SWEDISH
LIFE CYCLE
CENTER

Environmental Footprint in Swedish Industry

– increased understanding and implementation

Report number: 2023:04
December 2023
Gothenburg, Sweden

December 2023
Gothenburg, Sweden
Swedish Life Cycle Center, Chalmers University of Technology
Report no (Swedish Life Cycle Center's report series): 2023:04
Authors: Maria Rydberg, Anna Wikström and Yulia Liu, Swedish Life Cycle Center, Erika Kloow and Josefin Neuwirth, IVL, Jonas Larsson, SSAB, Torun Hammar and Mats Zackrisson, RISE Research Institutes of Sweden, Jennifer Davis, Felipe Oliveria, Morgana Santos de Lima and Ben Whitaker, Volvo Car Corporation, Babak Kianian and Sofia Poulikidou, Höganäs AB, Lionel Belzons and Lisa Åkerlund, CEVT.
Layout: Technical secretariat, Swedish Life Cycle Center (Chalmers University of Technology)
Contact: lifecyclecenter@chalmers.se

Summary

The project Environmental Footprint in Swedish Industry – increased understanding and implementation started in November 2022. The aim of the project has been to enhance awareness among businesses, authorities, and the public sector in Sweden regarding product-related policy development based on the Environmental Footprint framework at the EU level. The project aimed also at elucidating and highlight the ramifications of various methodological choices in the assessment of Product Environmental Footprints (PEF), thereby fostering a deeper comprehension of the potential impacts on the Swedish industry.

To highlight effects and to test parts of the Environmental Footprint methodologies, two case studies have been executed within the project. One case study focused on modelling impact on climate change with focus on biogenic carbon in an interlinked product systems and in long living products. The other case study focused on better understanding the consequences of implementing the Circular Footprint Formula (CFF), which is part of the PEF framework, within the automotive industry and with focus on materials used in batteries. Results from the case studies revealed challenges with the Circular Footprint Formula. Mostly due to CFFs complexity, lack of clear guidance, and ambiguity in its application. A specific concern is raised within one case study about the effective use of CFF to differentiate between post-consumer and pre-consumer materials, as the pre-consumer materials often come from manufacturing inefficiencies or manufacturing losses, and therefore in many cases should not give the same credit as post-consumer materials. The lack of specific guidance on biogenic carbon content modelling was also identified and a lack of harmonization between the PEF guidance and the EN 15804 standard, leading to varied results across different modelling approaches. The case studies also emphasized data availability and interpretation challenges, with inconsistent usage and interpretation of data leading to non-comparable results.

Besides the case studies, communication regarding upcoming regulations within the EU that refer to Environmental Footprint has been conducted to increase understanding and further prepared the Swedish industry. Expert groups and other dialogue meetings have expanded the network of people that have knowledge about the Environmental Footprint. The project has increased collaboration between Swedish actors to both exchange knowledge and to manage Environmental Footprint.

Contents

Project information

Project title

Environmental Footprint in Swedish Industry - increased understanding and implementation

Funded by

Vinnova, Sweden’s innovation agency

Aim

To make business, authorities and the public sector in Sweden aware of product-related policy development based on Environmental Footprint at the EU level. Make visible and clarify the consequences of proposed methodology choices in Product Environmental Footprint. Contribute to the further development of Environmental Footprint and its implementation.

Project manager

Maria Rydberg, Swedish Life Cycle Center

Coordination of the project

Swedish Life Cycle Center

Project management team

Anna Wikström and Maria Rydberg, Swedish Life Cycle Center
Erika Kloow, IVL Swedish Environmental Research Institute
Torun Hammar, RISE Research Institutes of Sweden

Time period

2022-12-01 - 2023-11-30

Acknowledgements

Thank you to the project group, Björn Spak, Naturvårdsverket, Tomas Ekvall, TERRA, Cecilia Matsson, Jernkontoret, Kai Yee Thim, Skogsindustrierna, Cecilia Sundberg, SLU and Peter Bennich Energimyndigheten.

Thank you to Volvo Cars, Höganäs AB, CEVT and SSAB for taking part in case studies.

About Swedish Life Cycle Center

Swedish Life Cycle Center is a collaboration platform for universities, industries, research institutes and government agencies for competence building and the exchange of experience to move the life cycle field forward. Current partners are Chalmers University of Technology (host of the Center), KTH Royal Institute of Technology, Swedish University of Agricultural Sciences, Luleå University of Technology, Swedish Environmental Protection Agency, Electrolux, Essity, Höganäs, ASKER Healthcare, Vattenfall, Volvo Car Group, Volvo Group, IVL Swedish Environmental Research Institute, RISE Research Institutes of Sweden, Scania and CEVT. The Center hosts a dialogue group with twelve government agencies in Sweden. For more information about Swedish Life Cycle Center, please visit www.lifecyclecenter.se

1. Introduction

Introduction to Environmental Footprint

The need to communicate the environmental impact of products in a credible way from a life cycle perspective is increasing. Several ecolabels and different ways of communicating the environmental impact of products exist and the European Commission has therefore identified a need to develop a common methodology for companies to build their environmental claims on. The overall aim of this common method, called Environmental Footprint, is to reduce the environmental impact of consumption and production in Europe by helping companies to calculate their environmental performance and manufacture more environmentally friendly products.

The Environmental Footprint measure and communicate the environmental performance of products (both goods and services) and organizations across their whole life cycle, from raw material extraction or growing to the end-of-life management, via production, distribution and use. The Environmental Footprint includes two methods: Product Environmental Footprint (PEF) and Organisation Environmental Footprint (OEF), which are both built on scientifically developed assessment methods that have been agreed upon at international level.

The methods cover 16 environmental impact categories, including climate change, and impacts related to water, air, resources, land use and toxicity. The general methods are complemented with product- or organization- specific calculation rules enabling comparison of environmental performances between similar products or companies active in similar sectors (European Commission 2021).

For more information on Environmental Footprint several publications have been developed within an earlier project within the Swedish Life Cycle Center. These can be found on Swedish Life Cycle Center's web page here. For the latest update on the Environmental Footprint please visit European commission.

Introduction to the project

Since the launch of the Single Market for Green Products Initiative by the European Commission, Swedish Life Cycle Center (a Center of Excellence for competence building and knowledge exchange in the field of life cycle thinking) has followed and participated in the process and the development of the Environmental Footprint methods PEF and OEF. The Swedish Life Cycle Center has experienced an increased need to better understand the process, the methodology and its application, but also a great interest in influencing the methodology based on the long experience of life cycle assessment (LCA) that exists in Sweden, among industry, academia, research institutes, industry associations and authorities. The Environmental Footprint expert group, within the Center, also saw a need to coordinate the work in Sweden with the aim of developing knowledge about understanding of both methodology and policy development process among companies and authorities in Sweden.

To respond to this interest, the project Environmental Footprint in Sweden - increased understanding and implementation has been performed in close collaboration with partners in the Swedish Life Cycle Center and the Center's Environmental Footprint expert group, with funding from Vinnova, Sweden's innovation agency. Within the project three interlinked parts have contributed to the outcome and to the fulfillment of the goals: communication efforts, the Expert group Environmental Footprint and two case studies.

Project objective

The primary objective of the project has been to enhance awareness among businesses, authorities, and the public sector in Sweden regarding product-related policy development based on the Environmental Footprint framework at the EU level. The project aimed at elucidating and highlight the ramifications of various methodological choices in the assessment of Product Environmental Footprints, thereby fostering a deeper understanding of the potential impacts on the Swedish industry.

Furthermore, the project contributed to the ongoing refinement of Environmental Footprint method and its implementation. This, in turn, will bolster Swedish competitiveness in the international arena. The multifaceted approach of the project encompasses the following key activities:

Conducting case studies:
Two comprehensive case studies were conducted to assess and validate specific aspects of the Environmental Footprint methodologies, with a focus on understanding their effects on industry and potential improvements in the methodology.

Coordinating life cycle professionals & Swedish representation in the EU Environmental Footprint Technical Advisory Board:
Facilitating effective coordination among life cycle professionals and ensuring active participation and representation of Swedish interests in the Environmental Footprint Technical Advisory Board (TAB).

Communication activities:
Engaging in targeted communication initiatives to disseminate information, raise awareness, and foster a clear understanding of the implications of proposed methodology choices in EU Environmental Footprint assessments.

Collaboration with government agencies in Sweden:
Establishing collaborative partnerships with key government agencies in Sweden to align project objectives with national priorities and regulatory frameworks.

By systematically implementing these activities, the project aims to provide stakeholders with valuable insights, ultimately contributing to informed decision-making, industry advancement, and the continued evolution of Environmental Footprint methodologies. This collective effort will play a pivotal role in fortifying the competitive position of Sweden in the context of environmental sustainability and regulatory compliance.

2. Case studies

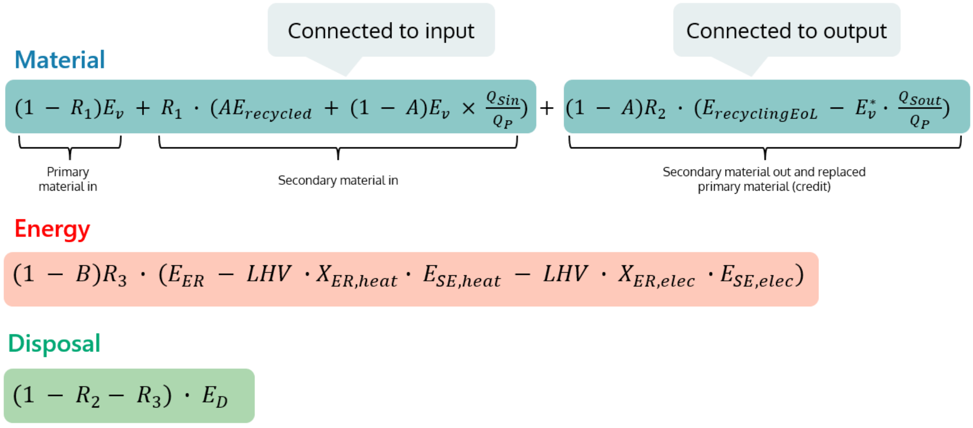
Introduction to case studies

Within the project, two case studies were carried out. The case studies were chosen to reflect current methodological developments within the EU Environmental Footprint process. Stakeholder dialogues were conducted within each case study. In these, we gathered stakeholders from the industry and others to participate and discuss the interpretations and results, and obtained input from experts in academia, industry, and authorities.

One case study focused on modelling impact on climate change with focus on biogenic carbon in an interlinked product systems and in long living products. The case study was managed by IVL and SSAB participated as case industry, having several different types of carbon flows that are relevant to include.

The other case study focused on better understanding the consequences of implementing the Circular Footprint Formula (CFF), which is part of the Product Environmental Footprint (PEF) framework, within the automotive industry and with focus on materials used in batteries. The focus arises from interpreting that the proposed Battery regulation will require adherence to the PEF method and Product Environmental Footprint Category Rules (PEFCR) for batteries. RISE Research Institutes of Sweden managed the case study which included several industries: Volvo Car Corporation, Höganäs AB and CEVT.

Both case studies have incorporated the testing of the Circular Footprint Formula, an integral component of the PEF methodology. The purpose of the CFF is to allocate environmental burdens or benefits arising from material recycling, energy recovery, and disposal. The formula facilitates the distribution of these burdens and benefits between products, with the specific shares determined by various factors that depend on the type of material that is being recycled or disposed. The equations and factors that are part of the formula can be found in Appendix A - Case study Circular Footprint Formula.



$$\underbrace{(1-R_1)E_v}_{\text{Primary material in}} + \underbrace{R_1\cdot\left(AE_{recycled}+(1-A)E_v\times\frac{Q_{Sin}}{Q_P}\right)}_{\text{Secondary material in}} + \underbrace{(1-A)R_2\cdot\left(E_{recyclingEoL}-E_v^{*}\cdot\frac{Q_{Sout}}{Q_P}\right)}_{\text{Secondary material out and replaced primary material (credit)}}$$

$$(1-B)R_3\cdot\left(E_{ER}-LHV\cdot X_{ER,heat}\cdot E_{SE,heat}-LHV\cdot X_{ER,elec}\cdot E_{SE,elec}\right)$$

$$(1-R_2-R_3)\cdot E_D$$

***Figure 1**. The Circular Footprint Formula.*

Brief summaries of each case study and its results can be found on the following pages and full reports on both case studies can be found in Appendix A - Application of the Circular Footprint Formula within the automotive industry and Appendix B - Modelling of biogenic carbon following the guidance in the PEF method.

3. Case study: Circular Footprint Formula

Background and aim

The case study focused on better understanding the consequences of implementing the Circular Footprint Formula (CFF) within the automotive industry in Sweden, with focus on materials used in batteries. The focus arises from the interpretation that the proposed Battery regulation will require that the Product Environmental Footprint (PEF) method, and Product Environmental Footprint Category Rules (PEFCR) for batteries, should be followed, which have been, more or less, confirmed (Andreasi Bassi et al., 2023).

RISE Research Institutes of Sweden led the case study group that included Volvo Car Corporation, Höganäs AB and CEVT. The case study group consisted of ten members with varying previous experience in life cycle assessment and knowledge of the PEF method.

The specific aim of the case study was to:

- Test and evaluate the practical feasibility of using the CFF for selected materials
- Evaluate results compared to using other end-of-life approaches
- Evaluate data availability for implementing the CFF.

What has been studied?

To achieve the objective and introduce the topic to the case study group of industries, the initial step involved conducting a study circle. During and after the study circle, challenges in interpreting the CFF related to the materials selected in the case study were identified. Suggestions for clarifying the existing documentation and guidelines were developed. To address ambiguities in the documentation and guidelines, we reached out to the PEF helpdesk. The environmental impact category chosen as the focus for the case study was climate change.

The next step involved the practical testing of the Circular Footprint Formula. This was accomplished using both a simplified Excel worksheet and professional Life Cycle Assessment (LCA) tools, employing a simplified product example such as the one shown in Figure 2. To enhance comprehension, alternative methods for modelling the end of life were also tested on the same products. Knowing this, the final step encompassed an evaluation of the implications of implementing the Circular Footprint Formula in the Swedish automotive industry.

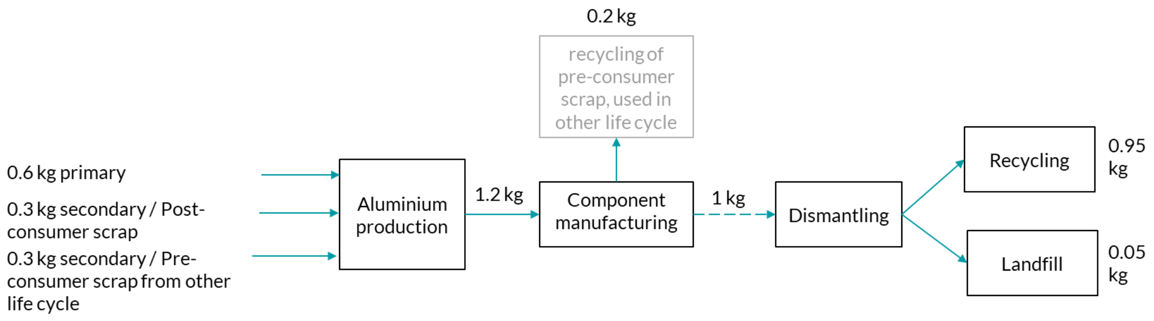


***Figure 2**. Simplified example of a one material product used in the case study.*

Results

Since the aim of the case study was to better understand the consequences of implementing the Circular Footprint Formula (CFF) within the automotive industry in Sweden the results from specific modelling is not the most important, rather the identified challenges and implications.

The first identified challenge was how to handle pre-consumer scrap and post-consumer materials. This challenge is related to several of the factors and parameters of the CFF, R1 factor that is related to the proportion of material in the input to the production that has been recycled from a previous system, R2 factor that is related to , emission factors and quality parameters. What challenges that arises differ from factor/parameter, but the definitions and modelling choices of pre-consumer scrap and between post-consumer materials are affecting them all.

Proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.

Another challenge arose during the practical testing of the CFF in both Excel and LCA software. The process proved to be time-consuming, particularly during the initial attempt. Once the model was established, performing additional calculations for other materials became less time-consuming. Finally, a challenge was encountered in finding the right datasets, which was determined to be an issue not only for CFF but also for other allocation methods. An overview of the data availability for the materials that was include in the case study can be seen in Table 1.

***Table 1**. Data availability where color codes indicate limited or no data availability (red), medium data availability (orange) or good data availability (green).*

Parameter	**Primary material**	**Secondary material (recycling process)**	**Energy recovery or disposal**
Steel	🟩	🟩	🟧
Aluminum	🟧	🟧	🟧
Copper	🟧	🟩	🟩
Nickel	🟧	🟥	🟩
Lithium	🟧	🟥	🟥
Cobalt	🟧	🟥	🟥
Manganese	🟧	🟥	🟥
Polypropylene (PP)	🟧	🟧	🟧
Polyamide (PA)	🟧	🟧	🟧

Voices from case study organization - Volvo Cars

Jennifer Davis, a life cycle specialist at Volvo Cars, played a crucial role in initiating the case study on the Circular Footprint Formula (CFF) and actively participated in the project team overseeing its execution. We asked Jennifer a few questions to uncover insights into the project's value and its potential contributions to the future.

Throughout the duration of this case study, have there been any noteworthy lessons or insights that your team has acquired?

Yes, we were especially interested in how the CFF should be applied on material being recycled from manufacturing processes; here the project team concluded that the CFF rules on this is not 100% clear, which was a bit of a disappointment, but still, it was good that we could highlight to Joint Research Centre (JRC) that clearer guidance is needed.

How has the case study and active participation in the project influenced the ongoing collaboration with PEF within your organization?

Based on the outcome of the project we have concluded that we will use the CFF for internal investigations at the company, for example when exploring different material choices. But when asking our suppliers for LCA data, and calculating the impact of our cars, we will stick to the simple cut-off approach until there is consensus in the automotive industry to use the CFF. Clearer rules around pre-consumer material and data selection in general are needed before the CFF can be widely applicable.

Voices from case study organization - Höganäs

Sofia Poulikidou is an LCA Specialist at Höganäs AB who participated to the case study on the practical implications of the Circular Footprint Formula (CFF) within the automotive industry. We asked Sofia a few questions to uncover insights into the project's value and its potential contributions to the future.

What proved to be the most valuable outcome for your organization as a result of the case study?

First, I would note the open and insightful discussions among the project participants which helped to clarify many of the questions and challenges in relation to the implementation of the CFF. Then of course the hands-on modelling and practical examples on different materials.

How has the case study and active participation in the project influenced the ongoing collaboration with PEF within your organization?

We have now gained practical experience of implementing the CFF and know where further investigation and effort is required.

Voices from case study organization - CEVT

Lionel Belzons is a Senior Sustainability Developer at CEVT and his role in the project is to participate in discussions and workshops with sustainability expertise. We asked Lionel a few questions to uncover insights into the project's value and its potential contributions to the future.

What proved to be the most valuable outcome for your organization as a result of the case study?

The most valuable outcome for my organization from the case study was to learn more about the scope and discuss with other organizations about the topic. What kind of skills and expertise is requested to use the Circular Footprint Formula (CFF) into a project and, also, the topic needs also to be addressed to the supply chain beside the Original Equipment Manufacturers (OEMs) and expertise as well as skills to run the tool is mandatory.

Throughout the duration of this case study, have there been any noteworthy lessons or insights that your team has acquired?

One lesson learned while working with this case study was the possibility to make different interpretations and choices when it comes to input to the CFF. The use of the formula in a project seems to be not so efficient as expected due to the skills requested versus the interpretation part in it.

5. Case study: Biogenic carbon

Background and aim

This case study, led by IVL with active participation from SSAB, focused on the modelling of biogenic carbon according to PEF in interlinked product systems and in long-living products. The focus arises from the need to better understand the modelling of climate change with a focus on biogenic carbon following the PEF method. Two steel products were included in the case study, SSAB Fossil-free™ steel and scrap-based steel. To further clarify the differences and challenges, the EN 15804, which is the EPD standard for construction products, was used for modelling besides the PEF.

The overall aim of this case study was to better understand the consequences of using the PEF methodology to model the climate impact with focus on biogenic carbon in interlinked product systems and long living products.

The specific aims of the case study were to:

- Evaluate **data availability** to model the PEF sub-category 'Climate change – biogenic' for the specific products.
- Test and evaluate the feasibility **to model** the PEF sub-category 'Climate change – biogenic' with special focus on use of recycled materials, materials going to recycling and long-living products.
- **Understand consequences** of data availability and climate change modelling on SSABs products.

What has been studied?

To meet the aim of the case study the first step conducted was to identify relevant guidance for how to model biogenic carbon. The PEF method, PEFCRs including intermediate paper and steel products, and EN 15804 were included. The studied key aspects include:

- **Modelling**: any specific guidance related to modelling and reporting of biogenic carbon.
- **Allocation:** any specific guidance on how allocation shall be conducted since both recycled content and recyclability are relevant for the products.
- **Time:** any specific guidance on how to handle the time perspective related to biogenic carbon modelling since steel can be in both short and long-living products.

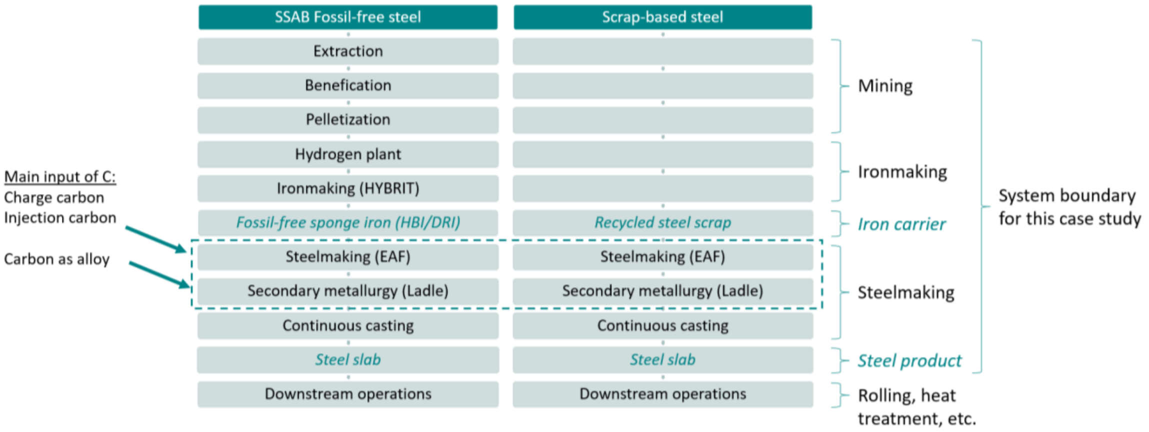


Figure 3. *Illustration of the two production routes for steel products investigated in this study.*

The environmental impact category climate change was selected as focus for the case study. Defining the products to include and gaining information and knowledge about them was the next step before deciding which modelling approaches to include for biogenic carbon. As in the other case study conducted an evaluation of data availability and collection of relevant data to use was done to prepare for the calculations following the identified guidance and modelling approaches. After this step the results were analysed to understand consequences of the modelling approaches for biogenic CO_2 flows.

Results

The climate change impact for biogenic carbon has been calculated for four different modelling approaches, as shown in figure 4. The presented figure illustrates the total result of all life cycle stages. The breakdown results between these stages can be found in the appendix B.

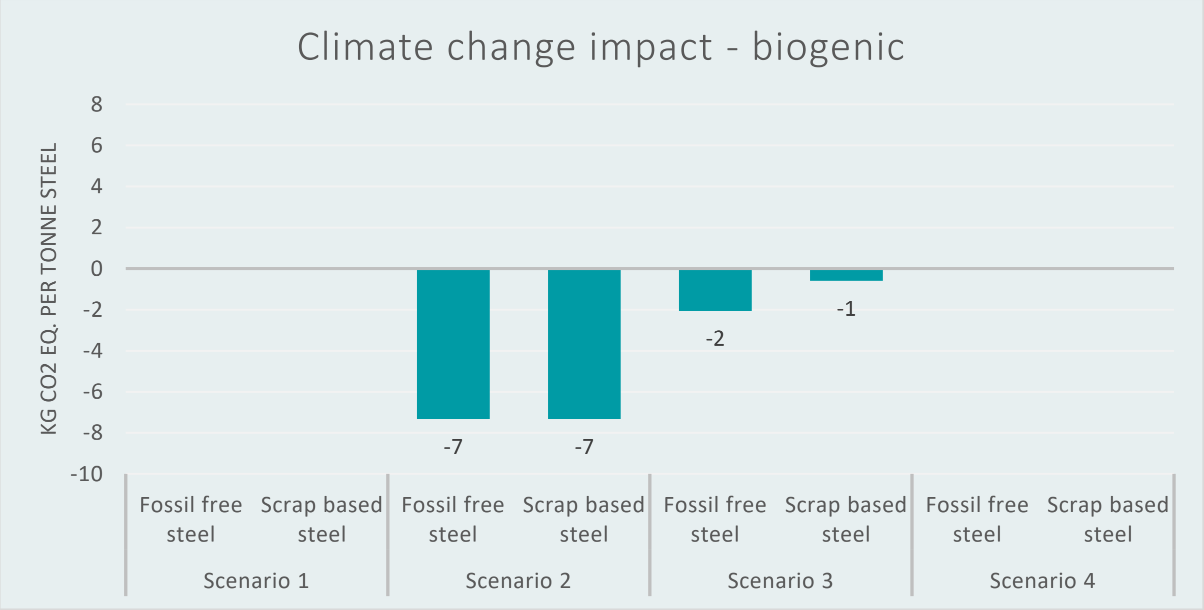


Figure 4. *Climate change impact from different modelling scenarios.*

The results are expressed per ton of steel, considering both fossil-free and scrap-based steel, with the end-of-life (EoL) steel directed to recycling. The system is modelled with the default allocation factor for steel, i.e. 0,2. In the context of CFF, an A-factor below 0,5 means an emphasis on recyclability at EoL.

For modelling approach 1, the result is zero. This is because the characterisation factor for biogenic CO2 is set to zero, which is in line with the PEF method. Modelling approach 2 yields a negative value of 7, representing the biogenic carbon content of the product. In modelling approach 3, the result reached -2 for fossil-free steel and -1 for scrap-based steel. This deviation does not accurately reflect the biogenic carbon content of the product. Still, it is due to an imbalance in recycling, with 10% less steel being recycled at EoL than the amount used in the product. For modelling approach 4, the overall impact is zero. Yet, when the result is broken down into various stages of the product's life cycle, biogenic carbon content becomes visible. In summary, the results vary depending on the modelling approach. A more comprehensive breakdown of these findings is available in Appendix B, providing detailed insights into different phases of the product life cycle.

Voices from case study organization - SSAB

Jonas Larsson is Director of Environmental Affairs at SSAB and has participated in this project as a case study partner providing the project with company- and industry-specific calculation data, production route descriptions, etc. We asked Jonas a few questions to uncover insights into the project's value and its potential contributions to the future.

What proved to be the most valuable outcome for your organization as a result of the case study?

There were many valuable insights that we can use when calculating the carbon footprint for fossil-free steel in the future. SSAB aims to be the first in the industry to launch fossil-free steel on the market and we need to be at the forefront also in carbon footprint reporting.

How has the case study and active participation in the project influenced the ongoing collaboration with PEF within your organization?

Hard to say at this early stage. However, we have extensive experience in Environmental Product Declaration (EPD) reporting and carbon footprint in particular. Going forward, we also need to manage Product Environmental Footprint (PEF) methodology. This project was an important step on that journey of learning and understanding.

Could you provide recommendations for other organizations intending to implement the Circular Footprint Formula based on your experience?

Be aware that PEF guidance may not be completely comprehensive at this early stage. Regarding biogenic carbon and the modeling of long-living products, interpretations need to be made and additional documentation will play a crucial role for the transparency of the results.

6. Recommendations from case studies

The insights from the two case studies reveal several critical challenges and areas for potential improvement in Environmental Footprint modelling.

A primary issue identified in case study Biogenic Carbon (SSAB) is the lack of specific guidance on biogenic carbon content modelling. This gap mainly affects the allocation of biogenic carbon content among interlinked product systems, especially for products made from renewable resources. The current simplified approach to modelling biogenic carbon content might not be sufficient since there is a growing expectation to report biogenic carbon content. Leaving the choice open in the PEFCR might lead to different product categories treating biogenic carbon content differently. Another notable limitation of the PEF method is its approach to time-related emissions modelling. All emissions and removals are treated as occurring 'now', with no provision for discounting overtime, which fails to differentiate the environmental impacts of long- and short-living products.

In addition to these challenges, the study identifies a lack of harmonization between the PEF guidance and the EN 15804 standard, leading to varied results across different modelling approaches. Four distinct approaches are identified, each with challenges in accurately reflecting carbon content and balancing it over a product's life cycle.

Both case studies revealed the challenges with the Circular Footprint Formula (CFF) due to its complexity, lack of clear guidance, and ambiguity in its application. This ambiguity particularly complicates the application of the CFF in scenarios involving recycled inputs and outputs, making it challenging to interpret results across different life cycle stages. A specific concern is raised about the effective use of CFF to differentiate between post-consumer and pre-consumer materials, as the pre-consumer materials often come from manufacturing inefficiencies, and therefore in many cases should not give the same credit as post-consumer materials. The case studies also emphasize data availability and interpretation challenges, with inconsistent usage and interpretation of data leading to non-comparable results.

To address these issues, the studies recommend the implementation of more explicit guidelines and standardized approaches within the PEF framework. This involves ensuring compatibility with existing databases, providing open access to data, and offering detailed guidance for accurately assessing and improving the environmental impact of products.

7. Expert group

Important to the projects aim and result has been the Swedish Life Cycle Center Environmental Footprint Expert group. The overarching aim of the Environmental Footprint Expert group is to actively monitor, comprehend, and influence the ongoing development of Environmental Footprint (EF) methodologies, specifically the Product Environmental Footprint (PEF) and Organizational Environmental Footprint (OEF). The group serves as a platform for the exchange of information and experiences among Swedish Life Cycle professionals, fostering dialogue on EF methodologies' implementation in both EU and national policies. Additionally, the expert group undertakes coordination responsibilities for Technical Advisory Board (TAB) representatives from Sweden.

The group conducts meetings, discussions, and consultations to support Swedish representatives in TAB and EF sub-group activities, addressing and impacting methodological challenges as they arise. The success of this initiative hinges on proactive engagement, continuous information exchange, and strategic coordination efforts within the broader context of environmental sustainability and policy development. The direct connection to the TAB gives the possibility to influence the development as well as keep the Swedish experts updated on the progress and agenda regarding EU Environmental Footprint.

During the project, the Expert group had four meetings with different focuses, and the group has had the possibility to give input on the case studies conducted within this project.

Meeting 1: Update from TAB meeting and Green claims communication.
Meeting 2: Data availability and update on the process for Database development for Environmental Footprint, presentation of case studies.
Meeting 3: Presentation from the project Modelling Electricity in Product Environmental Footprint and discussion on the results and its implications.
Meeting 4: Reporting from TAB meeting.

The group was also invited to take part in the Stakeholder dialogue meeting that was held within each case study.

8. Communication

To reach out to different stakeholders and to further increased awareness on Environmental Footprint, and to disseminate the results from the project and its case studies, several communication efforts have been undertaken. The project has continuously informed about case studies, about meetings in the Expert group and about the open webinar that presented the result from the project in relevant channels such as the Swedish Life Cycle Center webpage, on Swedish Life Cycle Center LinkedIn page and in newsletters and through event invites from the Center.

Specific communication efforts include:

- Taking part in a meeting for the construction industry. The meeting focused on Environmental Footprint and Environmental product declarations. A presentation was held about Environmental Footprint, its differences from Environmental Product Declaration (EPD) and ongoing projects of interest.

- Presenting preliminary results from the project at the LCM 2023 conference that was held in Lille, France in September 2023. At the conference further contact with the EU Environmental Footprint team was established which has been utilized for invitation to the open webinar and to communicate the results.

- Case study stakeholder meetings to present preliminary results and discuss implications and further development.

- Hosting an open webinar on October 26, 2023 to present the results from the project. The webinar covered practical aspects of both the applied and tested methodology. As it included both the presentation of results from case studies and provided an update on the broader legislative perspective of the EU Environmental Footprint process. A recording of the webinar is available on YouTube.

- Having dialogue meetings with relevant authorities to both get their insights on the policy process and to raise their awareness on the EU Environmental Footprint process.

9. Outcomes

The primary objective of the project, which aimed to enhance awareness among businesses, authorities, and the public sector in Sweden regarding product-related policy development based on the Environmental Footprint (EF) framework at the EU level. This has been achieved through well-thought-out case studies and communication efforts. These efforts targeted specific groups (e.g., the EU Environmental Footprint team) and were open to everyone (e.g., webinars and social media). Additionally, fruitful and open meetings were held in the Swedish Life Cycle Center's Expert group, and successful dialogues were established with Swedish government agencies.

The conducted case studies have been instrumental in deepening our knowledge of the consequences and effects of method choices for different industries in Sweden. They greatly contribute to the understanding of the Environmental Footprint methodology. Additionally, these studies play a significant role in enhancing our comprehension of the practical application and implications of Product Environmental Footprints (PEFs). This increased understanding equips the case study industries and stakeholders who have followed the studies with greater readiness for implementing Environmental Footprint practices.

By using parts of the EF methodology, the project has made visible the further need for method development and clarification of existing guidelines for both the Circular Footprint Formula and for how to model biogenic carbon using the Environmental Footprint methodology. Read more about these recommendations in chapter 7: Recommendations from case studies. These project results have been communicated to the European Commission's Environmental Footprint team to spread knowledge about identified consequences and suggestions for improvements to influence the development of the method and guidelines.

Besides the previously highlighted recommendations from the case studies, the project highlights the need for closing data gaps and making relevant data available for EF studies. Additionally, feasibility tests must be conducted to evaluate the applicability of Environmental Footprint methods, aligning with upcoming EU policies. Striking a balance between complexity and simplicity but still giving a result that is correct is deemed critical for the widespread adoption of Environmental Footprint. Further case studies are recommended to explore this dynamic.

Besides the case studies, the communication regarding upcoming regulations within the EU that refer to Environmental Footprint has further prepared the Swedish industry and gave insight into both timeline and possible effects of these policy frameworks. The expert group and other dialogue meetings have expanded the network of people that have knowledge about Environmental Footprint. The project has increased collaboration between Swedish actors to both exchange knowledge and to manage Environmental Footprint.

10. Meet the team

Maria Rydberg

Title: Director

Organization: Swedish Life Cycle Center

Role in the project: Project Manager

Why has this project been important to implement?

The project successfully combines expertise, integrating legislative framework development and practical testing. This synergy has proven exceptionally fruitful, allowing the project to effectively communicate both the applied and tested methodology's practical aspects and its broader legislative perspective. Refining Environmental Footprint methodologies to align with evolving regulatory standards is crucial, as is effective communication. It involves raising awareness amid impending legislative proposals that incorporate the method.

What is important to focus on going forward?

Looking ahead, effective communication of identified challenges during the PEF development process is very important. Bridging data gaps and engaging with suppliers across multiple tiers are critical for up-stream adaptation and ensuring accurate environmental assessments. This strategic focus is necessary for maintaining relevance and ensuring the effective implementation of Environmental Footprint methodologies. Addressing concerns about potential overcomplication of Life Cycle Assessment (LCA) work is integral to ongoing harmonization efforts, striking a delicate balance between complexity and simplicity for widespread adoption.

Torun Hammar

Title: Researcher

Organization: RISE Research Institutes of Sweden

Role in the project: Leader of the case study "Application of the Circular Footprint Formula within the automotive industry"

What was the most valuable outcome for you as a researcher from working with the case?

Participating in the case study was valuable for gaining a deeper understanding of the PEF method, and in particular how to apply the Circular Footprint Formula in practice. It was also very valuable to collaborate with several industry partners to learn more about the industry's perspective and the challenges they face.

What has been the biggest challenge while working on the case study?

First, interpretating the Circular Footprint Formula and ensuring that we understood the methodology as intended. Here, the opportunity to discuss with the case study group was a great advantage. Second, for the practical application, finding the right data was a challenge.

Erika Kloow

Title: Senior expert

Organization: IVL Swedish Environmental Research Institute

Role in the project: Leader and performer of the case study "Modelling of biogenic carbon following the guidance in the PEF method"

Have there been any new lessons learned while working with this case study?

In the case study we tested the dynamics of the Circular Footprint Formula's "A factor" by studying different values for the factor. This gave us an opportunity to understand how the Circular Footprint Formula (CFF) allocation approach compares to other methods, such as the "cut-off" method and the "system expansion" method.

Do you have any recommendations for other industries that will use the PEF-methodology for products with biogenic carbon?

When using the CFF we found it useful to divide the formula into different life cycle steps (upstream, core, downstream). This helped us in the modelling but maybe more importantly when interpreting the results. As it is not defined in the PEF method how the biogenic carbon content of the material should be allocated between product systems, a more detailed presentation of the results visualized the impact of the assumptions made in the modelling.

Josefin Neuwirth

Title: Expert

Organization: IVL Swedish Environmental Research Institute

Role in the project: Performer of task in the case study "Modelling of biogenic carbon following the guidance in the PEF method"

What was the most valuable outcome for you as a researcher from working with the case?

To get more knowledge about the methodology behind the Product Environmental Footprint, especially concerning how to model recycling and biogenic carbon flows. When it comes to recycling it concerns both products using recycling and going to recycling at end of life.

What has been the biggest challenge while working on the case study?

The biggest challenge was to understand and use the Circular Footprint Formula (CFF). The CFF shall be used to model recycled input and products going to recycling. The application of the CFF on negative biogenic climate change impact values (being the biogenic carbon content of the product) made the analysis even more challenging, leaving room for interpretation.

11. References

Andreasi Bassi, S., Biganzoli, F., Ferrara, N., Amadei, A., Valente, A., Sala, S., & Ardente, F. (2023). *Updated characterisation and normalisation factors for the Environmental Footprint 3.1 method.* ISBN 978-92-76-99069-7, doi:10.2760/798894, JRC130796. EUR 31414 EN, Publications Office of the European Union, Luxembourg. https://publications.jrc.ec.europa.eu/repository/handle/JRC130796

Andreasi Bassi, S., Peters, J. F., Candelaresi, D., Valente, A., Ferrara, N., Mathieux, F., & Ardente, F. (2023). *Rules for the calculation of the Carbon Footprint of Electric Vehicle Batteries* (CFBEV). Luxembourg: Publications Office of the European Union, 2023.

EN 15804 SS-EN 15804:2012+A2:2019/AC:2021. Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products.

EN 45557. (2020). *General method for assessing the proportion of recycled material content in energy-related products* (EN 45557:2020).

European Commission. (2012). *Product Environmental Footprint (PEF) Guide*. European Commission (EC) and Joint Research Centre (JRC).

European Commission. (2020). *The CFF formula and its practical application.* https://ec.europa.eu/environment/eussd/videos/2020-11-10_1502_The_CFF_Formula_and_its_practical_application.mp4

European Comission (2021) Environmental Footprint methods. Commission adopts Recommendation to help companies to calculate their environmental performance and manufacture more environmentally friendly products. News article December 16, 2021 https://ec.europa.eu/environment/news/environmental-footprint-methods-2021-12-16_en

ISO 14021. (2016). *Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)* (ISO 14021:2016).

PEF method C (2021) 9332 final: COMMISSION RECOMMENDATION *on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations*. https://eur-lex.europa.eu/resource.html?uri=cellar:75e0de0f-5e6d-11ec-9c6c-01aa75ed71a1.0019.02/DOC_1&format=PDF

PEF method C (2021) 9332 final: COMMISSION RECOMMENDATION *on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations. Annexes 1 and 2.* https://eur-lex.europa.eu/resource.html?uri=cellar:75e0de0f-5e6d-11ec-9c6c-01aa75ed71a1.0019.02/DOC_2&format=PDF

PEFCR metal sheets (2019), *Product Environmental Footprint Category Rules (PEFCR) for Metal Sheets for Various Applications*. Version: 28/06/2019 Time validity: 31/12/2021 Based on the template from the PEFCR Guidance ver. 6.3 (May 2018)

PEFCR intermediate paper (2018), *Product Environmental Footprint (PEF) Category Rules (PEFCRs)* INTERMEDIATE PAPER PRODUCT. Version number: Final draft. Date of publication: 18 October 2018.

RECHARGE. (2020). *PEFCR - Product Environmental Footprint Category Rules for High Specific Energy Rechargeable Batteries for Mobile Applications* (Version 1.1). The Advanced Rechargeable & Lithium Batteries Association.

Zampori, L., & Pant, R. (2019). *Suggestions for updating the Product Environmental Footprint (PEF) method*. EUR 29682 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76- 00654-1, doi:10.2760/424613, JRC115959.

Appendix A - Application of the Circular Footprint Formula within the automotive industry

Contents

1. Background and aim of the study

This case study is part of the Vinnova funded project *Environmental Footprint in Swedish Industry – increased understanding and implementation*, which has the overall aim to make businesses, authorities and the public sector in Sweden aware of product-related policy development based on Environmental Footprint at the EU level. Furthermore, the aim is to make visible and clarify the consequences of proposed methodology choices in Environmental Footprint to better understand what effects an implementation can have in the Swedish industry.

This case study focused on better understanding the consequences of implementing the Circular Footprint Formula (CFF) within the automotive industry in Sweden, with focus on materials used in batteries. The focus arises from the interpretation that the proposed Battery regulation will require that the Product Environmental Footprint (PEF) method, and Product Environmental Footprint Category Rules (PEFCR) for batteries, should be followed. This has been, more or less, confirmed (Andreasi Bassi et al., 2023).
The specific aim of the case study was to:

- Test and evaluate the practical feasibility of using the CFF for selected materials,
- Evaluate results compared to using other end-of-life approaches,
- Evaluate data availability for implementing the CFF.

RISE Research Institutes of Sweden led the case study group that included Volvo Car Corporation, Höganäs AB and CEVT. The case study group consisted of ten members with varying previous experience in life cycle assessment and knowledge of the PEF method.

Circular Footprint Formula

The Circular Footprint Formula is built of three components: material recycling, energy recovery and disposal, where the total Circular Footprint is the sum of the three:

$$Material = (1 - R_1)E_v + R_1 \cdot (AE_{recycled} + (1 - A)E_v \times \frac{Q_{Sin}}{Q_P}) + (1 - A)R_2 \cdot (E_{recyclingEoL} - E_v^* \cdot \frac{Q_{Sout}}{Q_P}) \quad (1)$$

$$Energy = (1 - B)R_3 \cdot (E_{ER} - LHV \cdot X_{ER,heat} \cdot E_{SE,heat} - LHV \cdot X_{ER,elec} \cdot E_{SE,elec}) \quad (2)$$

$$Disposal = (1 - R_2 - R_3) \cdot E_D \quad (3)$$

The parameters are defined in Table A1.

***Table A1**. Description of parameters in the Circular Footprint Formula (Equation 1-3) (EU, 2021).*

Parameter	Description
A	Allocation factor of burdens and credits between supplier and user of recycled materials.
B	Allocation factor of energy recovery processes: it applies both to burdens and credits.
$\frac{Q_{Sin}}{Q_P}$	Q_{Sin} is the quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution. Q_P is the quality of the primary material, i.e. quality of the virgin material.
$\frac{Q_{Sout}}{Q_P}$	Q_{Sout} is the quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.
R_1	Proportion of material in the input to the production that has been recycled from a previous system.
R_2	Proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.
R_3	Proportion of the material in the product that is used for energy recovery at EoL.
$E_{recycled}$	Specific emissions and resources consumed (per unit of analysis) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.
$E_{recyclingEoL}$	Specific emissions and resources consumed (per unit of analysis) arising from the recycling process at EoL, including collection, sorting and transportation process.
E_v	Specific emissions and resources consumed (per unit of analysis) arising from the acquisition and pre-processing of virgin material.
E_v^*	Specific emissions and resources consumed (per unit of analysis) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.
E_{ER}	Specific emissions and resources consumed (per unit of analysis) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, etc).
$E_{SE,heat}$	Specific emissions and resources consumed (per unit of analysis) that would have arisen from the specific substituted energy source, heat.
$E_{SE,elec}$	Specific emissions and resources consumed (per unit of analysis) that would have arisen from the specific substituted energy source, electricity.
E_D	Specific emissions and resources consumed (per unit of analysis) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.
$X_{ER,elec}$	Efficiency of the energy recovery process for electricity.
$X_{ER,heat}$	Efficiency of the energy recovery process for heat.
LHV	Lower Heating Value (LHV) of the material in the product that is used for energy recovery.

2. What was studied and how?

The case study was conducted in the following steps:

- Study circle on CFF including reading and discussing relevant literature and documentation,
- Identifying challenges in interpretating the CFF, related to the materials selected in the case study, and developing suggestions for how to clarify the existing documentations and guidelines,
- Practical testing of the CFF, both in a developed Excel tool for a simplified product example (see Figure A1), and in selected LCA software for several materials,
- Evaluating the results compared to using another end-of-life allocation method,
- Evaluating the overall implications of implementing the Circular Footprint Formula in the Swedish automotive industry.

During the interpretation work, the PEF helpdesk[1] was consulted to help clarify ambiguities in the documentation and guidelines. Furthermore, a reference group meeting with interested parties was arranged to discuss findings of the case study. The environmental impact category climate change was selected as focus for the case study.

Study circle

As a first step of the case study, a study circle was conducted where the following literature was reviewed and discussed:

- Suggestions for updating PEF guide (Zampori & Pant, 2019) and PEF guide (European Commission, 2012) (with focus on Circular Footprint Formula)
- PEFCR batteries (RECHARGE, 2020)
- Webinar on CFF (European Commission, 2020)
- Annex C v2.1 May 2020 - CFF default parameters (Excel sheet)
- Annexes 1 to 2 (EU, 2021)

During the case study period, the draft for the *Rules for the calculation of the Carbon Footprint of Electric Vehicle Batteries* (CFBEV) (Andreasi Bassi et al., 2023) was published, which includes the Circular Footprint Formula, with some alterations from the version included in the PEF documentation. This report was therefore also read and discussed when evaluating the implications for the Swedish automotive industry.

Simplified product example

As a second step of the case study, to help interpretate the Circular Footprint Formula, a simplified product example was defined based on one material (aluminium) (Figure A1). An Excel tool was also developed to test the formula and to evaluate the data availability for this specific example. The product example included both primary and secondary input materials, from both post-consumer and pre-consumer materials. Furthermore, both manufacturing losses (pre-consumer material) and end-of-life materials (post-consumer material) sent to recycling was considered. The functional unit for the simplified example was defined as 1 kg aluminium product, with a reference flow of 1.2 kg input material and 0.2 kg manufacturing loss.

---

[1] PEF helpdesk (EF_Helpdesk@sphera.com)

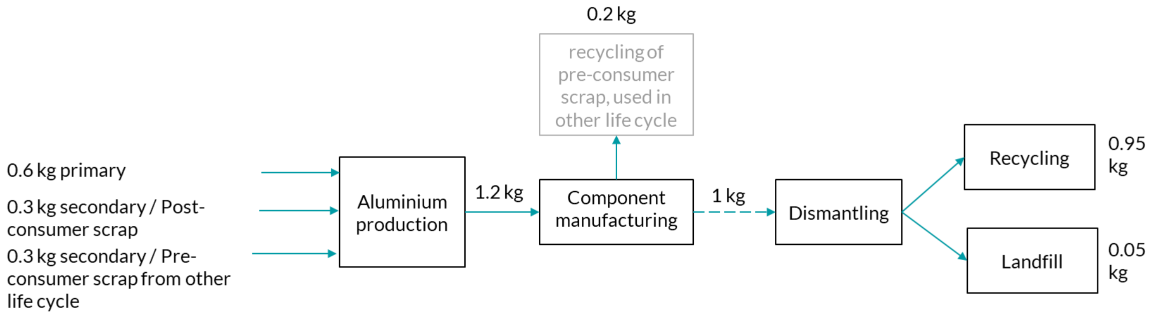


Figure A2. *Simplified example of a one material product used in the case study.*

Practical testing in an LCA software

In addition to the simplified product example tested in an Excel tool, several materials were tested in an LCA modelling software (LCA for Experts (GaBi)) by Volvo Car Corporation and Höganäs:

- Aluminium
- Steel
- Iron
- Copper

During the practical testing, the two companies evaluated how the CFF can be directly integrated into the software. Moreover, data availability for the specific materials was investigated. Additionally, the difference compared to end-of-life allocation methods normally used at each organization was discussed within this case study.

3. Findings

Interpretation of the Circular Footprint Formula

Challenges

During the initial study circle and practical testing of the simplified product example in the developed Excel tool, several challenges in interpreting the formula were identified, mainly related to how pre-consumer and post-consumer materials should be handled. The definitions used within the case study are listed in Box A1, which were also checked against the definitions in ISO 14021:2016 listed in Box A2 and EN 45557:2020 listed in Box A3. For this case study, there was a need to separate between internal and external pre-consumer materials, since it is not only the recycled content in the material input that has an importance for the Circular Footprint Formula, but also the secondary material leaving the studied system.

The main questions identified were:

1) How should pre-consumer scrap and post-consumer materials be handled in R1? Is there a difference between internal and external pre-consumer materials (see Box A1)?
2) Should the R2 factor include pre-consumer materials as well as post-consumer materials that goes to recycling (i.e. should also manufacturing losses sent to recycling be considered in R2)?
3) How should differences in emission factors ($E_{recyclingEoL}$ and $E_{recycled}$) for pre-consumer materials and post-consumer materials be handled?
4) How should the quality parameters be defined for pre-consumer materials and post-consumer materials?

The case study group are aware that there are variations in definitions of different types of pre-consumer materials, but have for this case study followed the definitions listed in Box A1.

Box A1. Definitions of post-consumer and pre-consumer material used in case study

Post-consumer material	Material derived as waste stream at products end of life, after use by households, commercial, industrial or institutional facilities.
Pre-consumer material	Material derived as waste stream from manufacturing process.
Internal pre-consumer material	Material derived as waste stream from manufacturing process, which is used within the same manufacturing facility (e.g. reutilization of material within the same facility that generated the material).
External pre-consumer material	Material derived as waste stream from manufacturing process, which is used within another manufacturing facility (e.g. reutilization of material within another facility than the process that generated the material).

Interpretation

Several possible interpretations were found and discussed (see Table A2-A5 for more details), and after consulting the PEF helpdesk, the following interpretations were considered correct:

1) Both post-consumer and pre-consumer materials should be included in R1. There is no stated difference between how internal and external pre-consumer materials should be handled in R1 (see Table A2 and Figure A2 for more details). However, in case the definitions in ISO 14021 (Box A2) are followed, only external materials should be claimed as recycled content, and consequently internal materials are not included in R1. Here, clarifications in the PEF documentations are needed to avoid misinterpretations.
2) Two separate R2 factors should be defined, one for pre-consumer materials (generated during manufacturing) and one for product end-of-life waste (generated at end of life) (see Table A3 and Figure A2 for more details). In terms of R2, the generation of internal pre-consumer materials may be relevant. However, this should be clarified in the PEF documentation.
3) The $E_{recyclingEoL}$ emission factor do not only consider emissions from end-of-life, but also emissions for recycling from the manufacturing stage (i.e. two different emission factors are used for pre-consumer and post-consumer materials). The $E_{recycled}$ emission factor can also be set differently for pre-consumer and post-consumer materials used as input material (see Table A4 for more details).
4) Since the recycled materials from manufacturing and end-of-life (pre-consumer and post-consumer materials) are handled as two different materials, the quality parameters are also defined differently for the two materials, i.e. with different quality parameters (see Table A5 for more details).

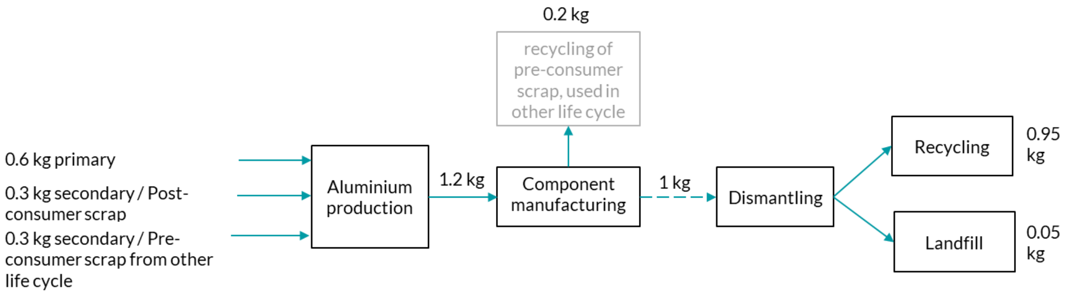
For the simplified example, we defined two R2 factors as $R2_{manufacturing}$ and $R2_{EoL}$, where $R2_{manufacturing}$ represents pre-consumer materials and $R2_{EoL}$ represents post-consumer materials (Figure A2).

Box A2. Definitions of post-consumer and pre-consumer material in ISO 14021:2016

Post-consumer material	Material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product which can no longer be used for its intended purpose. This includes returns of material from the distribution chain.
Pre-consumer material	Material diverted from the waste stream during a manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.

Box A3. Definitions of post-consumer and pre-consumer material in EN 45557:2020

Post-consumer material	Material recovered from waste generated by households or by commercial, industrial, and institutional facilities in their role as end-users of a finished product[1]. [1] This includes returns of products, or parts thereof, from the distribution of finished products for end-users.
Pre-consumer material	Material diverted from the waste generated during a manufacturing process excluding reutilization of materials such as rework, regrind or scrap generated in a process and being reincorporated in the same process that generated it[2]. [2] Same process means the same manufacturing operation for the same type of product in the same or different physical location.



$$R1 = (0.3+0.3)/1.2 = 0.5$$

$$R2_{manufacturing} = 0.2/0.2 = 1$$

$$R2_{EoL} = 0.95/1 = 0.95$$

Figure A3. *Simplified example used in the case study, including R1 and R2 factors for pre-consumer materials (R2manufacturing) and post-consumer materials from end-of-life (R2EoL).*

Table A2. *Challenges in interpretating R1 (defined as 'Proportion of material in the input to the production that has been recycled from a previous system' in Circular Footprint Formula).*

Challenge/ question	Possible interpretation	Reference	Our interpretation/ comment
How should pre-consumer materials and post-consumer materials be handled in R1? Is there a difference between internal and external pre-consumer materials?	R1 considers both pre-consumer materials and post-consumer materials.	EU (2021) p. 49: "R1: the proportion of material in the input to the production that has been recycled from a previous system." EU (2021) p. 53: "Option 1: the impacts to produce the input material that leads to the pre-consumer scrap in question shall be allocated to the product system that generated this scrap. Scrap is claimed as pre-consumer recycled content. Process boundaries and modelling requirements applying the CFF are shown in Figure A6."	There is an option 2 described in EU (2021) where pre-consumer scrap is not claimed as pre-consumer scrap. We have assumed the first option, where scrap is claimed as pre-consumer recycled content. We interpretate that the two options on p 53-54 in EU (2021) refers to internal recycling of pre-consumer materials, and do not clarify how external pre-consumer materials should be handled. After consulting PEF help desk, we interpretate that there is no difference between internal and external materials.

Table A3. *Challenges in interpretating R2 (defined as 'Proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.' in Circular Footprint Formula).*

Challenge/ question	Possible interpretation	Reference	Our interpretation/ comment
Should the R2 factor include pre-consumer materials as well as post-consumer materials that goes to recycling (i.e. should also manufacturing losses sent to recycling be considered in R2)?	Option 1: R2 only includes post-consumer materials (i.e. share of material in final product that is recycled at end of life).	EU (2021) p. 50: "R2: the proportion of the **material in the product** that will be recycled (or reused) in a subsequent system. Therefore, R2 shall take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant."	References to option 1 and 2 contradict each other. We select option 3 based on PEF helpdesk response. Conclusion from test calculation show that option 2 and option 3 gives the same result when using the same quality parameters and emission factors.
	Option 2: R2 includes both pre-consumer materials and post-consumer materials (i.e. total amount of materials send to recycling during manufacturing and end of life).	EU (2021) p. 64: "The Circular Footprint Formula (see Section 4.4.8.1) provides the approach that shall be used to estimate the overall emissions that result from a certain process involving recycling and/or energy recovery. **These moreover also relate to waste flows generated within the system boundary**."	
	Option 3: Two separate R2 factors are defined, one for pre-consumer materials (generated during manufacturing) and one for product waste (generated at end of life).	E-mail from PEF helpdesk: "R2: you need to address the end-of-life (EoL) of the two flows (manufacturing losses and product EoL) in the life cycle stage (LCS) where it occurs. Therefore, you will need to define a R2 figure for the 0.2 kg in LCS3 (manufacturing) and another R2 figure for the product mass at the product end-of-life (1 kg in the example), i.e. LCS5." *Note: We believe LCS3 is incorrect, and that it should be LCS2 (manufacturing).*	

Table A4. *Challenges in interpretating emission factors for pre-consumer and post-consumer materials ($E_{recyclingEoL}$ and $E_{recycled}$).*

Challenge/ question	**Possible interpretation**	**Reference**	**Our interpretation/ comment**
How should differences in emission factors for pre-consumer materials and post-consumer materials be handled?	Option 1: Emission factors are considered the same for both pre-consumer materials and post-consumer materials.	From definition of $E_{recyclingEoL}$: "Specific emissions and resources consumed (per unit of analysis) arising from the **recycling process at EoL,** including collection, sorting and transportation process."	Based on response from PEF helpdesk regarding parameter R2, we interpretate that $E_{recyclingEoL}$ do not only consider emissions from end of life but also emissions for recycling from the manufacturing stage. Thereby, different emission factors can be applied for pre-consumer and post-consumer materials, representing the specific material/process.
	Option 2: Pre-consumer materials and post-consumer materials are handled as two different materials occurring at two different life cycle stages and with different emission factors.	Based on PEF helpdesk response in Table A2.	

Table A5. *Challenges in interpretating quality parameters ($\frac{Q_{Sin}}{Q_P}$ and $\frac{Q_{Sout}}{Q_P}$).*

Challenge/ question	**Possible interpretation**	**Reference**	**Our interpretation/ comment**
How should the quality parameters be defined for pre-consumer materials and post-consumer materials?	Option 1: Quality parameters are the same for both pre-consumer materials and post-consumer materials		Based on response from PEF helpdesk regarding parameter R2 (see Table A2), we interpretate that the quality parameters are handled as two different materials with different quality parameters.
	Option 2: Pre-consumer materials and post-consumer materials are handled as two different materials with different quality parameters	Based on PEF helpdesk response in Table A2.	

It was also noted that the identified challenges are probably also relevant for the other parameters related to materials going to energy recovery or disposal (e.g. R3 and E_D parameters). However, since this was not the primary focus of this simplified example, we did not include a further discussion on this topic.

The Circular Footprint Formula included in the *Rules for the calculation of the Carbon Footprint of Electric Vehicle Batteries* (CFBEV) has some alterations compared to the original version in the PEF documentation. The CFBEV states that "*The recycled content and the waste generated during all the life-cycle stages shall be modelled with the use of the Circular Footprint Formula (CFF) and shall be reported at the life-cycle stage where the waste management occurs.*", which strengthens the interpretation in Table A3. Furthermore, the CFBEV states that "*The CFF shall not be used for any waste (i.e., materials or objects rejected during the battery manufacturing process) that is re-used as an integral part in the same process and that does need to be recycled (e.g., run-around scrap) since this is not considered manufacturing waste according to the Article 2 of the Battery Regulation Proposal.*", and thereby introduces an additional type of scarp referred to as run-around scarp. It does not clarify if pre-consumer materials that need further processing (for example cleaning) before being recycled within the same process should be considered. Additionally, it is stated that the CFF should be applied per material part (except the battery cell and printed wiring board (PWB)), where the formula has been divided into four material terms:

1) Impacts of using primary and secondary materials in the battery production, i.e., when the recycled content is different than 0.
2) Impacts of producing secondary materials from the dismantling: steel and aluminium from the housing and copper from the cables.
3) Impacts of producing secondary materials from the PWB recycling after the battery dismantling: copper, gold, and palladium.
4) Impacts of producing secondary materials from the battery cell recycling: copper, nickel sulphate, and cobalt sulphate in the default 'End-of-life' life-cycle stage.

The adjusted CFF in the CFBEV thus includes a formula part for (1) material input, (2) dismantling, (4) electronics recycling, (5) cell recycling, (6) energy recovery and (7) disposal. The CFBEV do not specify in more detail how the CFF should be applied for the upstream manufacturing processes for materials, but focuses more on the end-of-life of batteries.

Suggestions for clarifying Circular Footprint guidelines

To decrease the risk of misinterpreting the Circular Footprint Formula, a few suggestions for clarifications were formulated:

- Clarify that manufacturing losses should be handled as a separate waste material from the end-of-life waste in the Circular Footprint Formula, i.e. as two different materials, which in turn means that each related parameters (e.g. emission factor and quality parameters) will be defined for the different waste streams (see Figure A3).
- Update descriptions of the Circular Footprint Formula parameters according to above mentioned points (see Table A6).

Table A6. *Suggested updates of the descriptions of the Circular Footprint Formula parameters (current description from EU (2021), page 49-50).*

Parameter	Current description	Suggestion for updated description
R_1	Proportion of material in the input to the production that has been recycled from a previous system.	Proportion of material in the input to the production that has been recycled from a previous system **(both pre-consumer and post-consumer materials).**
R_2	Proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.	Proportion of the material in the product **or in manufacturing waste** that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.
R_3	Proportion of the material in the product that is used for energy recovery at EoL.	Proportion of the material in the product **or in manufacturing waste** that is used for energy recovery at EoL.
$E_{recyclingEoL}$	Specific emissions and resources consumed (per unit of analysis) arising from the recycling process at EoL, including collection, sorting and transportation process.	Specific emissions and resources consumed (per unit of analysis) arising from the recycling process at EoL **or from the recycling process of manufacturing waste**, including collection, sorting and transportation process.
E_D	Specific emissions and resources consumed (per unit of analysis) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.	Specific emissions and resources consumed (per unit of analysis) arising from disposal of waste material at the EoL **or from the recycling process of manufacturing stage** of the analysed product, without energy recovery.
$\frac{Q_{Sin}}{Q_P}$	Q_{Sin} is the quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution. Q_P is the quality of the primary material, i.e. quality of the virgin material.	Q_{Sin} is the quality of the ingoing secondary material, i.e. the quality of the recycled material **(either pre-consumer or post-consumer)** at the point of substitution. Q_P is the quality of the primary material, i.e. quality of the virgin material.
$\frac{Q_{Sout}}{Q_P}$	Q_{Sout} is the quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.	Q_{Sout} is the quality of the outgoing secondary material, i.e. the quality of the recyclable material **(either pre-consumer or post-consumer)** at the point of substitution.

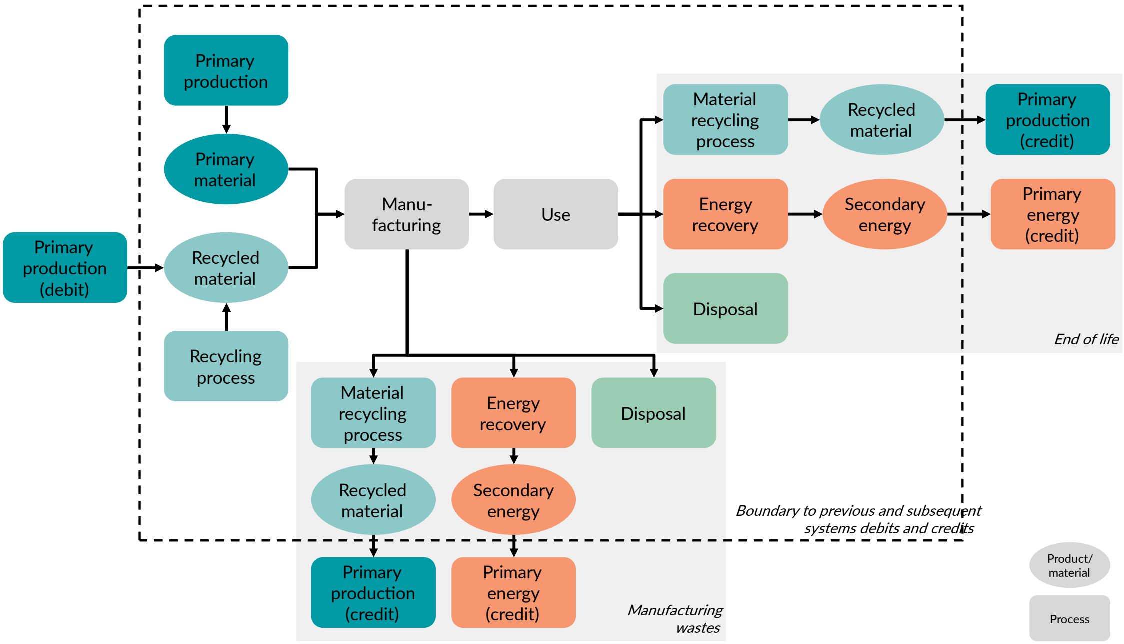


Figure A4. *Example of how the distinction between manufacturing wastes and end-of-life wastes in the Circular Footprint Formula could be visualized (debit = environmental cost, credit = environmental benefit). Figure is based on figure from PEF training material.*

Practical feasability and data availability

The practical implementation of the CFF in an LCA model was tested in the commercial LCA software, LCA for Experts. The CFF was modelled using parameters, a feature that enables the reproducibility of the model by simply changing the values of the parameters. All factors of the CFF as listed in Table A1 were represented by a parameter or an equation in the model. The different parameters and their respective flows were then linked to available datasets in the software that could represent for example the life cycle inventory of primary material production or end of life process etc.

The overall findings from the practical testing were that:

- Modelling the CFF formula in the selected LCA software for the first time was time consuming. Once the model was available, however, it was less time-consuming to add the same calculation for additional materials. It can be also expected that the time for conducting full LCA studies where different impact categories are to be considered is reduced.
- Finding the right datasets was identified as most challenging (see Table A7) and more guidance on how to select emission factors are needed, for example:
  - selecting datasets for the replaced primary material (E_v^*), where finding datasets for e.g. 100% primary steel was difficult since the available primary steel datasets include a share of recycled steel
  - Datasets for alloys was also identified as challenging
- The CFF results differed from using the cut-off approach, where the CFF gave a lower climate impact for the simplified product case due to the credit received from materials sent to recycling at end of life. How the result differs would however depend on materials and case specific parameters, and therefore drawing general conclusions between the allocation methods are difficult, and also not the main goal of this case study.

The data availability was evaluated qualitatively for nine selected materials that were identified as important for the automotive industry (Table A7). The data availability was checked by a screening of databases normally used by the companies, e.g. not a complete review of available data sources nor including the EF database that was not openly available during this case study. There were a variety of datasets available for steel, however as previously mentioned, the share of secondary and primary material included in these datasets were not always clear. For metals like cobalt, copper, nickel etc, there were available datasets for primary materials but not for secondary materials. Plastics were on the other hand better documented and datasets were available for all considered aspects.

It should be noted that the availability of LCI datasets is not only a potential challenge for the CFF, but also when using other methods for handling recycled content and material being sent to recycling, like the simple cut-off approach.

***Table A7**. Data availability where colour codes indicate limited or no data availability (red), medium data availability (orange) or good data availability (green).*

Parameter	Primary material	Secondary material (recycling process)	Energy recovery or disposal
Steel	🟩	🟩	🟧
Aluminum	🟧	🟧	🟧
Copper	🟧	🟩	🟩
Nickel	🟧	🟥	🟩
Lithium	🟧	🟥	🟥
Cobalt	🟧	🟥	🟥
Manganese	🟧	🟥	🟥
Polypropylene (PP)	🟧	🟧	🟧
Polyamide (PA)	🟧	🟧	🟧

4. Conclusions and recommendations

In this case study report, both the possibilities as well as the encountered and foreseen challenges when applying the Circular Footprint Formula within the Swedish automotive industry were described and discussed. The main conclusions and recommendations from the case study were that:

- A benefit with the CFF is the possibility to give incentives for both using recycled materials as input, and that materials leaving the system throughout the whole value chain are recycled. The CFF is thus a useful tool for internal decision-making regarding e.g. material selection.
- It was discussed and agreed that the CFF ideally should reflect and give incentives for using post-consumer materials over pre-consumer materials, since pre-consumer materials can be results of inefficiencies in manufacturing processes. Moreover, pre-consumer materials are generally considered more high-value materials than post-consumer materials, and should therefore in many cases not give the same credit as post-consumer materials (from replacing primary materials), which is not clearly reflected in the formula.
- Also, clearer definitions on how different types of secondary materials should be handled when implementing the CFF are recommended. In particular, clarifications regarding different types of pre-consumer materials are needed.
- In terms of the practical feasability of implementing the CFF, the data availability was identified as most difficult. It was also identified as challenging to ask suppliers to supply data according to the CFF, due to the risk of different interpretations and/or use of data sources resulting in non-comparable results. Therefore, until the CFF becomes mandatory, the cut-off approach will likely be continually used when asking suppliers for data and for publicly shared LCA results.
- Lastly, recommendations from this case study are to clarify guidelines on data selection, ensure compatibility with existing databases and provide open access data for making the PEF and CFF more widely applicable.

Appendix B - Modelling of biogenic carbon following the guidance in the PEF method

Contents

1. Background and aim of the study

This case study is part of the Vinnova funded project Environmental Footprint in Swedish Industry – increased understanding and implementation, which has the overall aim to make businesses, authorities, and the public sector in Sweden aware of product-related policy development based on Environmental Footprint at the EU level. Furthermore, the aim is to make visible and clarify the consequences of proposed methodology choices in Environmental Footprint to better understand what effects an implementation can have in the Swedish industry.

The focus of this study is the modelling of biogenic carbon according to PEF in interlinked product systems and in long living products.
SSAB have set targets to launch fossil-free steel on the market in 2026 and to largely eliminate CO_2 from its own operations. Understanding the modelling of climate change with focus on biogenic carbon following the PEF method, and the resulting climate change results, is relevant to SSAB.

This case study has been conducted during 2023. IVL has led the case study with the active participation of SSAB. Josefin Neuwirth and Erika Kloow have been involved from IVL and Jonas Larsson from SSAB.

Aim of study

The overall aim of this case study is to better understand the consequences of using the PEF methodology to model the climate impact with focus on biogenic carbon in interlinked product systems and long living products.

The specific aims of the case study are to:

- i. Evaluate **data availability** to model the PEF sub-category 'Climate change – biogenic' for the specific products.
- ii. Test and evaluate the feasibility **to model** the PEF sub-category 'Climate change – biogenic' with special focus on use of recycled materials, materials going to recycling and long-living products.
- iii. **Understand consequences** of data availability and climate change modelling on SSABs products.

Working procedure

The working procedure of this study was:

1. Search for guidance related to biogenic carbon modelling in PEF, relevant Product Environmental Footprint Category Rules (PEFCR:s) and other relevant standards.
2. Gain knowledge about SSAB products and their manufacturing processes.
3. Evaluate data availability and collect specific data of the climate change impact (fossil and biogenic) of SSAB's products.
4. Define modelling approaches based on the guidance collected in step 1.
5. Model climate change impact, both fossil and biogenic, according to the defined modelling approaches.
6. Analyse result and understand consequences of the modelling approach for biogenic CO_2 flows.

3. Standards and guidance

Information from standards and guidance related to the modelling of biogenic carbon in interlinked product systems is summarised in this section. The studied key aspects include:

- **Modelling**: any specific guidance related to modelling and reporting of biogenic carbon.
- **Allocation:** any specific guidance on how allocation shall be conducted since both recycled materials and recycling are relevant for the products.
- **Time:** any specific guidance on how to handle the time perspective related to biogenic carbon modelling since steel can be in both short and long-living products.

Product Environmental Footprint Method (the 'PEF method')

Modelling of biogenic carbon

The impact category 'climate change' includes the following three sub-categories in the PEF method:

- Fossil
- Biogenic
- LULUC

The sub-category 'Climate change – biogenic' shall be reported separately if the contribution is more than 5% of the total climate change impact category.

The PEFCR (PEF category rules) shall specify if a 'simplified modelling approach' should be used. A simplified approach means no inclusion of emissions or uptakes of biogenic CO_2 in the study. If a simplified approach is not used, all the biogenic CO_2 flows shall be modelled. However, the characterization factors (CF) for biogenic CO_2 are set to zero within the EF impact assessment method.

'Physical content and allocated content' of biogenic carbon shall be reported as additional information for intermediate products. No definition of 'allocated content' has been found in the PEF nor in PEFCR for intermediate paper.

Allocation

The Circular Footprint Formula (CFF) shall be used to model recycled input and material going to recycling. The CFF is described in detail in this report in the Section 'The Circular Footprint Formula (CFF)'.

There is no specific guidance on how to treat the biogenic carbon content of the material when allocating burdens and credits between product systems.

Time

All emissions and removals shall be considered as emitted 'now'. There is no discounting of emissions over time.

PEFCR metal sheets

Modelling of biogenic carbon

The simplified modelling approach shall be used, meaning that only emissions of biogenic methane are included. No other biogenic emissions and uptakes from the atmosphere are included.

When it comes to reporting of results, the sub-category 'climate change-biogenic' shall not be reported separately from the other sub-categories related to the climate change impact.
The biogenic carbon content of the product (at factory gate) shall be reported as 'additional technical information'. It should include both the physical content and allocated content. There is no definition of how allocated content is defined.

Allocation

The CFF is used to model the end-of-life of product and recycling content of products.

Time

The models shall assume that all emissions take place at the same time, no credits related to delayed emissions shall be considered.

PEFCR intermediate paper

Modelling of biogenic carbon

The PEFCR for intermediate paper contains the same guidance regarding modelling of biogenic carbon as the PEFCR for metal sheets. However, when it comes to reporting of result for the 'climate change-biogenic' the result shall be reported separately from the other sub-categories related to the climate change impact.

Allocation

The PEFCR for intermediate paper contains the same guidance as for the PEFCR for metal sheets.

Time

No specific information on how to handle time is given. The PEFCR is valid for intermediate paper products which means that the product is studied from cradle to gate perspective. This could be a possible reason to why discounting of emissions is not mentioned.

EN 15804: Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products

Modelling of biogenic carbon

Biogenic carbon content of the product shall always reflect the physical flow: the carbon should be treated as a 'material inherent property' and shall not reflect allocated content. The removal of biogenic CO_2 into biomass (i.e. uptake of CO_2) shall be modelled with a characterisation factor of -1 when entering the product system. Emission of biogenic CO_2 from incineration and transfer of biobased products into subsequent product systems shall be modelled with a characterisation factor of +1. This implies that the uptake and emission or transfer into subsequent product systems of biogenic CO_2 are balanced out over the life cycle of the studied product. This also applies for products being stored on for example landfills for more than 100 years, meaning that an emission of biogenic CO_2 shall be reported.

Allocation

For recycled material input (from post-consumer waste) (referred to as secondary material input in EN 15804) the processing (i.e. the recycling process) of the material before being used as input for manufacturing of the process shall be included, but processes that are part of the waste processing in the previous product system shall not be included (i.e. the cut-off method). However, this does not apply for pre-consumer waste where co-product allocation shall be applied (not relevant in this case study and guidance about co-product allocation can be found in EN 15804).

If a product goes to recycling at end-of-life (EoL), the impact from the recycling process shall not be quantified in the studied system (cut-off). However, burdens and benefits beyond the system boundary shall be handled in module D. In module D potential environmental gains from recycling, which is beyond the system boundary, is considered. The environmental burden of the recycling process up to the point where the material is assumed to replace virgin material is studied. This applies not only for material recovery, but also for energy recovery and reuse.

Time

The models shall not include carbon storage and delayed emissions (i.e. discounting emissions and removals). No credits related to delayed emissions shall be considered. It is possible to consider how storage of biogenic carbon would influence the result under additional environmental information.

4. Description of the products

Steel products and the production routes

This case study focuses on evaluating low-alloyed carbon steel over an entire product life cycle. However, the calculations were made for one metric tonne of steel slab, that is a semi-finished casting product. Furthermore, the calculations have been made for steel slabs produced via two different production routes; SSAB Fossil-free™ steel and ordinary scrap-based steel:

- SSAB Fossil-free™ steel
  - Steel production: A unique steel covering the entire value chain based on the HYBRIT Technology with direct reduction of iron ore using fossil-free hydrogen. (i.e., replaces iron ore blast furnace route using coal).
  - Iron carrier: Using fossil-free sponge iron as external input material (only internal scrap from fossil-free steel production).
- Scrap-based steel
  - Steel production: Scrap-based steel production in electric arc furnace.
  - Iron carrier: Using recycled steel scrap.

Below (Figure B1) is an illustration of the two production routes in question and additional information is also given to clarify the main input of carbon into the system, and the system boundary for this case study.

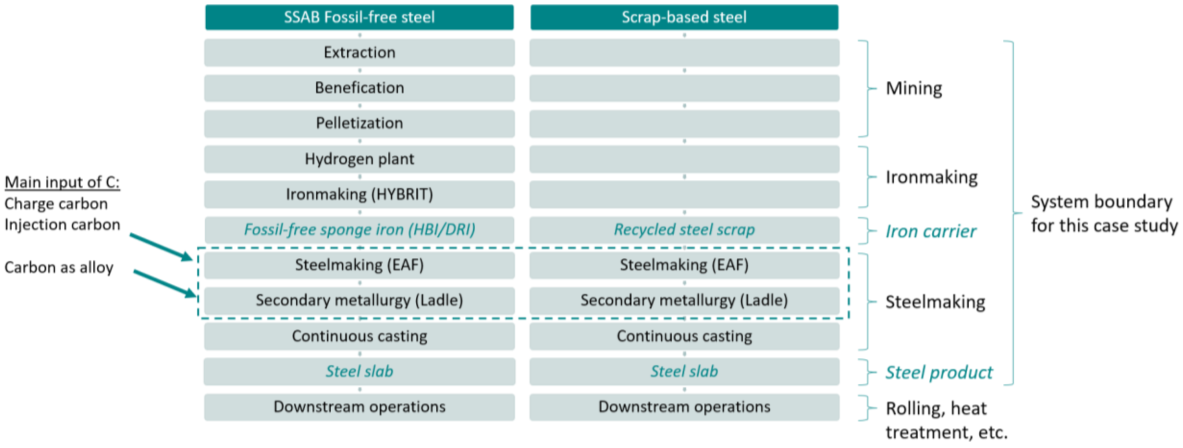


***Figure B1**. Illustration of the two production routes for steel products investigated in this study.*

Carbon sources

In this study we have assumed that all carbon that can be bound in the steel product has been replaced with biogenic carbon. A carbon content of 0.2% in the steel product has been assumed in this study.

Examples of sources for carbon input:

- Charge carbon in the steelmaking (EAF)
- Injection carbon in the steelmaking (EAF)
- Carbon as alloy in the secondary metallurgy (Ladle)
- Graphite electrodes in the steelmaking (EAF), and in the secondary metallurgy (Ladle)

Biogenic carbon in product

The focus of this study was the modelling of biogenic carbon content in the product. Biogenic carbon is derived from biomass (e.g. trees and plants). Biogenic carbon in product is the carbon kept in the product during use. Depending on the lifetime of the product the carbon can be released within a short or a long period of time (see Figure B2).
Biogenic carbon in energy resources was excluded from the scope of this study since the carbon is kept in the energy resources for a short period of time. The biogenic carbon in the energy resource is balanced with the emission at incineration and thus has a net balance of zero.

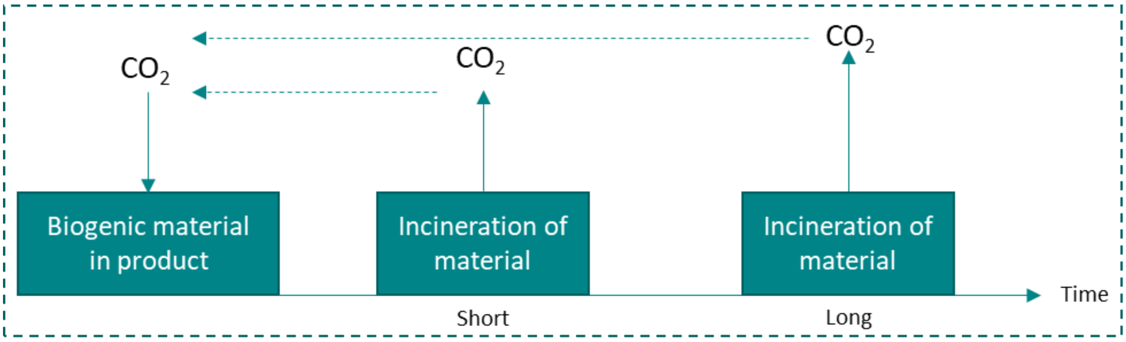


Figure B2. *Cycle of biogenic carbon in short and long-lived products.*

5. Description of analysis

Introduction

A description of the analysis is presented in this chapter. First, the studied systems are described, followed by information about how climate change biogenic and fossil were modelled in the analysis. This is followed by information about how the CFF was applied. Lastly, the data used in the analysis are described.

Studied systems

In the analysis both fossil-free and scrap-based steel were investigated (see Figure B3). As mentioned in the section about the SSAB case study, fossil-free steel is produced from virgin material, while scrap-based steel is produced from recycled material. The steel at end of life (EoL) was modelled as recycled. The modelling of climate change impact biogenic and fossil were conducted on both steel products.

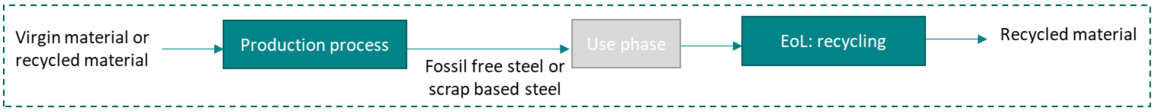


Figure B3. *System boundary of the studied system. The use phase was not included in the study.*

Modelling approaches for climate change – biogenic

The modelling approaches for biogenic carbon (also referred to as 'bio CO_2') are based on the key methodological aspects described in the previous section related to standards and guidance. The scenarios go beyond the guidance in PEF since the PEF states that the simplified modelling approach shall be used, meaning that the result for climate change – biogenic is set to zero. So, in this study we aim to capture the most relevant modelling approaches for biogenic carbon, going beyond the current guidance in the PEF method. The modelling approaches for climate change biogenic are described in the text below and summarised in Table B1.

Table B1. *Biogenic carbon modelling approaches.*

Methodological aspect	**Modelling approach 1: PEF with bio CO_2 CF* set to 0**	**Modelling approach 2: PEF with bio CO_2 CF* -/+1**	**Modelling approach 3: PEF with bio CO_2 CF* -/+1 and bio C content allocated to primary production**	**Modelling approach 4: EN 15804**
Bio C modelling	Yes	Yes	Yes	Yes
Bio CO_2 CF*	0	-/+1	-/+1	-/+1
Allocation	CFF	CFF	CFF	Cut-off
Allocation of bio C in the product	No	No, handled as material inherent property	Yes, the bio C is allocated to the primary production	No, handled as material inherent property
Time	No discounting of emissions over time			

*CF=characterisation factor

Modelling approach 1: PEF with bio CO2 CF set to 0

In the first approach the biogenic CO_2 flows were modelled and the uptake of biogenic CO_2 was balanced with an emission of CO_2. However, the characterisation factor for biogenic CO_2 was set to zero. This is in line with the PEF method. In the CFF the E-parameters ('specific emissions and resources consumed') were set to zero.

Modelling approach 2: PEF with bio CO2 CF -/+1

In the second approach the content of CO_2 was followed through the life cycle of the product, meaning if the carbon is not released an emission of CO_2 was not included. The characterisation factor for an uptake of CO_2 was set to -1 and +1 for an emission. In the CFF, all E-parameters ('specific emissions and resources consumed') were set to the biogenic CO_2 content in the product.

Modelling approach 3: PEF with bio CO2 CF -/+1 and bio C content allocated to primary production

The third scenario is similar to the second scenario, except that the CO_2 content of the steel was attributed to the primary production. This mean that in the CFF the E-parameters related to primary production (*Ev* and *Ev**) were set to the CO_2 content in the product. The E-parameters related to the recycling processes (*Erecycled* and *ErecyclingEoL*) were set to zero.

Modelling approach 4: EN 15804

The last modelling approach was included to understand the differences if using the PEF method or the method according to EN 15804 (used as basis for conducing environmental product declarations (EPD) for construction products). Here an uptake of biogenic CO_2 was reported upstream (both if virgin or recycled material is used) and this was balanced downstream with an emission of CO_2 even though the emission might not occur (e.g. when the product goes to recycling). The CFF was not used in this case.

Modelling approach for climate change – fossil

The focus of this work was on modelling the climate change impact biogenic. However, to understand how to use the CFF and to interpret the results, the climate change fossil was also studied.

There is only one modelling approach included in this case study for climate change fossil. The modelling approaches of climate change biogenic are not relevant for assessing the fossil climate change impact as the method is well defined.

The data used in the modelling is presented in the Section 'Data used in the analysis'. In the scenario different values for the allocation factor (the A factor) were tested in order to understand the dynamics of the CFF allocation formula.

The Circular Footprint Formula (CFF)

One important result from this study is the knowledge created of how to use the Circular Footprint Formula and thus this section summaries how we applied the formula.

According to PEF, the Circular Footprint Formula (CFF) shall be used to model recycled input and recycling at end of life. The formula is a combination of 3 parts (see Equation B1): material (Equation 1) + energy (Equation 2) + disposal (Equation 3).

This study focuses on part one of the CFF: material (Equation 1). Energy recovery and landfill are assumed not to be relevant waste management options for steel.

Equation B1. *CFF formula divided between the three different equations.*

Material: $(1-R1)E_v + R1 \times \left(AE_{recycled} + (1-A)E_v \frac{Qsin}{Qp}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_v^{*} \frac{Qout}{Qp}\right)$ (1)

Energy: $(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$ (2)

Disposal: $(1-R_2-R_3) \times E_D$ (3)

A description of the parameters, in the material part of the formula, is found in Table B2.

Table B2. *Description of the parameters related to the material part in the Circular Footprint Formula.*

Parameter	Description
R1	The proportion of material in the input to the production that has been recycled from a previous system.
R2	Proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.
A	Allocation factor of burdens and credits between supplier and user of recycled materials.
Qsin	Quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.
Qp	Quality of the primary material, i.e. quality of the virgin material.
Qout	Quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.
Ev	Specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.
Erecycled	Specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.
*Ev**	Specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.
ErecyclingEoL	Specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.

To be able to use the CFF one must understand what the different parts of the formula means and where the burden or credits belongs in the life cycle of the studied product. As mentioned before, this is not clearly described in the PEF guidance document or the PEFCR:s. In the PEFCR for metal sheet, separation of the formula into different parts are done for construction products, however there are no information about what the different parts mean. Based on the formula for construction production and discussion with SSAB, the formula was divided into three parts, see Equation 4, 5 and 6.

The first part of the equation, referred to production burdens (see Equation 4), is related to the environmental burden of the virgin material used in the product. The amount of virgin material used is multiplied with the environmental impact of producing the product from virgin material.

Production burdens: $(1-R1)E_v$ (4)

In the second part of the equation, referred to secondary material input (see Equation 5), is related to the environmental burden and credit associated with the use of recycled material in the product.

Secondary material input: $R1 \times \left(AE_{recycled} + (1 - A)E_v \frac{Qsin}{Qp}\right)$ (5)

In the last part of the equation, referred to secondary material output (see Equation 6), is related to the environmental burden and credit associated with recycling of the product at end of life (EoL).

Secondary material output: $(1 - A)R_2 \times (E_{recyclingEoL} - E_v^* \frac{Qout}{Qp)})$ (6)

Data used in the analysis

Data used in the analysis are presented and described in this section. The values applied for the recycling parameters, the allocation factor and the quality factors in the CFF, for all modelling approaches, are presented in Table B3.

Table B3. *Values applied for the recycling parameters, the allocation factor and the quality factors.*

Parameter	Value applied	Comment
R1	0 (100% virgin material input) 1 (100% recycled material input)	The value of 0 is applied in scenario with fossil-free steel and 1 is applied in the scenario with scrap-based steel.
R2	0.9	The default value in PEF for steel is 0.85-0.95
A	0.2	The default value in PEF for steel
Qsin	1	All material is assumed to have similar quality
Qp	1	
Qout	1	

Data for the E-parameters ('specific emission and resources') were provided by SSAB. The collected data reflects the climate change impact of virgin and recycling processes. The values applied for the E-parameters in the modelling of the climate change impact fossil in the fossil-free steel scenario are found in Table B4.

For the fossil-free steel scenario, the following applies:

- *Ev* is the production of virgin steel and reflects the fossil-free steel production.
- *Erecycled* and *ErecyclingEoL* were set to the same value since the processes are the same.
- *Ev** is the production of virgin steel material that is assumed to replace the recycled material. The recycled material was assumed to replace the most common steel on the market (i.e. steel produced in the blast furnace).

Table B4. *Values applied to the E-parameters to model the climate change impact fossil for fossil-free steel. EAF=Electric arc furnace, BF=Blast furnace.*

Parameter	Fossil-free steel (kg CO_2 eq./tonne steel)	Process	Reference
Ev	300	The virgin iron is produced with the HYBRIT technology and further processed in the EAF	SSAB (target value)
Erecycled	600	Recycled steel produced in the EAF	worldsteel
*Ev**	2400	Virgin steel produced in the BF	worldsteel
ErecyclingEoL	600	Recycled steel produced in the EAF	worldsteel

The values applied for the E-parameters (‘specific emissions and resources’) in the modelling of the climate change impact fossil in the fossil-free steel scenario are found in Table B5. For the scrap-based steel scenario, the following applies:

- *Ev* is the production of virgin steel and reflects the most common steel on the market (i.e. steel produced in the blast furnace).
- *Erecycled* and *ErecyclingEoL* was set to same value since the processes are the same.
- *Ev* is assumed to be equal to *Ev** since in this scenario the processes are the same.

Table B5. *Values applied to the E-parameters to model the climate change impact fossil for scrap-based steel. EAF=Electric arc furnace, BF=Blast furnace.*

Parameter	Scrap-based steel (kg CO_2 eq./tonne steel)	Process	Reference
Ev	2400	Virgin steel produced in the BF	worldsteel
Erecycled	600	Recycled steel produced in EAF	worldsteel
*Ev**	2400	Virgin steel produced in the BF	worldsteel
ErecyclingEoL	600	Recycled steel produced in EAF	worldsteel

The values applied for the E-parameters (‘specific emissions and resources’) in the modelling of the climate change impact biogenic are found in Table B6. The values for the E-parameters were applied for both fossil-free steel and recycling steel, meaning that it is assumed that both virgin and recycled steel consist of the same amount of biogenic carbon.

Steel typically contains a small share of carbon, as described in the previous Section ‘4. Description of the products’. The carbon in the steel is in this study assumed to be biogenic.

Table B6. *Values applied to the E-parameters to model the climate change impact biogenic in the different modelling approaches. The same values were applied for fossil-free steel and recycled steel.*

Parameter	Modelling approach 1: PEF	Modelling approach 2: PEF with bio CO2 CF -/+1*	Modelling approach 3: PEF with bio CO2 CF -/+1 and content allocated to primary production*
	(kg CO_2 eq./tonne steel)		
Ev	0	-7.3	-7.3
Erecycled	0	-7.3	0
*Ev**	0	-7.3	-7.3
ErecyclingEoL	0	-7.3	0

*The CO_2content of the product was calculated accordingly: 0.2% assumed carbon content multiplied with 1000 kg steel multiplied with 44 g CO_2/mol and divided with 12 g C/mol.

6. Results

In this chapter, the climate change impact fossil and biogenic results are presented. As mentioned before, the focus of this work was modelling the climate change impact biogenic but in order to understand how to use the CFF and to interpret results, climate change fossil was also studied.

Climate change impact (fossil)

The result of the climate change impact fossil is presented for fossil-free steel and scrap-based steel in Figure B4, Figure B5 and Figure B6. The products are all modelled as recycled at end-of-life. In Figure B4 - Figure B6, the results if varying the allocation factor (A) between 0 and 1 and setting the A factor to 0.2, are presented. Scenarios with an A factor set to 0 and 1 are theoretical calculations since the A factor should be between 0.2 and 0.8, according to the PEF method. For steel products the default A factor is 0.2.

A Factor: 1

In Figure B4 the A factor is set to 1, which reflects the 100:0 approach (i.e. credits are only given to the recycled content). This theoretical scenario represents an allocation methodology similar to the method know as 'cut-off'. Cut-off means that no process beyond the product life cycle is included, meaning that there is no burden (impact) from virgin material allocated to the use of recycled material or any burden or credit from recycling of the product at EoL.

The result for fossil-free steel, which is based on virgin raw material, shows that the product is only burdened with the climate change impact of producing the steel from virgin material (i.e. the E-factor in CFF). For the product scrap-based steel, which is based on recycled material, the burden of the recycling process is put on the product (i.e. the *Erecycled*-factor in CFF).

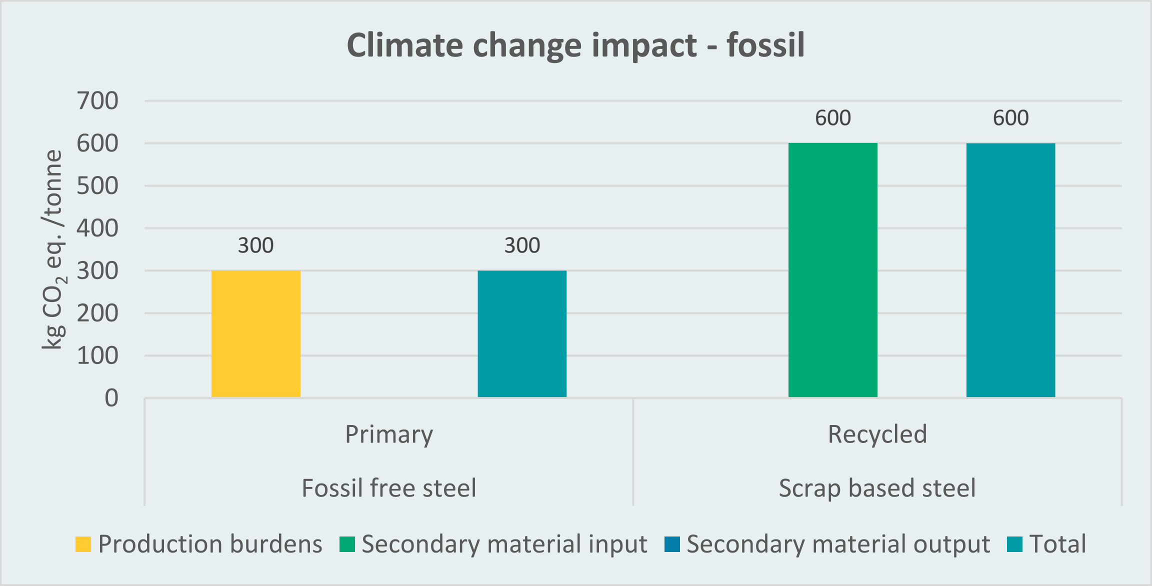


Figure B4. *Climate change impact fossil (kg CO_2 eq per tonne steel) result of using the CFF to allocate burden and credit of recycled content and recycling at EoL in two steel scenarios (fossil-free steel and scrap-based steel). The allocation factor (A) is set to 1. Production burdens are related the environmental burden of the virgin material used in the product. Secondary material input is related to the environmental burden and credit associated with the use of recycled material in the product. Secondary material output is related to the environmental burden and credit associated with recycling of the product at EoL.*

A Factor: 0

In Figure B5, the A factor is set to 0, which reflects the 0:100 approach (i.e. credits are given only to the recyclable material at EoL). In this theoretical scenario the result is similar to the allocation method know as system expansion. System expansion means that processes beyond the product life cycle are included, both upstream and downstream, if recycled material is used in the product and the product goes to recycling at EoL (e.g. scenario scrap-based steel).

The result for fossil-free steel, which is based on virgin raw material, shows that the product is burdened with the climate change impact of producing the steel from virgin material (i.e. the E-factor in CFF) and there is a credit from the recycling at EoL. The credits origin from the recycled material which is assumed to substitute virgin material production. The credit is calculated as impact from the recycling ($ErecyclingEoL \times R2$) minus the impact of producing the recycled material from virgin material ($Ev^{*} \times R2$). The credit is large since the recycled material is assumed to substitute virgin steel production produced in a blast furnace.

In the result for the scrap-based steel, the system expansion both upstream and downstream is visible. The secondary material input is burdened with the entire impact from virgin material production (Ev) since the A factor is set to 0. The climate change impact of virgin steel production in the blast furnace is 2400 kg CO_2 eq. per tonne steel. The credit from recycling at EoL (secondary material output) is the same as for the scenario with fossil-free steel.

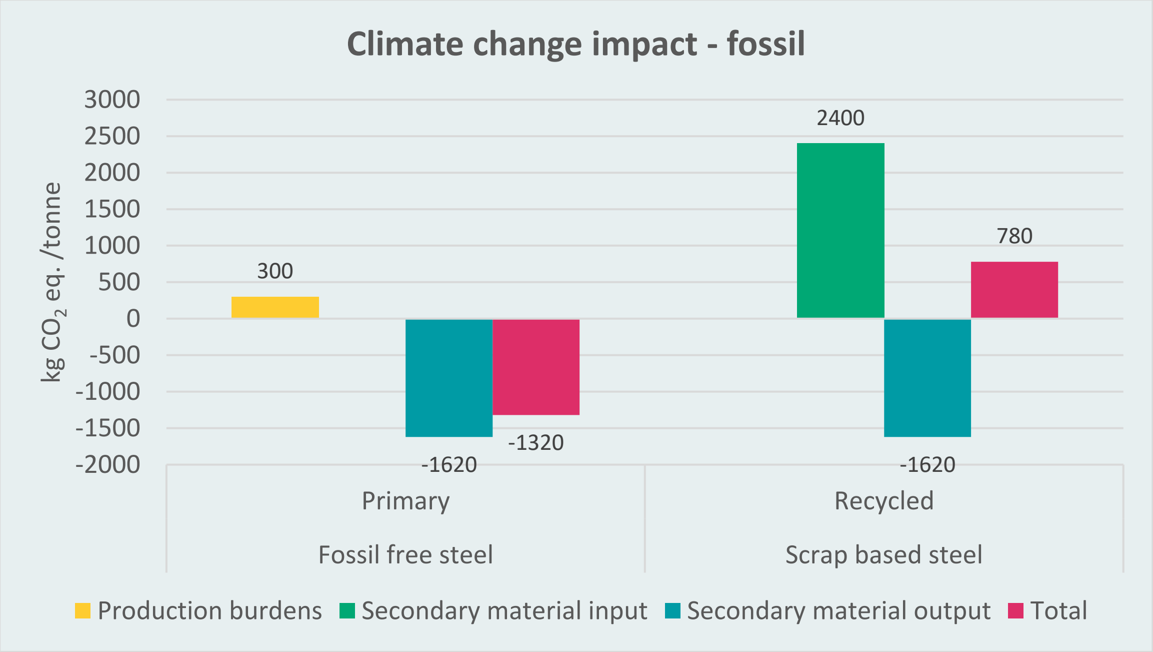


Figure B5. *Climate change impact fossil (kg CO_2 eq per tonne steel) result of using the CFF to allocate burden and credit of recycled content and recycling at EoL in two steel scenarios (fossil-free steel and scrap-based steel). The allocation factor (A) is set to 0. Production burdens are related the environmental burden of the virgin material used in the product. Secondary material input is related to the environmental burden and credit associated with the use of recycled material in the product. Secondary material output is related to the environmental burden and credit associated with recycling of the product at EoL.*

A Factor: 0.2 (default value for steel)

In Figure B6, the A factor is set to 0.2 (default value for steel), which represents a low supply of recyclable materials and a high demand. The CFF with an A factor of 0.2 focuses on recyclability at EoL by rewarding a high recycling rate with a benefit (i.e. through giving a credit).

The result for fossil-free steel, shows similar result as when the A factor is set to 0. However, the credit from recycling at EoL (secondary material output) is slightly lower and this is because the A factor is 0.2 instead of 0. The credit becomes 20% lower (i.e. multiplied with 1-A).

For the scrap-based steel, the secondary material input is burden with some of the impact from virgin material production ($Ev \times R1 \times (1-A)$) and the recycling process ($Erecycled \times R1 \times A$).

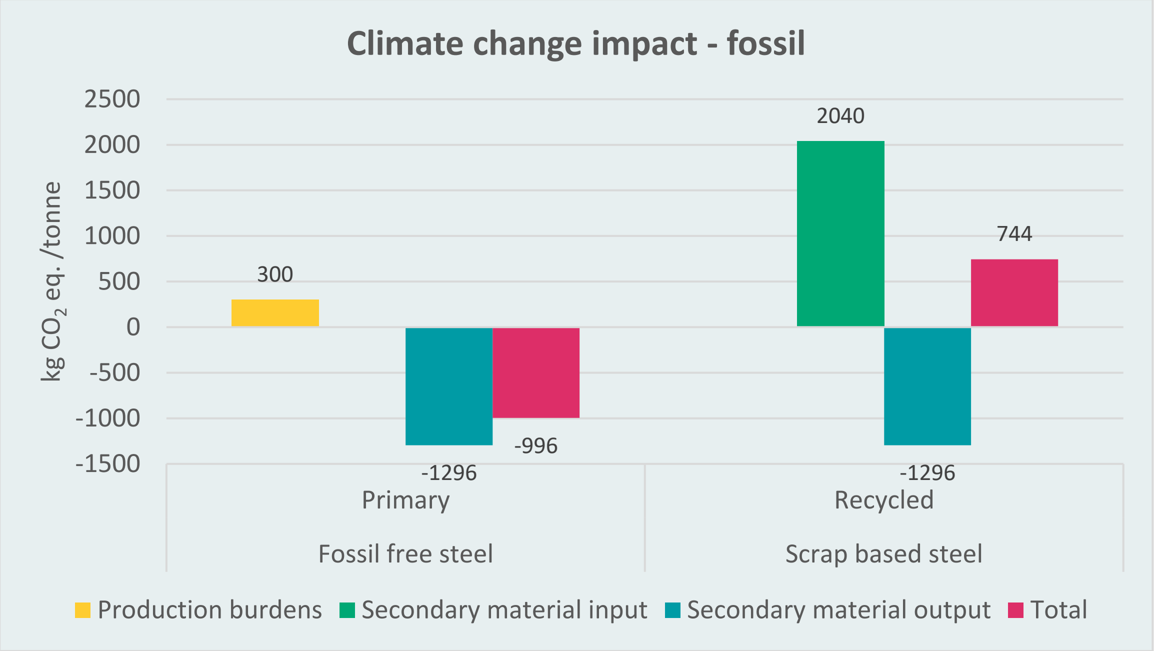


Figure B6. *Climate change impact fossil (kg CO_2 eq per tonne steel) result of using the CFF to allocate burden and credit of recycled content and recycling at EoL in two steel scenarios (fossil-free steel and scrap-based steel). The allocation factor (A) is set to 0.2 (default value for steel products). Production burdens is related the environmental burden of the virgin material used in the product. Secondary material input is related to the environmental burden and credit associated with the use of recycled material in the product. Secondary material output is related to the environmental burden and credit associated with recycling of the product at EoL.*

Climate change impact (biogenic)

Results for climate change impact biogenic are presented in Figure B7, for both fossil-free steel and scrap-based steel, and assuming recycling at EoL. In the figure the result of the biogenic modelling approaches 1-3 are presented. In Figure B8 the result of biogenic modelling approach 4 is presented (based on EN 15804). The different calculations steps of the CFF for climate change impact biogenic for biogenic modelling approach 2-3 are found in Appendix B:1 – CFF calculations. An important highlight of the result is that the climate change impact biogenic is small in comparison with the climate change impact fossil. The reason for this is that the steel product consists of small amounts of biogenic carbon (0.2% assumed in this study).

Modelling approach 1: PEF with bio CO_2 CF set to 0

In Modelling approach 1 all values are 0 and the reason for this is that the E-parameters were all set to zero. The result of this scenario shows that no difference in carbon content is captured between fossil and biogenic material.

Modelling approach 2: PEF with bio CO_2 CF -/+1

In the biogenic carbon modelling approach 2 the total result for fossil-free and scrap-based steel are the same. The value in production burdens for fossil-free steel reflects the biogenic CO_2 content in the product and the value for scrap-based is reflected in the secondary material input. The biogenic CO_2 content reflects the value in the Ev parameter. There is no burden or credit from the difference in impact from virgin material production and recycled material production since the parameters Ev and $Erecycled$ have the same value. The secondary material output is not burdened nor credited since the biogenic CO_2 content is the same in virgin material and for recycled material.

Modelling approach 3: PEF with bio CO_2 CF -/+1 and bio C content allocated to primary production

The result for biogenic modelling approach 3 differs compared to approach 1 and 2. For the fossil-free steel, the value of production burdens is similar to the result in modelling approach 2. However, the secondary material output is burdened with impact since $ErecyclingEoL$ is set to zero and the credit from Ev^* is converted to a positive value (since negative value × negative value). The difference in production burdens and secondary material output is due to the fact that $R2$ is set to 0.9. If the recycled material would replace the same amount of virgin material in the system (i.e. setting $R2$ to 1), the value of secondary material output would be the same as for production burdens and the total value would be 0. Meaning that the biogenic carbon in the system would be in balance.

For the scrap-based scenario the value of secondary material input differs slightly compared to the biogenic CO_2 content of the material. The reason for this is the use of the A factor set to 0.2 making the biogenic CO_2 content of the material 20% lower. The secondary material output is burden with impact of the same reason mentioned for the fossil-free steel. The biogenic carbon in the system would also in this scenario be in balance if the $R2$ parameter was set to 1.

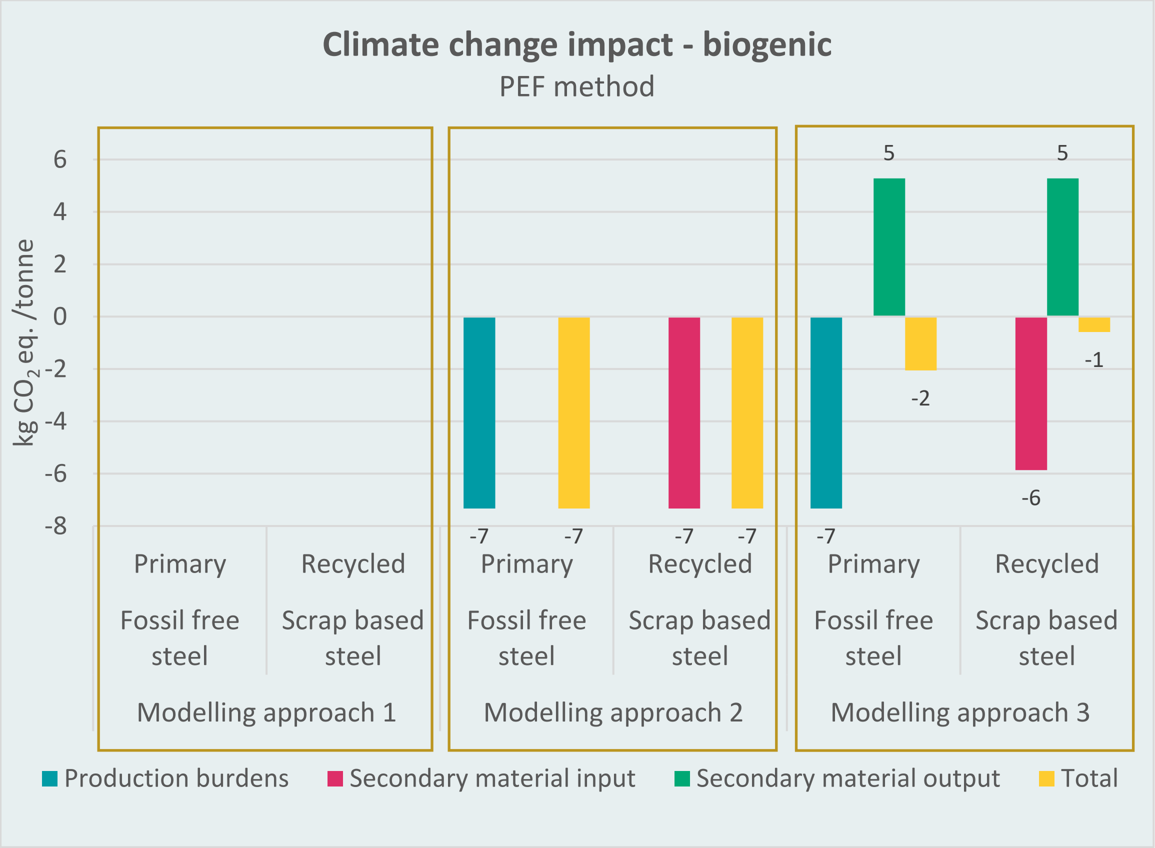


Figure B7. *Climate change impact biogenic (kg CO_2 eq per tonne steel) result of the biogenic modelling approaches 1-3. Modelling approach 1 is referred to as PEF, approach 2 is referred to as PEF with bio CO_2 CF -/+1 and approach 3 is referred to as the PEF with bio CO_2 CF -/+1 and content allocated to primary production. The result is representative for recycling at EoL in two steel scenarios (fossil-free steel and scrap-based steel).*

The allocation factor (A) is set to 0.2 (default value for steel products). Production burdens is related the environmental burden of the virgin material used in the product. Secondary material input is related to the environmental burden and credit associated with the use of recycled material in the product. Secondary material output is related to the environmental burden and credit associated with recycling of the product at EoL.

Modelling approach 4: EN 15804

The result of Modelling approach 4 is presented in Figure B8. The result is presented in a slightly different way compared to the result figures of which the CFF was used. Module A reflects the burden or credit for the upstream and core activities, and it can be seen as same as the production burdens and secondary material input in the CFF. Module D reflects the downstream activities and could be seen as the secondary material output in the CFF. In module A the biogenic CO_2 content of the product shall be reported with a negative value (CF set to -1), and in module C an emission of the biogenic CO_2 shall be reported with a positive value (CF set to +1). In module C the emission of CO_2 is treated as a 'virtual flow' if the product goes to recycling or the carbon is being stored in the product. It is not allowed to consider the effect of biogenic carbon storage according to EN 15804. This implies that the uptake and emission of biogenic CO_2 are balanced out over the life cycle of the product.

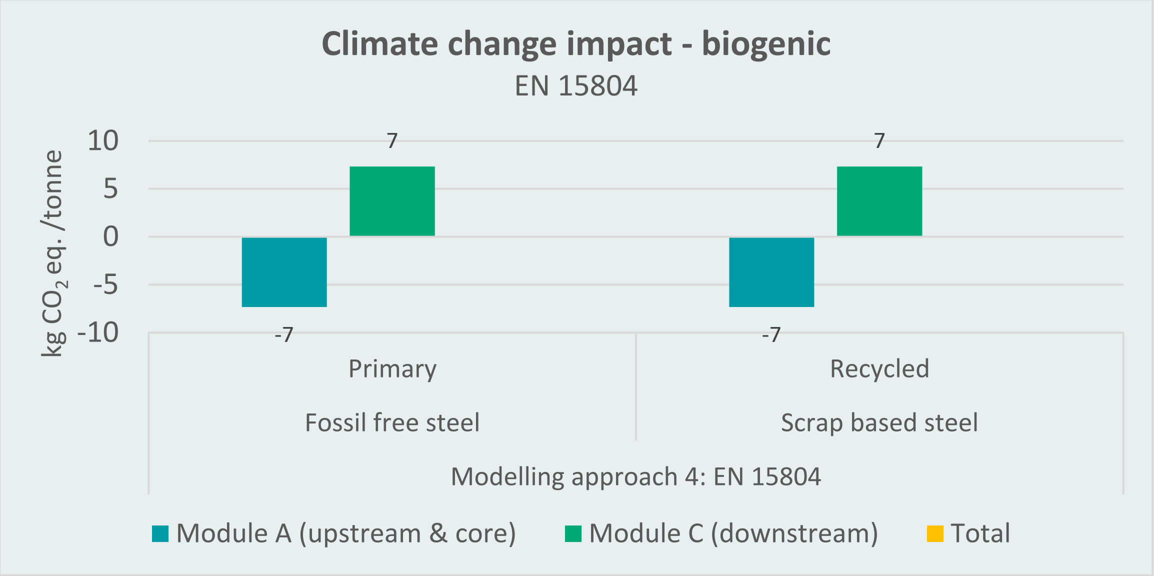


Figure B8. *Climate change impact biogenic (kg CO_2 eq per tonne steel) result of the biogenic Modelling approach 4 (EN 15804). The result is representative for recycling at EoL in two steel scenarios (fossil-free steel and scrap-based steel).*

7. Conclusions

Guidance in the PEF method

This case study shows that specific guidance in the PEF method related to biogenic carbon modelling and the modelling of long-living products is missing. This is further described in the sections and in the summary of the modelling approaches below.

Modelling of biogenic carbon content

It is not defined in the PEF method how the biogenic carbon content of the material should be allocated between interlinked product systems. For example, it is not clear whether the uptake of biogenic carbon in the material should be allocated to the primary product or if it should be sectioned as a material inherent property. For products made of renewable resources this can have a large impact.

Guidance in PEF versus PEFCR:s

There are two approaches available in PEF for modelling biogenic CO_2: ‘the simplified approach’ (which means no modelling) and the modelling of biogenic CO_2. According to PEF, the modelling approach is defined in the PEFCR. This means that for some product categories there could be no requirement to model biogenic CO_2. To date, this choice is not so visible as the characterisation factor for biogenic CO_2 is set to zero. However, the expectations to also report biogenic CO_2 are increasing which makes the simplified approach insufficient. Also, as a consequence of leaving the choice open in the PEFCR on how to model the biogenic carbon, products from different product categories might treat biogenic CO_2 in different ways.

Guidance on time

According to the PEF method, emissions cannot be discounted over time so all emissions and removals should be modelled as ‘emitted now’. Therefore, it is not possible to capture differences in the modelling for long-living versus short-living products.

Summary of conclusions from the specific modelling approaches

Modelling approach 1: PEF	✓ No difference in carbon content is captured between fossil and biogenic material
Modelling approach 2: PEF with bio CO_2 CF -/+1	✓ Differs to the current PEF method as the CF is -/+1 instead of zero ✓ Difference in carbon content is captured between fossil and biogenic material ✓ Difficult to understand how to handle the result for short and long-lived products
Modelling approach 3: PEF with bio CO_2 CF -/+1 and bio C content allocated to primary production	✓ Differs to the current PEF method as the CF is +/-1 instead of zero Difference between primary and secondary input is shown in the results (A-factor makes secondary input lower compared the carbon content in product since 20% is subtracted) ✓ Difficult to understand the result since it does not reflect the carbon content of the product nor is the carbon balanced over the product life cycle

Modelling approach 4: EN 15804 modelling approach	✓ No difference in carbon content is captured between fossil and biogenic material. The biogenic carbon in the material is treated as an 'material inherent property' and no allocation of this flow is done ✓ Details regarding the product being a carbon sink can be given in additional environmental information

Guidance and standards not harmonized

As the result highlighted, the guidance in PEF and the standard EN 15804 is not harmonized which can lead to different results. One difference between PEF (Modelling approach 1) and EN 15804 (Modelling approach 4) is that PEF does not showcase the biogenic carbon in the material in the result for climate change biogenic. Another conclusion from the result, when comparing Modelling approaches 2-3 with approach 4, is that the choice of allocation for recycled material input and recycling at EoL leads to different results. As for now, there is no clear guidance in PEF on how to allocate the biogenic carbon content in product. However, this is defined in EN 15804, where the biogenic carbon shall be treated as a material inherent property and there should not be any allocation between product systems.

Circular Footprint Formula

During this study several challenges related to the use of the CFF were identified. One of the challenges is related to the complexity of the CFF: it is difficult to understand the formula and the structure of the equations, and there is a lack of explanation within the PEF method. Quite some time was spent analysing the formula before applying it in this case study.

Another identified challenge is related to the applicability of the CFF and how it should be used according to 'best practices'. In the PEF method it is clearly stated that the CFF shall be used to model recycled input and product going to recycling, but no guidance is given on which part of the equation that is related to recycled input and product going to recycling at EoL. There is also a challenge to populate all parameters in the CFF with appropriate values since the definition leaves room for interpretation. This is for example relevant for the emissions parameters (E-values) and the quantity parameters (Q).

The last identified challenge is related to the interpretation of the result when the CFF has been applied. As an example, if you have a system with both recycled material input and product going to recycling the CFF adds all burdens and credits into one single number. To make an appropriate interpretation of the result and to conduct a dominance analysis (i.e. identify hot-spots) the result must be divided into the different life cycle stages and/or activities. In the PEF method there is no guidance on how to divide the CFF into the different life cycle stages (i.e. upstream, core and downstream). More guidance is available in the PEFCR for metal sheets, where the CFF has been divided into different parts for construction products. However, there is no information in the PEFCR about what the parts mean and where in the lifecycle the burdens and benefits belong and how the result should be presented.

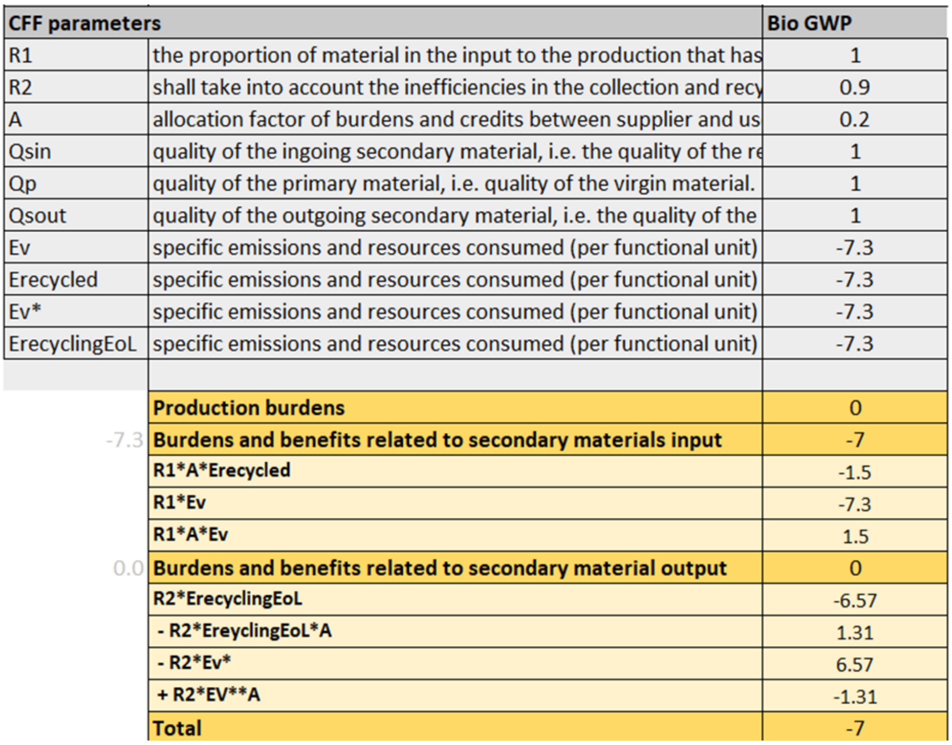
To meet all these challenges is time consuming and users of the PEF method would benefit from more detailed explanations in the PEF guidance.

Consequences for SSAB and other companies

Several challenges have been identified in this case study when it comes to the interpretation of the PEF method and the modelling of interlinked product systems. These are challenges that could affect any company with the ambition to use the PEF method, including SSAB.

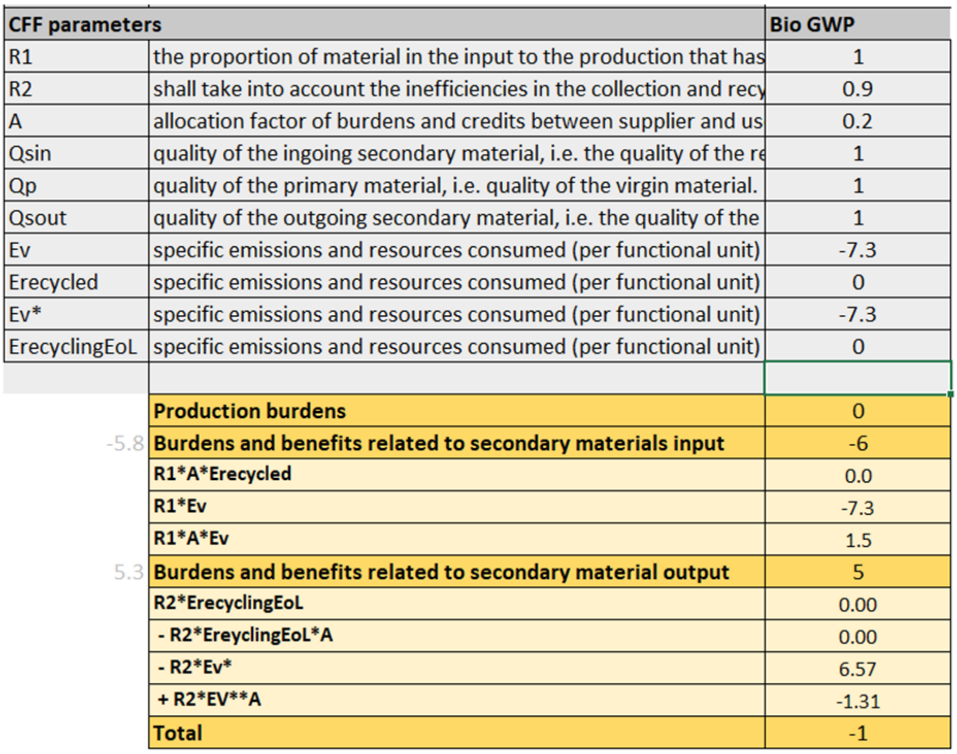
Appendix B:1 – CFF calculations from biogenic carbon case study

Table B7. *Biogenic carbon Modelling approach 2, scrap-based steel and recycling at EoL.*



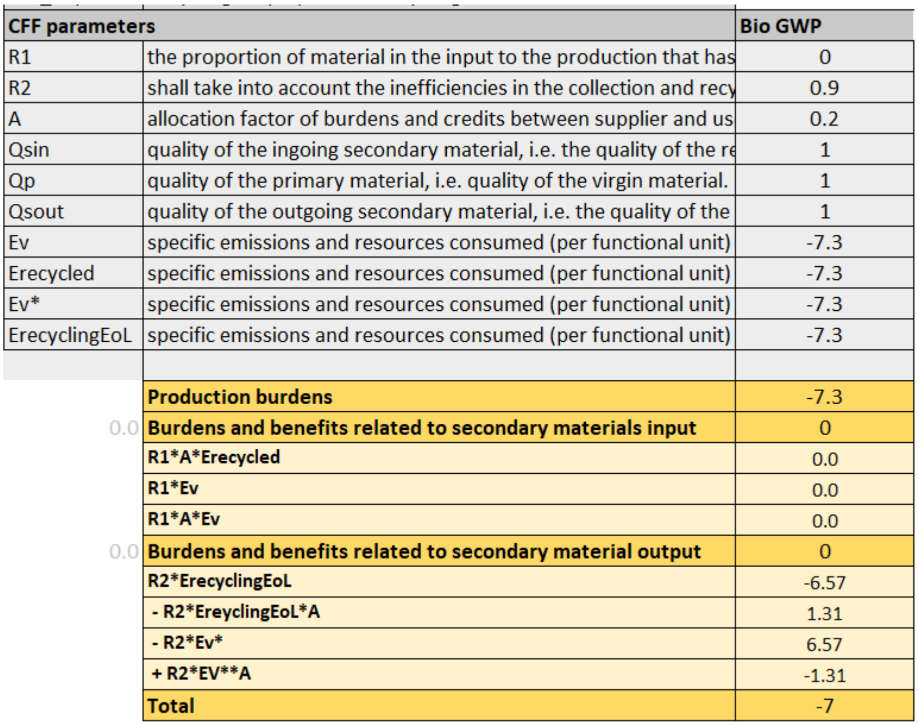
CFF parameters		**Bio GWP**
R1	the proportion of material in the input to the production that has	1
R2	shall take into account the inefficiencies in the collection and recy	0.9
A	allocation factor of burdens and credits between supplier and us	0.2
Qsin	quality of the ingoing secondary material, i.e. the quality of the re	1
Qp	quality of the primary material, i.e. quality of the virgin material.	1
Qsout	quality of the outgoing secondary material, i.e. the quality of the	1
Ev	specific emissions and resources consumed (per functional unit)	-7.3
Erecycled	specific emissions and resources consumed (per functional unit)	-7.3
Ev*	specific emissions and resources consumed (per functional unit)	-7.3
ErecyclingEoL	specific emissions and resources consumed (per functional unit)	-7.3
	Production burdens	0
-7.3	**Burdens and benefits related to secondary materials input**	-7
	R1*A*Erecycled	-1.5
	R1*Ev	-7.3
	R1*A*Ev	1.5
0.0	**Burdens and benefits related to secondary material output**	0
	R2*ErecyclingEoL	-6.57
	- R2*EreyclingEoL*A	1.31
	- R2*Ev*	6.57
	+ R2*EVA**	-1.31
	Total	-7

Table B8. *Biogenic carbon Modelling approach 3, scrap-based steel and recycling at EoL.*



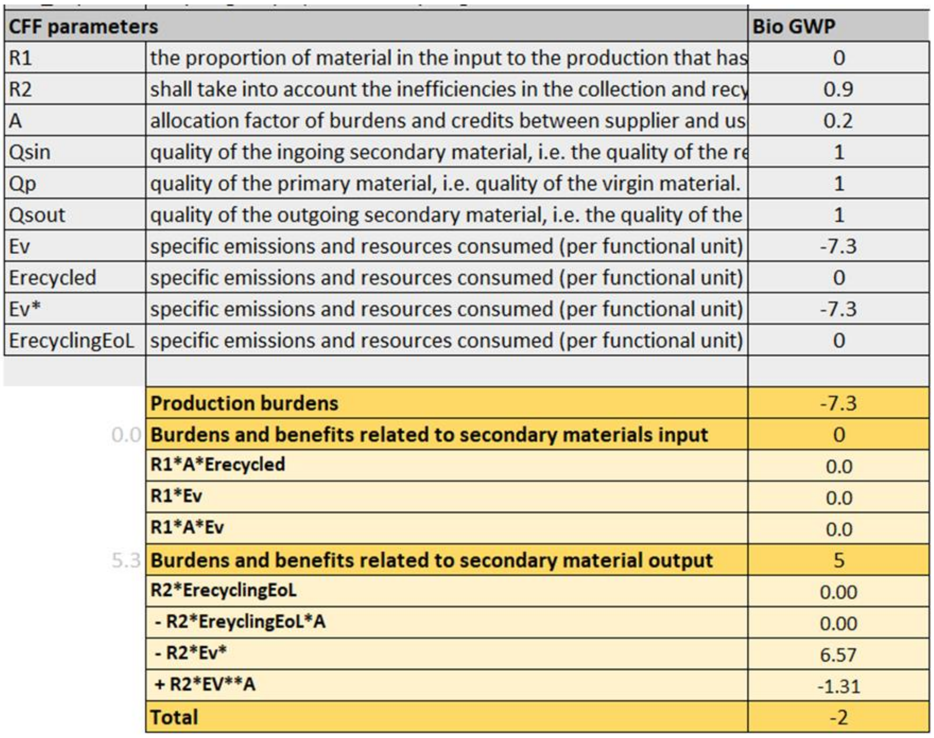
CFF parameters		**Bio GWP**
R1	the proportion of material in the input to the production that has	1
R2	shall take into account the inefficiencies in the collection and recy	0.9
A	allocation factor of burdens and credits between supplier and us	0.2
Qsin	quality of the ingoing secondary material, i.e. the quality of the re	1
Qp	quality of the primary material, i.e. quality of the virgin material.	1
Qsout	quality of the outgoing secondary material, i.e. the quality of the	1
Ev	specific emissions and resources consumed (per functional unit)	-7.3
Erecycled	specific emissions and resources consumed (per functional unit)	0
Ev*	specific emissions and resources consumed (per functional unit)	-7.3
ErecyclingEoL	specific emissions and resources consumed (per functional unit)	0
	Production burdens	0
-5.8	**Burdens and benefits related to secondary materials input**	-6
	R1*A*Erecycled	0.0
	R1*Ev	-7.3
	R1*A*Ev	1.5
5.3	**Burdens and benefits related to secondary material output**	5
	R2*ErecyclingEoL	0.00
	- R2*EreyclingEoL*A	0.00
	- R2*Ev*	6.57
	+ R2*EVA**	-1.31
	Total	-1

Table B9. *Biogenic carbon Modelling approach 2, fossil-free steel and recycling at EoL.*



CFF parameters		Bio GWP
R1	the proportion of material in the input to the production that has	0
R2	shall take into account the inefficiencies in the collection and recy	0.9
A	allocation factor of burdens and credits between supplier and us	0.2
Qsin	quality of the ingoing secondary material, i.e. the quality of the re	1
Qp	quality of the primary material, i.e. quality of the virgin material.	1
Qsout	quality of the outgoing secondary material, i.e. the quality of the	1
Ev	specific emissions and resources consumed (per functional unit)	-7.3
Erecycled	specific emissions and resources consumed (per functional unit)	-7.3
Ev*	specific emissions and resources consumed (per functional unit)	-7.3
ErecyclingEoL	specific emissions and resources consumed (per functional unit)	-7.3
	Production burdens	-7.3
0.0	**Burdens and benefits related to secondary materials input**	0
	R1*A*Erecycled	0.0
	R1*Ev	0.0
	R1*A*Ev	0.0
0.0	**Burdens and benefits related to secondary material output**	0
	R2*ErecyclingEoL	-6.57
	- R2*EreyclingEoL*A	1.31
	- R2*Ev*	6.57
	+ R2*EVA**	-1.31
	Total	-7

Table B10. *Biogenic carbon Modelling approach 3, fossil-free steel and recycling at EoL.*



CFF parameters		Bio GWP
R1	the proportion of material in the input to the production that has	0
R2	shall take into account the inefficiencies in the collection and recy	0.9
A	allocation factor of burdens and credits between supplier and us	0.2
Qsin	quality of the ingoing secondary material, i.e. the quality of the re	1
Qp	quality of the primary material, i.e. quality of the virgin material.	1
Qsout	quality of the outgoing secondary material, i.e. the quality of the	1
Ev	specific emissions and resources consumed (per functional unit)	-7.3
Erecycled	specific emissions and resources consumed (per functional unit)	0
Ev*	specific emissions and resources consumed (per functional unit)	-7.3
ErecyclingEoL	specific emissions and resources consumed (per functional unit)	0
	Production burdens	-7.3
0.0	**Burdens and benefits related to secondary materials input**	0
	R1*A*Erecycled	0.0
	R1*Ev	0.0
	R1*A*Ev	0.0
5.3	**Burdens and benefits related to secondary material output**	5
	R2*ErecyclingEoL	0.00
	- R2*EreyclingEoL*A	0.00
	- R2*Ev*	6.57
	+ R2*EVA**	-1.31
	Total	-2

SWEDISH
LIFE CYCLE
CENTER

Chalmers University of Technology
SE – 412 96 Göteborg
Vera Sandbergs Allé 8
+46 (0)31-772 56 40
lifecyclecenter@chalmers.se
www.lifecyclecenter.se