0.358
***Uncertainty intervals** (±20%)*	[0.108, 0.163]	[0.287, 0.430]

Table 4.7 GHG emissions per functional unit for stationary battery scenarios, where different electricity mixes have been used.

	Stationary battery, Swedish electricity mix	***Stationary battery, European electricity mix***	***Stationary battery, Solar power***
kg CO_2e /kWh	0.211	0.54	0.244
Uncertainty intervals (±50%)	[0.106, 0.317]	[0.270, 0.810]	[0.122, 0.366]

Moving on to the qualitative part of the hybrid approach, swapping conventional diesel gensets with hydrogen fuel cells imply accompanying rebound effects. Together with Victor Åkerlund[11], a number of such rebound effects were discovered and discussed. In general, the main consequences of a significant growth of the hydrogen fuel cell market revolve around the increased demand for hydrogen. As a consequence, possible rebound effects include the increased demand for hydrogen production sites and infrastructure development. Åkerlund explains that there is still much uncertainty around the future of hydrogen and, with that, what rebound effects are most probable. For example, the transport infrastructure around hydrogen could be primarily influenced by road transport, pipelines or alternative carriers, such as methanol or ammonia. Furthermore, there is uncertainty about what kind of hydrogen will dominate the future hydrogen market; green, blue, or other, also leading to different estimations of subsequent emissions. Åkerlund adds that there is an ongoing debate in whether hydrogen production sites could simply connect themselves to the power grid and buy some kind of certification on their power mix to label themselves as green, or if their production must run on additional renewable energy sources. Regardless, from a long-term perspective it is clear that the increasing demand for green hydrogen will imply an increased demand for renewable energy sources.

Another rebound effect discussed was the increased demand for platinum. On the one hand, platinum and other raw materials are already accounted for in Scope 3, but a substantially increased production of the P System 100 may theoretically lead to such high demand for platinum that the whole industry would need to

[11]Victor Åkerlund, Chief Analytics and Sustainability Officer, PowerCell Group. Interview 16th April of 2024.

expand. This could lead to rebound effects in new mines, new infrastructure and subsequent emissions that would not be allocated in the P System 100s LCA. However, Åkerlund contradicts this by referring to the fact that current engines contain platinum that most probably could be reused for future fuel cells. Therefore, the likelihood of such an expansion rate is considered low. To summarise, the possible rebound effects of an increasing demand for the P System 100, as well as the associated climate impacts, can be found in Figure 4.12:

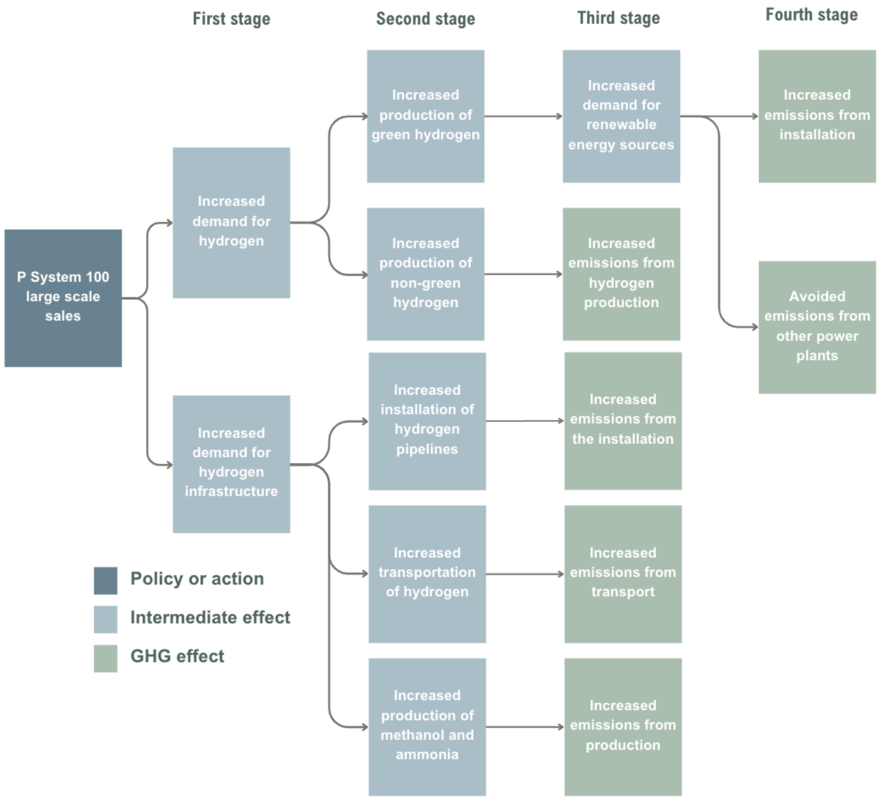

Figure 4.12 Possible rebound effects from the P System 100, with their direct and indirect climate impact. Grey denotes action; green intermediate effect and; blue GHG effect.

4.2.5 Quantify avoided emissions

The following section provides an overview of the calculations made to quantify the total amount of avoided emissions, as a result of a solution swap to P System 100. The calculations on the P System 100 scenarios, as well as on the genset fuelled on diesel, are directly integrated from the LCA by RISE. The other reference systems use both data from the same LCA and complementary data from external commercial sources. A full set of calculations can be found in Appendix A, including calculations with uncertainty intervals.

Following the procedure presented in 4.1.5, the first step in quantifying the avoided emissions is to calculate the total amount of GHG emissions for PowerCell's P System 100. The average results are compiled in Table 4.7, where "FC" denotes fuel cell.

Table 4.8 Total GHG emissions for P System 100: GHG emissions/kWh*number of kWh for climate solution (Equation 6).

Energy source	*Total GHG emissions P System 100 (assuming 1 GWh capacity)*
	Mg CO_2e
FC Burden free H_2	73
FC Swedish electricity mix	248
FC European electricity mix	1 570
FC Solar power	380
FC Future scenario, Burden-free H_2 and less Pt	69
FC Grey H_2	889

In parallel, calculations are performed on the reference systems, in this case a diesel genset solution and a battery system. The genset analysis encompasses three different fuel options, as shown in Table 4.8. Similarly, just like in the P System 100 calculations, different electricity mix scenarios are explored for the battery system, see Table 4.9.

Table 4.9 Total GHG emissions for reference scenarios, Genset: GHG emissions/kWH*number of kWh for climate solution (Equation 7).

Energy source	*Total GHG emissions Diesel genset (assuming 1 GWh capacity)*
	Mg CO_2e
Genset, Diesel	523
Genset, HVO100	136
Genset, HVO 42.5%/Diesel 57.5%	358

Table 4.10 Total GHG emissions for reference scenario, Battery: GHG emissions/kWh*number of kWh for climate solution (Equation 7).

Energy source	*Total GHG emissions Battery (assuming 1 GWh capacity)*
	Mg CO_2e
Stationary battery, Swedish electricity mix	211
Stationary battery, European electricity mix	540
Stationary battery, Solar power	244

Moving on to the comparative analysis, Tables 4.10 and 4.11 present the avoided emissions from transitioning from the reference systems to P System 100. Negative values denote instances where emissions have not been avoided but rather signify that the reference system exhibits a lower environmental impact compared to the fuel cell solution. Consequently, switching systems to improve environmental performance are in these cases counterproductive. Lastly, Figures 4.13 and 4.14 show the avoided emissions per year, where the total avoided emissions have been divided by the lifetime of the P System 100 (approximately 10 years). See Appendix B for calculations.

Table 4.11 Total avoided emissions for P System 100 fuel cell system compared to genset scenarios (Equation 8).

Scope 4 emissions Mg CO_2e avoided	***Genset, Diesel***	***Genset, HVO100***	***Genset, HVO 42.5%/ Diesel 57.5%***
FC Burden-free H_2	450	63	285
FC Swedish electricity mix	275	-112	110
FC European electricity mix	-1 040	-1 430	-1 210
FC Solar power	143	-244	-22
FC Future scenario, Burden-free H_2 and less Pt	454	67	289
FC Grey H_2	-366	-754	-531

Table 4.12 Total avoided emissions for P System 100 fuel cell system compared to battery scenarios (Equation 8).

Scope 4 emissions Mg CO_2e avoided	***Stationary battery, Swedish electricity mix***	***Stationary battery, European electricity mix***	***Stationary battery, Solar power***
FC Burden-free H_2	138	467	171
FC Swedish electricity mix	-37	292	-4
FC European electricity mix	-1 360	-1 030	-1 320
FC Solar power	–169	160	-136
FC Future scenario, Burden-free H_2 and less Pt	142	471	175
FC Grey H_2	-678	-349	-645

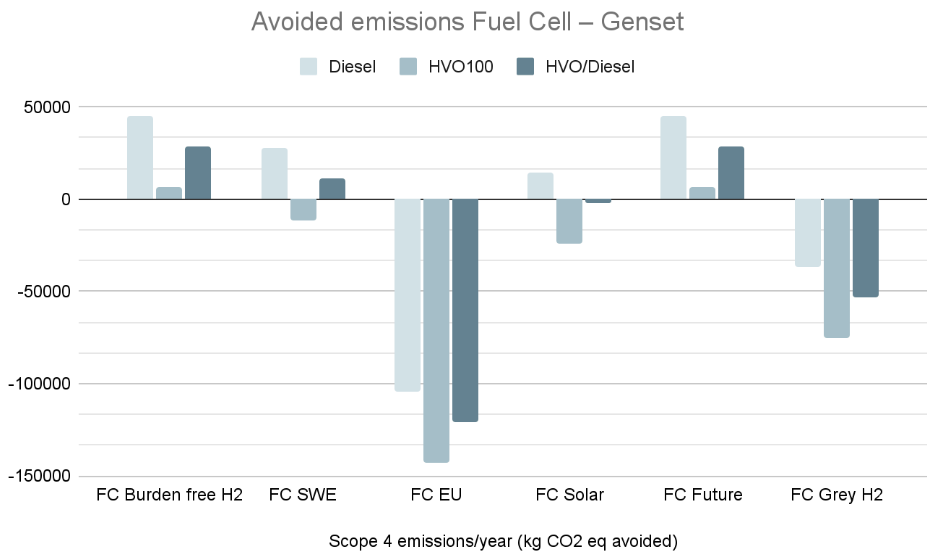

Figure 4.13 Illustration of avoided emissions per year with genset as reference system.

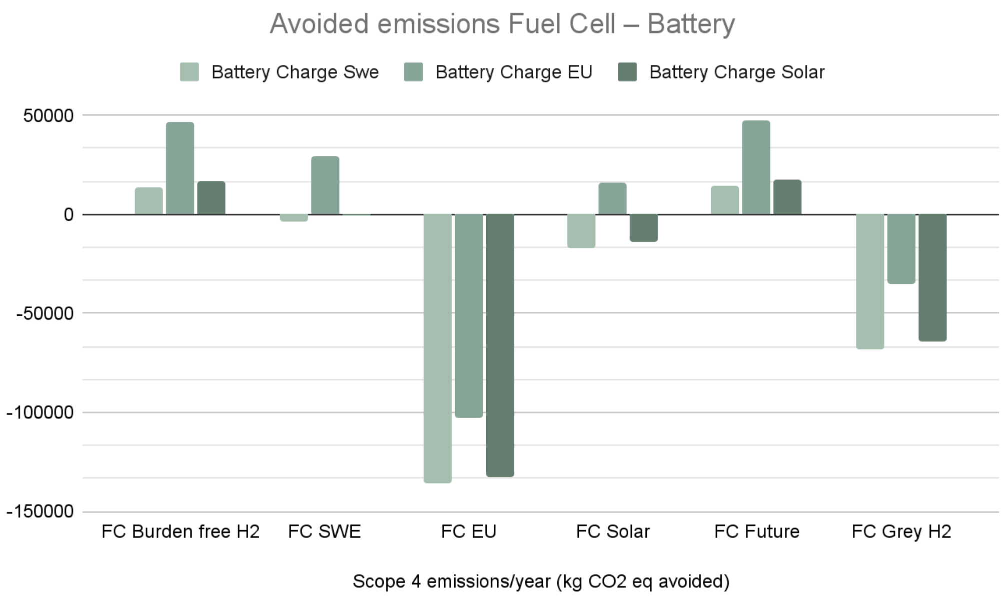

Figure 4.14 Illustration of avoided emissions per year with battery as reference system.

As explained in 4.1.4, the added uncertainty span to the input data provides uncertainty intervals to the final results. The purpose of the uncertainty analysis is to acknowledge that some results might span across the X-axis (as can be seen in the comparison between for example the diesel genset and the solar fuel cell in Figure 4.15), implying that avoided emissions cannot be guaranteed. These results should therefore be communicated with caution, and it is always recommended to acknowledge that the uncertainty interval exists. The uncertainty span is calculated by taking the minimal and maximal possible amount of avoided emissions, creating a continuous span of potential results. Figures 4.15 and 4.16 show the compiled uncertainties for each combination of the assessed- and the reference systems.

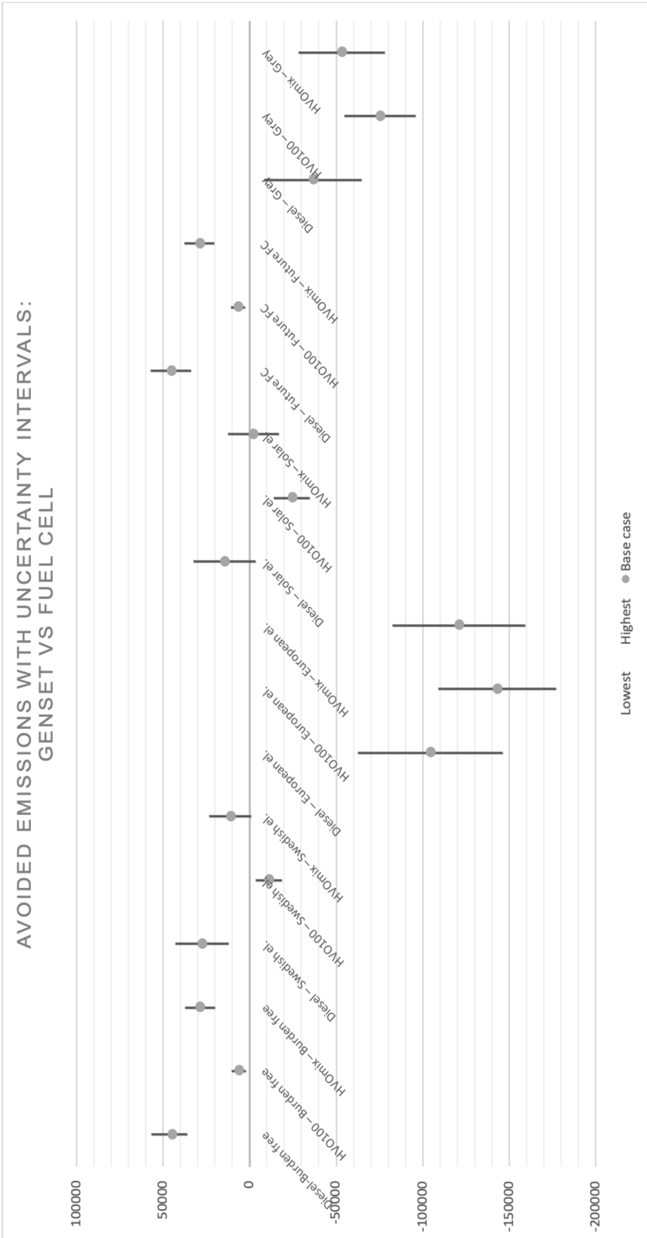

Figure 4.15 Avoided emissions per year with genset as reference system. Labels are structured as [Reference system scenario] – [Fuel Cell Scenario]. Nationalities define the specific electricity mix.

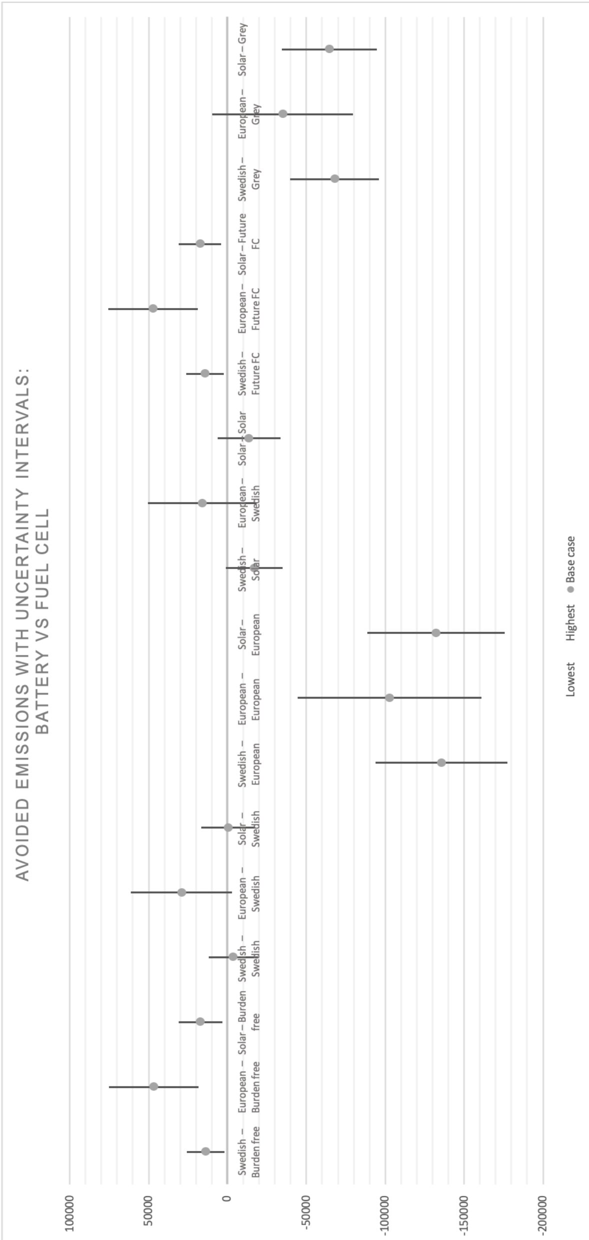

Figure 4.16 Illustration of avoided emissions per year with battery as reference system. Labels are structured as [Reference system scenario] – [Fuel Cell Scenario]. Nationalities define the specific electricity mix.

4.2.6 Finalise documentation

The final step of the Scope 4 Framework involves compiling the results given in the previous step as well as acknowledging other important actors along the value chain that could potentially also claim the same avoided emissions. In the case of the P System 100, this means that all actors who might be eligible to disclose similar results as PowerCell's avoided emissions should be addressed, and that the results that lack relevancy should be filtered out from the final set of numbers that can be publicly presented.

In terms of other relevant actors that should be acknowledged within the context of PowerCell, the question was raised during an interview with Victor Åkerlund[12]. According to the interview, the end users of the fuel cell might also claim the same avoided emissions. When using the P System 100 in a construction site application, primary end users involve the construction company. Furthermore, the suppliers of the container components involved in constructing the final product may also claim the same avoided emissions. PowerCell should therefore, when communicating their avoided emissions, also acknowledge these two actors and state that double counting might occur.

Continuing with a relevancy analysis, it is crucial to note that certain scenarios are fairer to compare than others, depending on their practical relevance. When deciding on what number(s) to communicate to different stakeholders, this is an important factor to consider. To acknowledge this, the following sections present discussions on each comparison, emphasising the time frames within which these comparisons could practically occur if such time frames exist at all.

Before assessing each scenario, it must first be acknowledged that the current hydrogen landscape more or less only comprises grey hydrogen (IEA 2019). This means that the scenarios with burden-free hydrogen and hydrogen generated from the Swedish electricity mix used in the LCA by RISE do not mirror the general reality. Consequently, none of the results can be publicly published without such accompanying comment. This is also the reason why the relevancy analysis will incorporate a time dimension. While projections show, as explained in section 1.4, that the production of green low-emissions hydrogen is likely to

[12] Victor Åkerlund, Chief Analytics and Sustainability Officer, PowerCell Group. Interview 16th April of 2024.

increase in the coming years, significant progress is still needed. To take the current stage and future development of the hydrogen market into account, the avoided emissions results have been categorised into two groups depending on their applicability by 2030 and 2050, as seen in Tables 4.12 and 4.13. Scenarios marked in dark purple indicate that they are likely to occur within the next five years, while those in light purple suggest relevancy only by 2050, since a significant expansion of green hydrogen production is required before such scenarios become reality.

The categorization has been implemented as a continuation of the conservative approach outlined in the Scope 4 Framework, with the purpose to ensure that PowerCell only communicates avoided emissions that align with the maturity of the hydrogen market. Again, this filtering process does not prevent the communication of less relevant numbers. Instead, it highlights the necessity of including relevance disclaimers in publications to mitigate accusations of greenwashing. Furthermore, the purpose of the relevancy analysis is not to pinpoint which explicit numbers will remain relevant in 5 years or by 2050, but rather to emphasise the actual scenarios that hold significance. This is motivated by the fact that all products, including P System 100, have a limited lifetime and that the market landscape continuously develops. The avoided emissions results are expected to decrease as the energy system transitions to a greener state. Essentially, the benefits associated with Scope 4 emissions will diminish over time as the energy system evolves, which also would require updates to the numbers provided above.

Table 4.13 Colours used to categorise relevancy of avoided emissions scenarios.

Relevant ~2030	***Relevant ~2050***	***Not relevant***

Table 4.14 The most relevant avoided emissions claims

Scope 4 emissions Mg CO_2e avoided per year	***Genset, Diesel***	***Genset, HVO100***	***Genset, HVO 42.5%/ Diesel 57.5%***	***Stationary battery, Swedish electricity mix***	***Stationary battery, European electricity mix***	***Stationary battery, solar power***
FC Burden-free H_2	45	6.25	29	14	47	17
FC Swedish electricity mix	28	-11	11	-3.70	29	-0.4
FC European electricity mix	-104	-143	-121	-136	-103	-132
FC Solar power	14	-24	-2.17	-17	16	-14
FC Future scenario, Burden-free H_2 and less Pt	23	3.33	15	7.10	24	8.75
FC Grey H_2	-37	-75	-53	-68	-35	-65

FC Burden-free H_2

All scenarios with burden-free H_2 are marked in light purple (except the comparison with the battery on European electricity). The chosen category indicates that these scenarios can be argued to increase in relevancy, if the McKinsey projection and the IEA Scenario by 2050 (see section 1.4) prove to be true; that by 2050 the majority of production will represent low-emission green hydrogen. With this said, hydrogen will never be entirely burden-free, meaning that these scenarios are still theoretical as previously outlined. The scenario with the battery using European electricity has been excluded since it is considered an unjust comparison that exaggerates the positive impact of the fuel cell.

FC Swedish electricity mix
The scenarios comparing the fuel cell powered by hydrogen generated from Swedish electricity with the diesel genset, HVO 42.5%/diesel 57.5% genset, and stationary battery charged with the Swedish electricity mix are all marked in dark purple, signifying high relevance within the next five years. This is due to the Swedish hydrogen strategy (mentioned in Section 1.4), which outlines green hydrogen production targets by 2030. Furthermore, the EU Energy Target of 42.5% renewable energy is set to 2030, motivating the inclusion of the HVO scenario.

FC European electricity mix
All claims involving the fuel cell powered on hydrogen from European electricity has been filtered out in the relevancy analysis. This is due to the expected expansion of green hydrogen production within the EU by 2030, as explained in section 1.4. The fuel cell scenarios using the current European electricity mix are therefore considered to lack relevancy and to be too pessimistic. These should instead be re-evaluated before 2030, if such green hydrogen production sites exist.

FC Solar power
Similarly to the fuel cell scenarios that include Swedish electricity mix, the same scenarios with solar power are marked in dark purple and are considered relevant within five years. The motivation for this is the expected expansion of green hydrogen production in the EU by 2030.

FC Future scenario with burden-free H_2 and less Pt
The scenarios based on burden-free hydrogen and less platinum represent a potential future scenario, and have thus not been considered relevant in the near future. For this scenario to become reality, both the expansion of green hydrogen production and successful product development from PowerCell are necessary.

FC Grey hydrogen
All scenarios involving grey hydrogen are considered highly relevant, since they represent the current state of the hydrogen market as of today (May 2024). These results, where no avoided emissions are achieved using the fuel cell, underscore the critical role of hydrogen in achieving positive GHG impact.

5 Discussion

This chapter aims to reflect on the relevance, limitations and practical requirements of the framework earlier presented. Furthermore, the future of Scope 4 reporting will be discussed and a proposal on which next steps PowerCell should take to secure sustainable Scope 4 reporting is presented.

5.1 Considerations of Reporting Avoided Emissions

The purpose of this thesis is to examine the question of whether companies should integrate avoided emissions into their sustainability reporting, and to propose an appropriate methodology for doing so. From the literature review, it is clear that Scope 4 reporting can become a powerful, complementary tool for communicating sustainability performance. Especially for start-ups, Scope 4 offers a promising opportunity for the rapid development and global spread of climate solutions. However, with current and upcoming regulations affecting the sustainability reporting climate, and with a lack of consistent official guidelines, there is no doubt that Scope 4 reporting could quickly become a magnet for greenwashing accusations. Hence, the following sections will discuss further factors that should be considered alongside the proposal of the Scope 4 framework earlier presented. More specifically, the implications, limitations and relevance of the framework will be considered in order to provide a final recommendation on whether Scope 4 reporting should be adopted or not.

5.1.1 Responsibility following the Scope 4 Framework

An important question when developing a framework is for whom it is designed and what purpose it aims to serve. In this case, emphasis is placed on mitigating the risk of greenwashing accusations, that is, staying compliant with current regulations and avoiding results that are too good to be true. Hopefully, the framework has been designed conservatively enough to filter out such approaches to avoided emissions in its first eligibility step. Ultimately, the users of the Scope 4 framework are instead part of organisations that benefit sufficiently from the solution they sell, meaning that they have a genuine interest in ensuring the accuracy and integrity of the avoided emissions claim they report. This alignment between the users' interests and the framework's design hopefully enhances its relevance and credibility, which in turn fosters trust among stakeholders.

On the other hand, one cannot overlook the fact that all companies will strive to present the most favourable figures in their reports, especially when extensive resources are needed to follow the framework perfectly. The framework naturally permits some flexibility, as the reporting company can select the comparative result that portrays them in the most favourable light. However, considering its risk mitigating purpose, this implies great responsibility on the team conducting the data selection: they must choose a fair and relevant comparison to ensure that the final disclosure avoids any accusations of greenwashing. It is also recommended that the selected comparisons are presented as "best estimates", but always accompanied by discussions of uncertainty and the factors most likely to cause variation. In terms of responsibility, Scope 4 emissions also place a duty on the management team to understand and promote a conservative approach to all hypothetical environmental claims. Again, if the company's offer is genuinely a climate solution, this should not impede the presentation of positive and competitive results.

5.1.2 Practical implications of the Scope 4 framework

Concerning the practical implications of following the Scope 4 Framework, one limitation of this framework is that of preciseness; it does not specifically provide information on how to perform the documents required, meaning that a substantial amount of knowledge about sustainability reporting is a must-have before attempting to use the Scope 4 Framework. This is not necessarily a flaw with the framework, since ensuring sufficient internal sustainability know-how is considered a crucial element to mitigate any greenwashing accusations. Thus, the rather strict requirements in complying fully with the EU Taxonomy and CSRD are considered necessary before initiating other reporting routines.

Another important consideration for companies wishing to apply the Scope 4 Framework is how to proceed with their LCA's. Conducting LCAs entail a considerable amount of resources if done according to ISO 14040 and 14044, both in terms of knowledge, data access and verification procedures, and can be executed either externally, as in the case of PowerCell, or internally. Whatever the choice, this step is undeniably the most resource-demanding. Consequently, it came to no surprise that this approach had not been employed in any of the company examples. The framework still advocates for this procedure since it is firmly supported by the findings of the literature review.

5.1.3 Relevance and further applications

After having addressed the managerial and practical implications of the Scope 4 framework, it is worth mentioning the rationale for investing efforts into a metric that is likely to face scrutiny and challenge. The framework does not aim to propose a pathway to a "least deceptive green claim", but rather to produce real comparative numbers that can guide all stakeholders towards more sustainable decisions. This includes helping customers to reduce their GHG footprint, steering R&D departments towards areas which can most effectively reduce product impact, convincing investors to place their capital on climate solutions, helping the management in building the most sustainable product portfolio, and so on. Furthermore, an important aspect is that Scope 4 can be used for learning purposes, enhancing the knowledge of all stakeholders about the potential differences between various solutions in terms of GHG impact.

From a general perspective, Scope 4 reporting cannot only become a powerful tool in a competitive context, but also in the system-wide green transition that is so urgently needed. Again, the conservative and resource-demanding approach of the framework aims to mitigate the risk of Scope 4 being perceived as a tactic to exploit green claims for deceptive marketing purposes. It is instead a way of giving companies with high sustainability ambition a fair chance of communicating their superiority to the status quo, when facts allow them to do so. Finally, it should again be noted that Scope 4 emissions should in no way compensate for performances in Scope 1-3, but must be allowed to complement it.

5.2 Future of Scope 4 reporting

When considering the future of avoided emissions reporting, it is crucial to view it as a dynamic and iterative process and the Scope 4 Framework as a first version of a proposed approach. As mentioned earlier, the Scope 4 Framework is designed to be both feasible and transparent while delivering results that are compliant, accurate, credible, and relevant. However, maintaining this balance is complex. On the one hand, quantifying avoided emissions can easily become overly complicated, but on the other hand, avoided emissions claims will lack trustworthiness if the process is too simplified, as was seen in the company examples (see section 3.3). Therefore, periodic updates and iterations are necessary to uphold the established criteria. The coming sections will discuss factors that must be taken into account when considering the future of Scope 4 reporting.

5.2.1 Scope 4 from a regulatory perspective

The legislative landscape will likely have a large impact on Scope 4 reporting going forward. After the literature review, it can be seen that there is a regulatory trend within the EU that moves towards stricter sustainability reporting. Although the Green Claims Directive is yet to be implemented, it is likely that this new directive will make it more resource-demanding for companies that want to make green claims, including avoided emissions claims. The Scope 4 Framework is conservative in its nature, and takes the potential requirements mentioned in the Green Claims proposal (see Table 3.3) into account. However, once the directive is fully determined, the implications of the exact requirements on the Scope 4 Framework will have to be re-evaluated.

As of today, the future implications of stricter sustainability regulations within the EU can only be discussed hypothetically. The primary objective of the Green Claims Directive is to reduce the number of unreliable environmental claims lacking scientific evidence. However, another potential consequence could be that climate solutions companies refrain from making environmental claims, due to the perceived risks. This would be a negative outcome, since climate solutions companies are well-positioned to make environmental claims. Communicating their, for example, avoided emissions could help them scale their solution, and thus accelerate the green transition. To mitigate the development of climate companies refraining from making environmental claims entirely, and in this case Scope 4 claims, it is thus important to periodically update the Scope 4 Framework, so that it can be trusted as a robust and credible approach to avoided emissions reporting.

5.2.2 Potential future improvements and required research

The long-term goal of Scope 4 reporting should naturally be to refine the quantification procedure so that avoided emissions claims represent reality as accurately as possible. One potential improvement would be to base the avoided emissions claim on consequential LCAs, rather than using attributional LCAs and only qualitatively discussing rebound effects, as the framework currently recommends. The consequential approach would take the comprehensive system-wide perspective, which would ensure that all changes in GHG emissions are considered, thereby giving a more accurate representation of avoided emissions. Thus, exploring how to conduct a consequential LCA within the context of a climate solutions company, in a way that is both feasible and practical, is an area that requires further research.

Allocation or portioning of avoided emissions is another area that requires more exploration. The presented Scope 4 Framework permits double counting, despite conflicting opinions on this topic in the literature review. The decision to allow double counting was motivated twofold: to avoid introducing additional complexity into the process and because no prohibition on the issue exists today (it is for instance permitted within Scope 3). However, while double counting within Scope 3 can be considered a conservative matter, this is not the case for Scope 4 emissions. Since Scope 4 emissions involve quantifying emissions that never occurred, double counting within Scope 4 can lead to an overestimation of the positive impact generated by a specific solution. Therefore, addressing the issue of double counting should be prioritised when developing future Scope 4 reporting procedures.

For Scope 4 reporting to gain recognition and impact, future research should prioritise the development of an international standard. Based on the discussions throughout this thesis, it can be concluded that Scope 4 reporting has the potential to address a crucial gap for climate solutions companies. However, in parallel, the regulatory landscape surrounding environmental claims is becoming more rigorous. An international standard outlining guidelines for reporting on avoided emissions would provide climate solutions companies with the confidence to disclose their Scope 4 emissions without fear of accusations of greenwashing or non-compliance.

5.3 Implications for PowerCell

The concluding segment of the discussion will present the actions needed from PowerCell for Scope 4 emissions to become a powerful tool that can be utilised with various stakeholders. The actions include finalising the case study so that the results can be publicly disclosed, selecting a Scope 4 process owner at PowerCell and designing the future Scope 4 roadmap.

5.3.1 Finalise case study for publication

For PowerCell to be able to disclose the results presented in the case study of this thesis, a few steps remain. First of all, the LCA conducted by RISE must be verified to fulfil the requirements outlined in the ISO standard, for PowerCell to be able to disclose the results. When this step has been completed, PowerCell can publicly communicate the avoided emissions claims for the fuel cell and the genset comparisons, preferably selecting those that are considered most relevant according to the relevancy analysis (see 4.2.6).

For PowerCell to be able to disclose the results from the battery scenarios, a comparative LCA between the fuel cell and a stationary battery must be performed. As previously outlined, the results from this comparison involve uncertainty since the underlying data that is being compared does not represent the same systems. However, since the results for the fuel cell are already available, only an LCA for the battery scenario needs to be performed, using the same system boundaries. As a last step, the results from this LCA must also be verified by a third-party.

5.3.2 Select Scope 4 process owner

An important step for PowerCell is to select an internal Scope 4 process owner who will have the overarching responsibility for the Scope 4 assessments. This role would entail leading the actual assessments and overseeing the internal and external communication regarding Scope 4. The primary tasks entail planning future assessments and ensuring compliance; both through updating the framework and the previously conducted assessments (step seven in the framework, see 4.1.7). Consequently, it is crucial that the Scope 4 owner has some legal expertise and can interpret the implications of new legislation on avoided emissions reporting. In terms of internal communication, the Scope 4 owner is responsible to make sure that relevant divisions within the company are well-informed about the concept of avoided emissions and in what contexts it can be utilised.

5.3.3 Create Scope 4 Roadmap

As PowerCell progresses with its Scope 4 reporting, it must be decided what other products and applications to assess and compare next. This step is essential not only for gaining a holistic view of their product portfolio's relative GHG impact but also for safeguarding against accusations of bias in their selected assessments. Also, adding more assessments would provide a clear direction for product prioritisation and development. When selecting new systems, the best-case scenario would be to include all possible applications and their current conventional alternatives. However, given the resource-intensive nature of conducting LCAs, it is advised to initially focus on a few systems where securing a high specificity on input data is achievable.

Given the results presented in section 4.2.5 and 4.2.6, it is also clear that the positive GHG impact of a fuel cell (in a construction site application) is directly correlated to what type of hydrogen that has been used. Consequently, PowerCell should carefully consider this factor when advancing their Scope 4 reporting. Conducting Scope 4 assessments is only meaningful if it is certain that the fuel cell is superior from a GHG perspective. However, when communicating Scope 4 claims, it must be clearly stated that the assessment is based on the assumption that green, low-emission hydrogen is used. For transparency purposes, it is also recommended to, if requested, be able to offer numbers on grey hydrogen. This is especially related to ensuring avoidance of cherry picking and greenwashing accusations.

Taking into account that the mobility sector is expected to drive the development of the green hydrogen market, and recognising that the aviation-, marine- and on-road segments constitute an important and promising part of PowerCell's offering, future Scope 4 assessments should focus on scenarios within these segments. However, it would not be feasible to carry out solution-specific Scope 4 assessments for all different product configurations. Therefore, the recommendation to PowerCell is to initially create three average scenarios, that within each segment represent the average configuration of the fuel cell and the system that it would most likely be used in. Thus, this approach would enable

PowerCell to communicate relevant numbers within three critical segments, arguably creating an adequate level of product portfolio coverage.

5.3.4. Publish Scope 4 claims

With all the mentioned processes conducted, PowerCell's aspiration should be to publicly disclose the results and accompanying discussions. As earlier outlined, avoided emissions can become a valuable tool in discussions with various stakeholders. For instance, it can become a sales argument for potential customers, create partnership encouragement for suppliers and incentives for investors. Thus, the calculated Scope 4 results can help PowerCell in communicating its environmental superiority universally.

In practice, the selected numbers could be presented on PowerCell's website, in their sustainability report and product brochures. To include all analysis, calculations and framework applications in a feasible and digestible format, it is recommended that the case study is compiled to a short report that is accessible where all claims are published.

6 Conclusion

This thesis aims to investigate the current status of Scope 4 reporting in terms of the regulatory context, guiding literature, and present practical examples, to answer how companies can apply Scope 4 reporting in practice. From the literature review, it was clear that Scope 4 is already used by some organisations to communicate environmental performance, but that inconsistency exists. The reviewed guiding papers showed similar results, indicating that Scope 4 is still an evolving area of research. One takeaway developed from investigating the regulatory context within the EU, where it became clear that upcoming legislation will require that all green claims take a life-cycle perspective. A distinct gap was found between this requirement and the studied examples, again emphasising the need for an updated guide to Scope 4 reporting practices.

The report culminates in the development of the Scope 4 Framework which was designed to incorporate all literature insights, prioritising the most conservative approach to mitigate the risk of greenwashing. The framework aims to establish a transparent and feasible method to avoided emissions reporting, that generates results that are compliant, accurate, relevant, and credible. Following the development of the Scope 4 Framework, the suggested process was applied in a case study on PowerCell. The results from this case study can be leveraged by PowerCell, however it is crucial that any avoided emissions claims derived from the study are used in accordance with provided recommendations.

It is crucial to recognise that a dynamic regulatory environment necessitates a flexible framework. The Scope 4 Framework has limitations that future research should address, and it is still recommended that official guidelines are developed to ensure a consistent approach to avoided emissions reporting. Nevertheless, the Scope 4 Framework is a proposal on how avoided emissions can be assessed in practice, serving as a valuable tool for climate solutions companies to communicate their crucial role in the ongoing green transition.

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Appendix

Appendix A – Data

Table A1. Overview of assessed systems. Systems marked (*, **, *) have been modified using other sources than the LCA by RISE.**

System	*kg CO_2e/kWh*	*Source*
P System 100, Burden-free H_2	0.073	Zackrisson (2022)
P System 100, Swedish electricity mix	0.248	Zackrisson (2022)
P System 100, Solar power	0.380	Zackrisson (2022)
P System 100, European electricity mix	1.57	Zackrisson (2022)
P System 100, Future scenario burden-free H_2 and less Pt	0.069	Zackrisson (2022)
P System 100, Grey hydrogen*	0.889	Zackrisson (2022), IEA (2023)
Genset, Diesel	0.523	Zackrisson (2022)
Genset, HVO 42.5%/ Diesel 57.5%**	0.312	Zackrisson (2022), Directive (EU) 2018/2001
Genset, HVO100**	0.0257	Zackrisson (2022), Directive (EU) 2018/2001
Stationary battery, Swedish electricity mix***	0.211	Andersson & Börjesson (2021), Zackrisson (2022)
Stationary battery, European electricity mix***	0.540	Andersson & Börjesson (2021), Zackrisson (2022)
Stationary battery, Solar power***	0.244	Andersson & Börjesson (2021), Zackrisson (2022)

(*) Table A2. Calculations on grey hydrogen.

kg H_2/kWh	*kg CO_2e/kg H_2*	*Average kg H_2/kWh*	*kg CO_2e/kWh*
0.072	10-14	12	0.889

(**) Table A3. Data (Directive 2018/200) and calculations on HVO. Mean used for scenarios with HVO input.

HVO type	*kg CO_2e/MJ*	*Conversion factor MJ to kWh*	*kg CO_2e/kWh*
Rape seed	0.073	0.278	0.165
Sunflower	0.248	0.278	0.142
Soybean	0.380	0.278	0.152
Palm oil, open effluent pond	1.58	0.278	0.224
Palm oil, methane capture at oil mill	0.069	0.278	0.159
Cooking oil	0.523	0.278	0.0428
Animal fats from rendering	0.312	0.278	0.0576
Mean (value used in calculations)			**0.135**

(***) Table A4. GHG emissions from different electricity mixes (Zackrisson 2022).

Electricity mix (average)	*kg CO_2e/kWh*
European	0.373
Swedish	0.044
Solar	0.077

(***) Table A5. Data on electric vehicle battery (Andersson & Börjesson 2021).

Estimated lifetime, km	***Electricity consumption, kWh/100 km***	***Battery capacity, kWh***	***Σ kg CO_2e/kWh (from production)***
200 000	15.9	64	83.5

(***) Table A6. Calculations from Table A5.

Σ Electricity consumed during lifetime, kWh	***No. of charges***	***Σ kg CO_2e/kWh (considering 500 potential charges)***
200 000 * 15.9/100 = 31 800	31 800 /64 ≈ 500	83.5/500 = 0.167

System name	Σ CO_2-eq/kWh	System breakdown		Σ CO_2-eq (1M kWh)		
Fuel cell (LCA by RISE)		*Fuel cell production*	*Use phase*		Lowest	Highest
Fuel cell – Burden-free H2	**0.073**	0.0254	0.0476	73000	58400	87600
Fuel cell – Swedish electricity mix	**0.248**	0.0254	0.223	248000	198400	297600
Fuel cell – Solar power	**0.38**	0.0254	0.355	380000	304000	456000
Fuell cell – European electricity mix	**1.567**	0.0254	1.54	1567000	1253600	1880400
Fuel cell – Future scenario, burden-free H2 and less Pt	**0.069**	0.0214	0.0476	69000	55200	82800
Fuel cell – Grey hydrogen (72 g H2/kWh electricity generation in FC)	**0.889**	0.0254	0.864	889400	711520	1067280
Genset - Diesel (LCA by RISE)		*Genset production*	*Use phase*			
Genset Diesel	**0.523**	0.001	0.522	523000	418400	627600
Genset - European HVO (REDII)						
Genset - European mean value - HVO100	**0.136**	0.001	0.135	135537	108430	162644
Genset - European mean value - 42.5% HVO/57.5% Diesel	**0.358**	0.001	0.357	358328	286663	429994
Stationary battery (LCA by Andersson & Börjesson)		*Battery production*	*Elecricity mix*			
BEV - Battery electric vehicle 64 kW, 31 800 kWh (Swedish electricity)	**0.211**	0.167	0.044	211000	105500	316500
BEV - Battery electric vehicle 64 kW, 31 800 kWh (European electricity)	**0.54**	0.167	0.373	540000	270000	810000
BEV - Battery electric vehicle 64 kW, 31 800 kWh (Solar power)	**0.244**	0.167	0.077	244000	122000	366000

Figure A1. Overview of assessed systems. For fuel cell and genset scenarios, an uncertainty interval of 20% has been added to the results. For the battery scenarios, the uncertainty interval is 50%.

Appendix B – Calculations of Avoided Emissions

Scope 4 emissions (kg CO2 eq avoided)	Diesel	HVO100	HVO/Diesel
FC Burden free H2	450000	62537	285328
FC SWE	275000	-112463	110328
FC EU	-1044000	-1431463	-1208672
FC Solar	143000	-244463	-21672
FC Future	454000	66537	289328
FC Grey H2	-366400	-753863	-531072

Scope 4 emissions /year (kg CO2 eq avoided)	Diesel	HVO100	HVO/Diesel
FC Burden free H2	45000	6254	28533
FC SWE	27500	-11246	11033
FC EU	-104400	-143146	-120867
FC Solar	14300	-24446	-2167
FC Future	45400	6654	28933
FC Grey H2	-36640	-75386	-53107

Scope 4 emissions (kg CO2 eq avoided)	Battery Charge Swe	Battery Charge EU	Battery Charge Solar
FC Burden free H2	138000	467000	171000
FC SWE	-37000	292000	-4000
FC EU	-1356000	-1027000	-1323000
FC Solar	-169000	160000	-136000
FC Future	142000	471000	175000
FC Grey H2	-678400	-349400	-645400

Scope 4 emissions /year (kg CO2 eq avoided)	Battery Charge Swe	Battery Charge EU	Battery Charge Solar
FC Burden free H2	13800	46700	17100
FC SWE	-3700	29200	-400
FC EU	-135600	-102700	-132300
FC Solar	-16900	16000	-13600
FC Future	14200	47100	17500
FC Grey H2	-67840	-34940	-64540

Figure B1. Calculations of avoided emissions between different fuel cell systems and reference systems.

Scope 4 emissions /year (kg CO2 eq avoided)	Diesel high	Diesel low	HVO100 high	HVO100 low	HVO/Diesel high	HVO/Diesel low
FC Burden Free H2 high	54000	33080	7504	2083	34239	19906
FC Burden Free H2 low	56920	36000	10424	5003	37159	22826
FC SWE high	33000	12080	-13496	-18917	13239	-1094
FC SWE low	42920	22000	-3576	-8997	23159	8826
FC EU high	-125280	-146200	-171776	-177197	-145041	-159374
FC EU low	-62600	-83520	-109096	-114517	-82361	-96694
FC Solar high	17160	-3760	-29336	-34757	-2601	-16934
FC Solar low	32360	11440	-14136	-19557	12599	-1734
FC Future high	54480	33560	7984	2563	34719	20386
FC Future low	57240	36320	10744	5323	37479	23146
FC Grey H2 high	-43968	-64888	-90464	-95885	-63729	-78062
FC Grey H2 low	-8392	-29312	-54888	-60309	-28153	-42486

Scope 4 emissions /year (kg CO2 eq avoided)	Battery Charge Swe high	Battery Charge Swe low	Battery Charge EU high	Battery Charge EU low	Battery Charge Solar high	Battery Charge Solar low
FC Burden Free H2 high	22890	1790	72240	18240	27840	3440
FC Burden Free H2 low	25810	4710	75160	21160	30760	6360
FC SWE high	1890	-19210	51240	-2760	6840	-17560
FC SWE Low	11810	-9290	61160	7160	16760	-7640
FC EU high	-156390	-177490	-107040	-161040	-151440	-175840
FC EU low	-93710	-114810	-44360	-98360	-88760	-113160
FC Solar high	-13950	-35050	35400	-18600	-9000	-33400
FC Solar low	1250	-19850	50600	-3400	6200	-18200
FC Future high	23370	2270	72720	18720	28320	3920
FC Future low	26130	5030	75480	21480	31080	6680
FC Grey H2 high	-75078	-96178	-25728	-79728	-70128	-94528
FC Grey H2 low	-39502	-60602	9848	-44152	-34552	-58952

Figure B2. Calculations of avoided emissions with uncertainty intervals.

Table B1. Calculation of the approximate lifetime of the P System 100.

System Lifetime (in hours, given)	*Hours in use per working day (construction site application)*	*Working days per week*	*Number of weeks in use per year*	*Lifetime of P System 100 (years)*
20 000	8	5	45	20000/(8*5*45) ≈10