Proba World BV
Laan van Kronenburg 14
1183 AS Amstelveen
The Netherlands

Methodology

Use of low-carbon building materials to transition to low-carbon construction

Replacing conventional building products with low-carbon alternatives in construction projects

[25 March 2025]

Methodology ID	PM.0003
Version	0.95 for public consultation
Type	New Methodology
Developer/co-developer	Proba World BV
Contact Information	methodologies@proba.earth

Table of contents

Summary

This methodology document outlines the systematic set of procedures and criteria for quantifying, monitoring, and verifying greenhouse gas emissions reductions achieved by adopting low-carbon building products in construction, thereby transitioning to more sustainable practices within the construction sector. Two types of credits can be generated through this methodology:

- GHG reduction credits resulting from switching from conventional high-emission building products to low-carbon alternatives
- Carbon removal credits resulting from the carbon stored in biobased building products.

The document provides equations to calculate both types of interventions, ensuring a transparent and standardized approach. It further includes guidance on evaluating topics such as additionality, risks, and co-benefits, offering a comprehensive framework to support sustainable and effective project implementation.

This methodology has been developed in accordance with the “Proba Standard”[1] and will be periodically reviewed and updated to align with the latest scientific consensus and regulatory requirements. This includes initiatives such as the European Parliament’s ongoing “Carbon Removals and Carbon Farming” framework (CRCF)[2]. Further details on the review and update process can be found in the “Methodology Approval and Development Process”[3] document.

To use this methodology document, Project Developers should follow the outlined procedures step-by-step, ensuring all data for GHGs emission calculation are accurately collected and reported.

[1] https://proba.earth/hubfs/Product/The_Proba_standard.pdf

[2] The European Parliament is actively working to establish a standardized, transparent, and credible framework for certifying carbon removals https://climate.ec.europa.eu/eu-action/carbon-removals-and-carbon-farming_en

[3] https://proba.earth/hubfs/Downloads/Methodology_approval_and_development.pdf

List of definitions

Additionality	Additionality refers to the concept that any carbon removal or reduction Project should result in greenhouse gas emissions reductions that would not have occurred without the Project. In other words, the Project's positive impact on reducing emissions should be "additional" to what would have happened under the business-as-usual scenario.
Baseline Scenario	Hypothetical reference case and related GHG emission sources, sinks and reservoirs that best represents the conditions most likely to occur in the absence of a proposed GHG Project.
Biogenic carbon	Biogenic carbon refers to the carbon that is absorbed by plants from the atmosphere during photosynthesis and subsequently stored in biomass.
Biomass crops	These are crops specifically grown for energy production or as raw materials for various industrial uses, not primarily for food consumption. In the context of GHG projects, biomass crops contribute to biogenic carbon sequestration.
Buffer Pool	A Buffer Pool is a reserve of Carbon Credits established to cover potential losses in GHG Projects, ensuring the integrity of emissions reductions or removals over time. The size of the Buffer Pool is aligned with the level of (reversal) risks associated with the GHG Project.
Carbon Dioxide equivalent - CO_2e	A metric used to compare the emissions of various greenhouse gasses based on their Global Warming Potential (GWP). It expresses the impact of different gasses in terms of the equivalent amount of CO_2, facilitating a standardized approach to assessing overall greenhouse gas emissions.
Carbon credit	A Carbon credit represents at least 1 tonne of CO_2 (tCO_2), or 1 tonne of CO_2e (tCO_2e) reduced or removed for a certain period of time. One tonne (metric ton) (t) equals 1000 kg. For carbon equivalency, Proba uses the AR-5 assessment from UNFCCC.
Product Carbon Footprint(PCF)	Sum of GHG emissions and GHG removals in a product system , expressed as CO2 equivalents and based on a life cycle assessment using the single impact category of climate change
Climate change impact category	This category accounts for the release of GHGs, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), over the entire

	lifecycle of a product or process. The impact is typically measured in terms of CO_2-equivalents (CO_2-eq), which standardizes the warming potential of different gases relative to CO_2. In the context of Life Cycle Assessments (LCAs) and Carbon Footprint Reports (PCFs), this category specifically focuses on the emissions and sequestration of GHGs, emphasizing the product's role in either contributing to or mitigating climate change.
Conservativeness	Use of conservative assumptions, values, Methodologies, and procedures to ensure that GHG emission reductions or removal enhancements are not over-estimated.
Crediting Period	The "Crediting Period" refers to the specific duration of time during which a GHG Project is eligible to generate and issue Carbon Credits for the GHG emissions it reduces or removes. This period is predefined and ensures that the project's emissions impact is monitored, verified, and Credited only within that set timeframe. A Crediting Period can be renewed once or multiple times.
Emission Factors	Emission factors are coefficients that quantify the amount of greenhouse gasses released into the atmosphere per unit of activity, substance, or process. They are essential tools in calculating emissions based on fuel consumption, industrial processes, or agricultural practices, facilitating the estimation of a project's total greenhouse gas emissions.
EPD	EPD stands for Environmental Product Declaration. EPDs are standardized documents that report the environmental impact of products based on predefined categories, making them invaluable for transparently communicating the environmental performance of building materials.
FAO	The Food and Agriculture Organization is a UN agency leading international efforts to defeat hunger, improve agriculture, and ensure food security. FAO offers essential guidance and data on forestry through its publications, contributing significantly to global knowledge on sustainable forest management and conservation.
GWP	Global Warming Potential, a metric that measures the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of carbon dioxide (CO_2). GWP is calculated over a specific time period, typically 100 years, providing a common scale for comparing the climate impact of different gasses.

GHG Project	Activity or activities that alter the conditions of a GHG Baseline and which cause GHG emission reductions or GHG removal enhancements. The intent of a GHG Project is to convert the GHG impact into Carbon Credits.
GHG Protocol	GHG Protocol establishes comprehensive global standardized frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions.
IPCC	The Intergovernmental Panel on Climate Change is a United Nations body, assessing science related to climate change to provide policymakers with regular scientific updates.
Life cycle assessment (LCA)	A life cycle assessment (LCA) is a systematic methodology that considers all stages of a product's life, from the extraction of raw materials to production, transportation, use and disposal. This methodology employs a cradle-to-grave approach, covering **Cradle-to-Gate**: From raw material supply to the manufacturing of building products **Gate-to-Grave**: From the transportation of products to the construction site, through the use phase, and finally, end-of-life disposal or recycling. **Cradle-to-gate + scenario-based use/end-of-life**: Hybrid life cycle assessment (LCA) approach used to evaluate the environmental impact of a product from raw material extraction to the point of sale, while incorporating modeled estimations for downstream impacts.
Life Cycle Inventory (LCI)	Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle
Life cycle impact assessment (LCIA)	Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product
Leakage	Leakage refers to the unintended increase in greenhouse gas emissions outside the Project Boundaries as a direct result of the project's activities.
Monitoring	The systematic observation and recording of parameters or conditions over time. In short rotation forestry projects, monitoring involves tracking tree growth, health, and other ecological factors to evaluate carbon sequestration effectiveness and overall forest health.

Permanence	Permanence refers to the duration over which carbon reductions or removals are maintained without being reversed. It reflects the expected time period during which the carbon sequestered or emissions reduced by a project will remain out of the atmosphere. This concept is crucial for reliable long-term carbon accounting and effective climate impact mitigation, ensuring that the benefits of a GHG project are sustained over time and contribute meaningfully to environmental goals.
Uncertainty	Uncertainty refers to the degree of doubt associated with the estimation of GHG emissions, removals, or reductions. It encompasses the potential variability in measurements, calculations, and assumptions used in the project, impacting the accuracy and reliability of the reported GHG benefits.

List of abbreviations

CO_2e	Carbon dioxide equivalents
PCF	Product Carbon Footprint
GHG	Greenhouse gasses
EPD	Environmental Product Declaration
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
MRV	Monitoring, Reporting, and Verification
POD	Project Overview Document
VVB	Validation and Verification Body

1 Introduction

1.1. Background

The construction sector is a significant contributor to global greenhouse gas emissions, with the production of building materials such as steel, cement, and aluminum accounting for approximately 11% of embodied emissions[4]. These emissions stem from the lifecycle processes of raw material extraction, manufacturing, and transportation. Concrete and steel productions in particular are responsible for a large share of global emissions. The IPCC's Sixth Assessment Report states that global GHG emissions from buildings were in 2019 at 12 GtCO2-eq, equivalent to 21% of global GHG emissions that year, out of which 57% were indirect emissions from offsite generation of electricity and heat, 24% direct emissions produced onsite and 18% were embodied emissions from the use of cement and steel[5]. Cement and steel, along with materials such as bricks, blocks, stone, and sand are the most widely used construction materials worldwide[6]. Reducing embodied emissions in construction requires a shift towards more sustainable building products, materials and construction practices. Low-carbon building products are made using sustainable practices, including the utilization of renewable resources, energy-efficient manufacturing processes, recycled materials, and biobased components. Compared to the commonly used products, they generally have lower embodied GHG emissions.

1.2. Interventions

To apply this methodology, projects must focus on replacing commonly used building products in construction projects with alternative building products that exhibit a lower carbon footprint throughout their lifecycle. The replacement generates two distinct carbon benefits (if possible), both of which are quantified through the methodology:

- **GHG emission reductions**: Achieved by replacing high-emission materials with low-carbon alternatives, leading to lower GHG emissions throughout the product lifecycle
- **Carbon removals**: Realized through the use of biobased products that incorporate biogenic carbon, enabling long-term storage of carbon within the building products

[4] https://wedocs.unep.org/handle/20.500.11822/43293
[5] https://edepot.wur.nl/640116
[6] https://doi.org/10.1016/j.enbuild.2020.110612

This methodology evaluates and calculates the GHG impact resulting from the substitution of commonly used building products. The calculations are based on the carbon footprints of the building products. A product's carbon footprint (PCF) includes all related emissions and carbon sequestration throughout its lifecycle, including raw material extraction, production, manufacture, usage, and end-of-life scenarios.

The calculation of the impact will be based on a PCF/LCA comparison analysis and will utilize the **cradle-to-gate + scenario-based use/end-of-life** assessment of commonly used products as a baseline for comparison with low carbon alternatives.

The Project Developer is responsible for implementing the project and applying this methodology in accordance with the provided guidelines. Additionally, the Project Developer must prepare a Project Overview Document (POD) that outlines the project's scope, objectives, methodology application, and key assumptions. The role of **the Project Developer** can be taken by:

- A low-carbon building product manufacturer
- A constructor responsible for technical choices, design, and project oversight
- A real estate developer managing property development with a sustainability focus
- A cooperative or NGO operating in the agriculture or construction sector
- An environmental NGO or sustainability consultant guiding and supporting project implementation
- A municipal or government agency undertaking sustainable construction initiatives

1.3. Standard compliance

This methodology aligns with internationally recognized standards that provide frameworks for quantifying both project-level emissions and the carbon footprints of products. In order to perform accurate calculations, it is mandatory for Project Developers to provide comprehensive PCF reports for both the project's product and the baseline alternatives.

- **ISO 14067**[7]: Focuses on the product carbon footprint (PCF)[8], providing principles and guidelines for quantifying and reporting GHG emissions. A PCF is a type of Life Cycle Assessment (LCA) that specifically focuses on the climate change impact category, addressing GHG emissions and carbon sequestration potential, expressed in kilograms of CO_2 equivalents (kg CO_2-eq). It

[7] https://www.iso.org/standard/71206.html#lifecycle

[8] The term CFP (carbon footprint of product) is used in the ISO 14067 document. However, in this methodology the PCF term is used

emphasizes the use of consistent functional units and adherence to standardized LCA methodologies such as ISO 14040[9] and ISO 14044[10]. This ensures comparability between low-carbon building products and baseline materials by maintaining uniformity in system boundaries, data quality, and impact assessment methods. Compliance guarantees a scientifically robust and transparent evaluation of product-level carbon impacts.

- **EN 15804**[11]: A European standard tailored to the construction sector, specifying LCA requirements and environmental impact categories for building materials. Environmental Product Declarations (EPDs) developed under EN 15804 are recommended as key inputs for quantifying GHG reductions or removals in this methodology. The applicability and details of EPDs are further presented in sub-chapter 9.2.
- This methodology will be regularly updated to reflect new developments and standards, for instance in alignment with the methodology development standards under EU's Carbon Removal and Carbon farming certification framework (CRCF)[12].

1.4. Applicability

This methodology has been developed in accordance with the Proba Standard, ensuring that all guidelines, principles, and requirements outlined in the standard are fully adhered to. Users of this methodology are expected to follow the Proba Standard to ensure consistency, credibility, and compliance with the broader framework established by Proba.

Project types and scale:

- The methodology can be applied to new constructions and renovation projects of existing constructions
- The methodology can be applied to both small-scale and large-scale construction projects

Project's objective:

- Projects must aim to replace commonly used (carbon intensive) building products with low-carbon building products to significantly reduce the overall carbon footprint of a construction project.

Geographical boundaries:

[9] https://www.iso.org/standard/37456.html
[10] https://www.iso.org/standard/38498.html
[11] https://eplca.jrc.ec.europa.eu/LCDN/EN15804.html
[12] https://climate.ec.europa.eu/eu-action/carbon-removals-and-carbon-farming_en

- Applicability of this methodology, in terms of geographical boundaries, is not limited to a specific country or region.

1.5. Eligible products

Projects to be eligible to use this methodology must focus on the usage of building products that demonstrate a lower product carbon footprint compared to the commonly used products equivalents.

1.5.1 Eligible products

1) **Biobased products[13]:** These are products derived from plant-based materials like fiber and biomass crops, as well as short-rotation forestry products (timber/lumber). These materials offer significant climate benefits by optimizing their natural ability to store biogenic carbon. This carbon, absorbed during the growth phase of the biomass, remains sequestered throughout the lifecycle of the product, thus keeping CO_2 out of the atmosphere. Eligible biobased products must belong to one of the two below categories:
    - Middle-cycle products (lifespan > 35 years)[14]: These products can demonstrate an extended lifespan. The CO_2 that is stored in it is preserved for at least 35 years (e.g. insulation products, such as wall insulation, roof insulation, etc)
    - Long-cycle products (lifespan > 100 years): These products can demonstrate an extended lifespan. The CO_2 that is stored in it is preserved for at least 100 years (e.g. biobased concrete, etc)[15]

Note: Products that are not entirely biobased but incorporate a proportion of biobased materials in their final composition are also eligible under this methodology. For example, biobased concrete, which integrates hempcrete (a mixture of hemp fibers and lime).

2) **Recycled material products:** These products are made out of recycled materials. Therefore, there is a lower demand for virgin resources by utilizing existing recycled materials, which lowers energy consumption and avoids emissions from raw material extraction and processing (e.g. recycled steel).

---

[13] Within this scope, explicit reference is made to wood-based elements and natural fiber-based insulations, in compliance with relevant technical specifications as per regulation 305/2011 Regulation - 305/2011 - EN - EUR-Lex

[14] https://climate.ec.europa.eu/document/download/0f796d21-dbe4-4f5a-b0ef-d71247544db1_en?filename=event_20240924_presentation_en.pdf

[15] https://research.tue.nl/nl/publications/assessment-of-the-sustainability-of-flexible-building-the-improve

Note: The recycling process may require significant energy input. If fossil-based energy is used, it may negate some of the benefits gained from replacing virgin materials. To ensure the environmental advantages of using recycled materials, the energy source for recycling must be low-carbon or renewable.

3) **Low-emission industrial products:** These products encompass materials such as cement and steel, that are produced by using (advanced) technologies that reduce the amount of GHG emissions during the production and manufacturing process, or injecting captured CO_2 into a product through a mineralization process, effectively lowering the overall carbon footprint or extending the CO_2 storage capacity of these products.

1.5.2 Not eligible products

Short-term application products (< 35 years): Products that are designed to be used for short-term applications. Consequently, the long-term storage and environmental benefits derived from CO2 sequestration within these materials cannot be guaranteed in projects.

As this methodology is based on PCF reports, there are certain criteria and limitations regarding the source of supply of the materials. Therefore, products originating from the following locations are not eligible:

- Land marked as an indigenous reserve where land rights require consultation with the indigenous authority
- Land where local communities have customary rights or stewardship to use the land
- Regarding the cultivation area of the raw material (fiber/biomass crops) for biobased products:
    - ❖ Land use change that involves deforestation
    - ❖ In the EU: Land that has been deforested later than December 31st, 2020[16]
    - ❖ Wetland/peatland
    - ❖ Land that is within or partly within a protected area or natural reserve (e.g. national parks, nature reserves)

1.6 Additionality

Additionality ensures that a GHG reduction project results in emissions reductions beyond what would have occurred under a "business-as-usual" scenario or existing regulations, guaranteeing

[16] Aligned with the cut-off date from the European Regulation on Deforestation-free products (EUDR)

that the reductions are genuinely "additional" and not merely a result of compliance with mandatory requirements or standard practices.

Depending on whether the project developer intends to use the generated claims in offsetting or insetting scenarios, different requirements apply.

1.6.1 Offsetting Scenario

For stricter offsetting purposes, the project developer must demonstrate the following three aspects of additionality:

Regulatory additionality
The project developer must prove that the adoption of low-carbon building products was not driven by local, regional, or national regulations. This includes:

- Demonstrating the absence of regulations mandating the use of low-carbon building products.
- Showing that no financial incentives or regulatory directives exist to fully cover the cost of implementing low-carbon building materials. If subsidies are available, the project developer must show that they do not sufficiently bridge the financial gap needed to adopt the intervention.

If a regulation that mandates the use of low-carbon building products is introduced and actively enforced during the crediting period, the crediting period will be terminated, as the project would no longer meet the criteria for additionality. For example, many countries, states, regions, or economic zones have set GHG emission targets for the construction sector supported by directives and subsidies, or incorporated the sector into a compliance system (e.g., Milieu Kosten Indicator[17], etc.), which classify some projects non-additional by default.

Prevalence
The project developer must prove that the use of low-carbon building products is not a common practice in the region(s) included in the project area. Common practice is defined as adoption exceeding 20%. For example, currently in the Netherlands the share of materials based on fiber crops (excluding wood) in construction in the Netherlands is only 0.1 percent. Given that the use of these climate-friendly materials occurs in less than 20 percent of construction projects in the Dutch

[17] In the EU's Carbon Removal Certification Framework (CRCF), certain projects may already be supported under existing compliance systems, such as the Carbon Border Adjustment Mechanism or national green building programs. Similarly, in the Netherlands, programs like the MKI (Milieu Kosten Indicator) incentivize sustainable building practices

market, it is regarded as additional to common practice. As a result, carbon credits can offer an additional incentive to further scale up their use in the supply chain.

Financial additionality

The project developer must demonstrate that carbon finance provides a critical financial incentive to adopt low-carbon building products, ensuring the intervention would not occur without this support. Tools such as the CDM's "Combined tool to identify the baseline scenario and demonstrate additionality"[18] can be used for this purpose. The analysis may remain confidential and does not need to be published in the public registry but must be accessible to the VVB and Proba.

1.6.2 Insetting Scenario

For insetting purposes, the project developer is only required to demonstrate regulatory additionality (see text above) but must also be transparent regarding prevalence and financial additionality in the POD.

1.7 Crediting period

The crediting period is the timeframe during which a validated project generates carbon credits for verified emissions reductions. At the end of the crediting period, the project must undergo re-validation to confirm that additionality is still present and to reassess the baseline.

For GHG projects utilizing low carbon building products, the crediting period can be set up to a range of 5 (minimum) to 10 years. This duration accommodates the use of multiple building products in a construction project and strikes a balance between providing enough time for projects to demonstrate their environmental impact and maintaining flexibility for project adjustments and improvements (e.g. new technologies or regulations).

Upon requesting renewal of the crediting period, Project Developers must also ensure compliance with any relevant updated version of this methodology, as well as any additional requirements introduced to maintain the integrity and credibility of the carbon credits.

[18] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v7.0.pdf

1.8 Permanence

To ensure permanence in construction projects that utilize low-carbon building products, project developers need to provide proof related to:

Building product's durability

The durability of the product is crucial to ensure the permanence in these types of projects. It is a prediction of the lifespan during which the product will perform its intended functions without significant degradation. The carbon that will stay sequestered in the product is directly linked to their durability.

Consideration of the construction's lifespan

The expected carbon-storage duration should reflect the total amount of years that the building product will remain a component of the construction. The permanence of carbon storage is influenced not only by the building product's inherent lifespan and durability but also by the expected lifespan of the construction in which it is used. For example, a building product with a potential lifespan exceeding 35 years will only store carbon for as long as the construction remains intact. If the construction is demolished after 30 years, the effective carbon storage duration will be significantly reduced.

Justification of permanence

The justification shall be based on credible sources, such as scientific literature, industry reports, public databases, or performance tests, among others and must be presented in the POD

1.9 Risks and mitigation measures

In designing and implementing GHG projects, it is essential for project developers to identify and address potential risks that could impact the credibility, effectiveness, and permanence of GHG reductions and removals.

Regulatory and market Risks

- **Sold low-carbon building products are not used:** There is a risk that products sold as "low-carbon building products" are not ultimately utilized in construction projects.

  Mitigation: Request formal contract that explicitly outlines the constructor's commitment to use the purchased quantities as specified (proper documentation). In later stages sample checks or audits should be conducted to verify the actual use of the product in construction.

- **Changes in regulation:** Regulatory changes could mandate the use of low-carbon products or alter the conditions under which credits can be claimed.

  Mitigation: Project developers should monitor regulatory developments and adjust the crediting period or project design as needed to ensure compliance.

Technical and implementation Risks

- **Risk of underestimated or miscalculated PCF:** Incomplete data, errors in PCF models, or changes in raw material sourcing could result in inaccuracies in carbon footprint calculations.

  Mitigation: Use robust PCF models, verify data quality regularly, and ensure independent validation of PCF reports.

- **Lack of skilled personnel**: Limitations in technical expertise can lead to poor installation, bad maintenance, and mismanagement of the low carbon building products transportation and integration to the construction.

  Mitigation: Provide targeted training, quality control processes, and clear protocols for construction and documentation.

Specific risks to products that store carbon (e.g. biobased building products): The risks outlined in this section primarily relate to reversal risks, which directly impact permanence, as they involve the potential re-release of stored carbon from building products back into the atmosphere.

- **Non-permanence risk:** Stored carbon may be released prematurely due to material degradation or other factors.

  Mitigation: Project developers must set a clear expected duration for carbon storage claims based on the scientific references ensuring alignment with the product's reference service life (RSL)[19] and the project's overall timeframe.

- **Vulnerability to natural degradation**: Materials may degrade due to moisture, pests, or other environmental factors, impacting their performance or lifespan.

  Mitigation: Appropriate treatments and materials that meet durability standards must be used and should be clearly defined in the POD.

[19] RSL: clear description can be seen in the following sections

- **Natural hazard risks or calamity:** Events such as fires, flooding, extreme temperatures, or earthquakes may damage the building product and lead to the premature release of stored carbon.

  Mitigation: Ensure compliance with safety standards, incorporate protective measures, and apply location-appropriate design and building product choices.

Project developers must also provide a risk evaluation form, which outlines the risks described above. This form must assess, document, and provide mitigation measures to potential risks associated with the project's intervention. Project developers may request the relevant template from Proba or use it as a reference to create their own version, provided it covers all required elements.

1.10 Co-benefits

This methodology does not prescribe any calculation methods for quantifying additional benefits resulting from projects that utilize low carbon building products in construction buildings. Proba expects that every project that utilizes this methodology, contributes to at least one or more UN Sustainable Development Goals[20] next to number 13 (Climate Action), and expects that Project Developers will take these into account when preparing and designing a project. Synergies and trade-offs of low carbon building products (e.g. biobased building products) with the SDGs are presented in the factsheet that was published by Wageningen University and Research[21]. Project Developers can use the factsheet to identify desired and undesired effects of their projects that go beyond GHG benefits, such as contributions to social, economic, and environmental goals.

1.11 Leakage

Leakage refers to potential direct or indirect relocation of GHG emissions to other areas due to the project intervention. Due to the fact that this methodology is based on PCF, all relevant upstream and downstream emissions should inherently be included in the calculations. Any significant sources of leakage must be conservatively taken into account in the GHG reduction calculations. Examples of leakage may include the following but are not limited to:

- Increase of GHG emissions due to the relocation of previous cultivation activities, if biobased materials are used

[20] https://sdgs.un.org/goals

[21] https://edepot.wur.nl/640116

- Unexpected waste during certain phases (manufacturing, usage, etc), if not included in the PCF report

2. Project boundaries

2.1 Spatial boundaries

The spatial boundaries of this methodology align with the system boundaries (Figure 1) defined in the life cycle assessment (LCA) of the building products. The methodology considers emissions across all relevant life cycle stages, including raw material extraction, manufacturing, transportation, use, and end-of-life processes. However, the **direct measurement, reporting, and verification (MRV) procedure is limited to the delivery/selling of the product to the constructor**, at which point credits are issued.

The **use phase and end-of-life stage emissions are not directly measured** but are instead estimated using scientifically validated scenario-based approaches (e.g. EN 15804 standardized scenario-based modeling). These scenarios rely on standardized assumptions regarding product lifespan, operational efficiency, and disposal pathways. The system boundaries and the associated stages are illustrated in the Figures below. Detailed information regarding the system boundaries can be seen in the [Appendix 1](#)

Figure 1: The life cycle stages of a building material are presented, according to the norm EN15804's terminology using modules A-D.

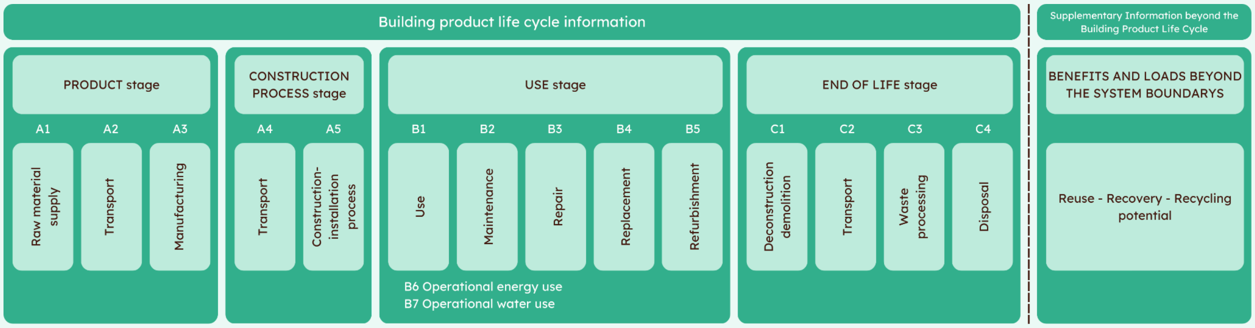
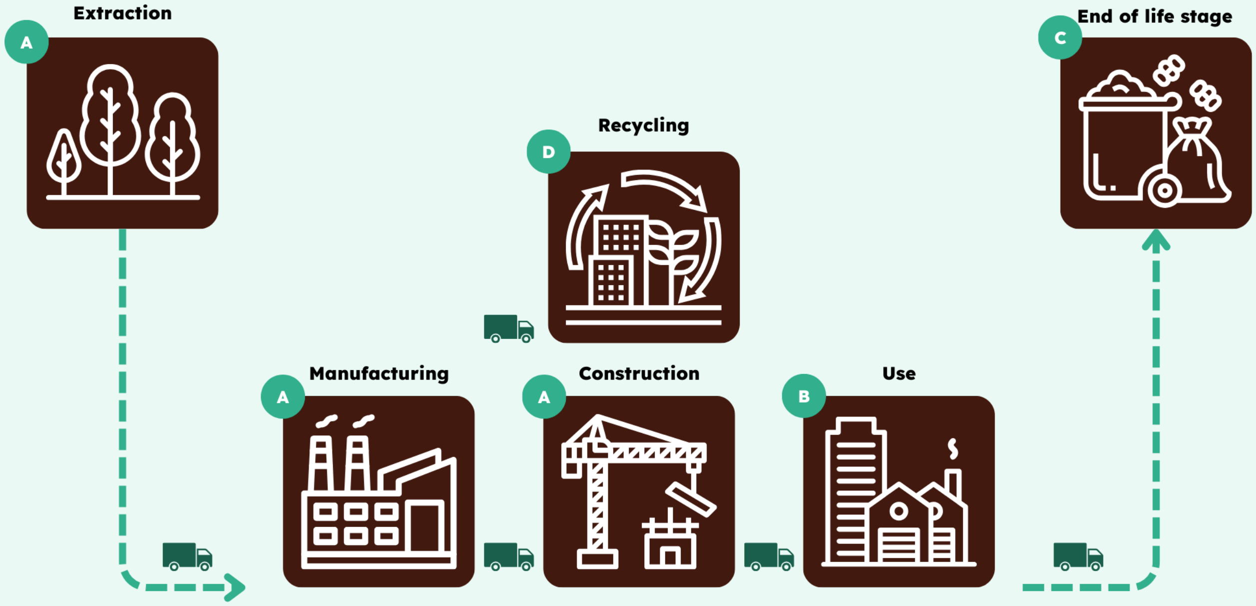


Figure 2: Schematic representation of the System boundaries of building products and their lifecycle in a construction project



2.2. Temporal boundaries

The temporal boundaries for this methodology span the entire life cycle of the building products, from raw material extraction to the end-of-life stage, ensuring consistency with the spatial boundaries and system boundaries. This includes all phases from raw material extraction, production, transportation, construction, use and end-of-life. However, the focus remains strictly on the building product itself, not the entire construction project. This means that operational energy is only assessed in relation to the product's specific performance, maintenance, and durability over time, without accounting for broader energy consumption at the building level. Monitoring and data collection take place during this timeframe (details are presented in Chapter 4. Monitoring, Reporting and Verification)

To account for the use stage and end-of-life phase, scientifically reasonable scenarios and GHG emissions must be applied by Project Developers when direct monitoring is not feasible. These standardized scenarios are outlined based on the PCF reports provided for the building products, qualified LCA studies, regulatory frameworks, and industry common practices.

3. GHG project

This methodology is structured around the substitution of commonly used products with lower carbon alternatives, making the substitution criteria crucial for accurately assessing and quantifying the GHG impact. This involves a direct comparison between the established baseline scenario, representing the GHG emissions from commonly used building products, and the project's intervention, which utilizes low-carbon building products to achieve measurable reductions and removals of emissions. Credible and verifiable data are essential to justify the substitution of commonly used building products with low-carbon alternatives, ensuring the baseline scenario and the project’s selected intervention are accurately assessed.

3.1 Data credibility and sourcing for PCF reports

The credibility of the PCF reports, including their sources and methodologies, is fundamental to this methodology. These reports form the foundation for accurately assessing and quantifying the GHG impact of substituting commonly used building products with lower-carbon alternatives. For that reason project developers must source data from reliable and verifiable sources. This includes using established databases or primary data directly related to the product's life cycle stages. There are two options regarding sourcing of data in order to approach this task:

Option 1: Existing databases and softwares

Project Developers can use PCF or LCA related databases (e.g. the International Environmental Product Declarations database - EPD) that offer pre-compiled, full life cycle/carbon footprint analyses for a wide range of building materials and products. These databases provide a broad spectrum of scientifically based information, facilitating quick access to reliable data for complete reports. Details and sources for these databases are provided in the Appendix 2.

However, while this option offers convenience, there may be trade-offs in terms of precision. There is a potential risk of reduced accuracy as the pre-compiled data might not reflect the specific conditions or latest changes relevant to a particular building product. In such cases (and other cases as depicted under option 2), the project developer is required to adopt Option 2 for data collection and analysis to ensure accuracy.

Option 2: Development of PCF report by Project Developers/manufacturers

If a pre-compilled (specific enough) PCF/LCA report is not available for the products in scope, an alternative PCF/LCA report shall be utilized, provided it contains the necessary information, has undergone independent verification, and adheres to relevant standards. Project Developers or manufacturers can conduct and present their own carbon footprint analysis by retrieving specific input data from available databases. This approach is necessary when:

- Available PCF/LCA reports from “option 1” are older than 15 years and/or the emission factors that were used for the calculations have been updated.

- Higher or lower carbon sequestration potential of the biomass or fiber crops than the one is presented in the PCF/LCA reports from option 1 (only for products that store carbon).
- Renewable energy sources are utilized in one or more stages of the product's lifecycle, replacing traditional fossil fuel-based energy.
- Processing and manufacturing activities are centralized, thereby eliminating transportation emissions.

3.2 Substitution criteria and justification

Project Developers must justify the selection of low-carbon building products by ensuring they meet the substitution criteria outlined below. These criteria focus on the product's ability to replace the baseline product effectively.

Functional unit selection and functional equivalence: Project developers must provide the carbon footprint of the low-carbon building product, calculated using a specified **functional unit.** The functional unit standardizes the basis for comparison by detailing the quantity, performance, lifespan, and function of the building product, ensuring it accurately represents the scope and objectives of the PCF. The project developer must justify the chosen functional unit to facilitate a meaningful comparison between low-carbon and commonly used building products in terms of GHG emissions and carbon sequestration.

A well-defined functional unit must capture key characteristics to provide a comprehensive and standardized basis for comparison. These characteristics include:

- **Product type:** clearly specifying the type of building product being assessed.
- **Quantity**: Defining the amount of material used, such as weight, volume or surface area.
- **Performance specification**: Ensuring the product meets the same functional requirements as the baseline product, such as thermal resistance for insulation materials or load-bearing capacity for structural components.
- **Geographic context**: Indicating where the product is manufactured or used, as environmental impacts may vary by region.
- **Service life**: Incorporating the expected lifespan of the product to ensure a fair assessment of long-term carbon impacts. Project developers must also provide evidence of the reference service life (RSL), showing how long it can perform its intended function without significant maintenance or deterioration. If the RSL of the project product differs from the baseline product, appropriate adjustments in calculations must be made.

Examples of functional units:

- 1 m² of external wall insulation with an R-value[22] of 4.5 m²·K/W and a 50-year service life, in the Netherlands: Specifying the thermal resistance of insulation materials, longevity, and its geographic specificity for an accurate comparison.
- 1 m² of load-bearing timber wall panel with a fire resistance rating of REI 60 and a 60-year service life, in a certain country. This unit highlights the importance of safety, durability, and carbon storage potential with its location.

Moreover, Project developers should provide any additional proof that the low-carbon building product performs the same functions as the commonly used product it replaces.

Price/quality ratio: The cost should reflect good value, balancing affordability with quality and performance. This selection factor is closely tied to financial additionality, particularly when the project aims to generate offset credits. For instance, if a low-carbon building product is cheaper than the commonly used product, often it would not be eligible for a GHG project. The price (or total cost for the end user) must be comparable or higher than the commonly used alternatives.

Relevant guidelines regarding the project's building product selection are explained in the Project scenario sub-chapter..

3.3 Baseline scenario

To establish the baseline scenario, it must first be **determined which commonly used products are currently in the market and can be substituted by the project's low-carbon building product.** The Project Developer must select the baseline building product by considering the replaced product type (e.g., thermal insulation) and material type (e.g., stone wool).

Specific product and material definition:

- A specific product type that will be replaced shall be defined by the project developer.
- A specific product type being replaced shall be defined. Otherwise, a mix of materials shall be selected. Their choice must be justified and the (weighted) average carbon footprint of these materials should be calculated and presented (see example in the Appendix 3)
- A specific product or material type from a specific manufacturer may only be considered with sufficient justification (see Substitution criteria and justification) and certainty (reliability of data). A mix of manufacturers and EPDs (if available) or verified LCA/PCF reports shall be used to represent the market mix of a given product or material type.

[22] R -value is a measure of how well a two-dimensional barrier, such as a layer of insulation, a window or a complete wall or ceiling, resists the conductive flow of heat. The R-value is the building industry term for thermal resistance "per unit area".

Validity of baseline scenario and potential adjustments:

The baseline scenario for a given project is valid for the entire crediting period, which is by default set to minimum 5 years. However, adjustments should be established under certain conditions:

- **Material changes:** Significant operational or environmental shifts can impact the initial PCF assumptions. This includes changes in production methods, scaling operations, technology, resource usage, regulatory conditions, and market dynamics. Such shifts may require a reevaluation of the baseline to ensure ongoing accuracy and relevance
- **Methodology revisions:** The baseline scenario may also need adjusting due to updates in the underlying methodologies, driven by new scientific research, technological progress, or regulatory changes.

3.4 Project intervention

Project developers must take specific actions to demonstrate that the low-carbon building products used in their projects meet the requirements outlined below.

- Project Developers must explain how the project's product substitutes the baseline product according to Substitution criteria and justification
- The activities outlined in the system boundaries and their relevant GHG emissions must be accurately documented in the PCF report, ensuring the GHG sources associated with the low-carbon building products are properly accounted for. The report must reflect the carbon sequestration (e.g. if biobased building products are in scope) and GHG emissions from all the activities during the life cycle of the products.
- In order to be conservative when determining the project GHG emissions, the uncertainty factor must be clearly defined and applied in the PCF report of the building product
- Project developers must also determine and present in the POD the appropriate performance indicators, which may vary by product and material type. For example,
    - Insulation capacity
    - Thermal resistance (R-value)[23]
    - Load-bearing capacity
    - Compressive strength

[23] For the LCA/PCF reports of low-carbon insulation products the same R-value as the commonly used product must be used to ensure a fair and equivalent comparison. This can result in a theoretical product format, needed to achieve comparable R-value

- The reference lifetime (RSL) of the product should optimally match that of the baseline product. If there are discrepancies in the service lifetimes between the baseline and the project products, the difference will be accounted for in the calculations (see example in Appendix 3)

3.5 GHG impact quantification

Project developers must calculate the annual avoided emissions and/or removals by multiplying the avoided emissions and/or removals per functional unit by:

- The quantity of low-carbon building products sold and used over the year (for building product manufacturers), or
- The quantity of low-carbon building products used in a construction project (for constructors).

The following equations must be used:

Equation 1 - GHG emissions of building products: This equation is used to calculate the overall GHG emissions from commonly used building products and low-carbon building products.

$$E_{product\ i} = (E_{Module\ A,\ product\ i} + E_{Module\ B,\ product\ i} + E_{Module\ C,\ product\ i} + E_{Module\ D,\ product\ i}) \times Q_{material\ i} \times \frac{FU_{lifetime}}{PCF/LCA_{lifetime}}$$

Where:

$E_{product\ i}$	=	The life cycle embodied GHG emissions of a building product i, normalized to one functional unit. (ton CO_2e/functional unit)
$product\ i$	=	Specific product defined in the project
$E_{Module\ A-D,\ product\ i}$	=	The GHG emissions per life cycle stage for one functional unit of a building product retrieved by the PCF report. The corresponding Modules A through D are shown in system boundary. (kg CO_2e)
$Q_{material\ i}$	=	The quantity of the building product which is either 1) sold by the building product manufacturer, or 2) used by the constructor, depending on the nature of the project.
$FU_{lifetime}$	=	The service lifetime of the building product. Namely, the expected lifespan of the project or building where the product is used. In this methodology, the $FU_{lifetime}$ for both commonly used and low-carbon products must be set the same. (year)

$LCA/PCF_{lifetime}$	=	The reference service lifetime of the building product as defined in the PCF report. This is the expected duration that the product is intended to last under normal conditions. Often, this is the same as the FU $_{lifetime}$. (year)
$\frac{FU_{lifetime}}{LCA/PCF_{lifetime}}$	=	The service time correction factor. In some cases the project's lifespan is different to the product's reference service lifetime. The service time correction factor must be applied to consider the actual usage time of the building product

Equation 2 - The total GHG emissions reduction : This equation will be used to calculate the emission reductions due to the substitution

$$E_{reduction} = \sum_{i=1}^{n} (E_{baseline\ product\ i} - E_{project\ product\ i})$$

Where:

$E_{reduction}$	=	The total annual tonnes CO_2eq of GHG was reduced due to the project. (ton CO_2e)
$E_{baseline\ product\ i}$	=	The life cycle embodied GHG emissions of the commonly used product, normalized to one functional unit. (ton CO_2e/functional unit)
$E_{project\ product\ i}$	=	The adjusted life cycle embodied GHG emissions of the low carbon building product, normalized to one functional unit. (ton CO_2e/functional unit)
n	=	The years of the project (year)

Equation 3 - Carbon storage in low-carbon building product : This equation will be used only **if a product that stored carbon is used in the GHG project**, in order to calculate and claim the carbon storage potential

$$R_{removal} = R_{storage} = C_{biobased\ product} \times C_{carbon} \times C_{weight} \times Q_{biobased\ product\ i} \times \frac{FU_{lifetime}}{LCA/PCF_{lifetime}}$$

Where:

$R_{storage}/R_{removal}$	=	Stored CO_2e in the biobased product per function unit. (ton CO_2e/functional unit)
$C_{biobased\ product}$	=	The kilograms of carbon stored in one functional unit of biobased product as defined based on the calculations of Project Developers included in the LCA/PCF report. (kg C/functional unit)
C_{carbon}	=	The conversion factor of carbon and CO_2. It is calculated by the molar mass of CO_2 divided by that of C, i.e.: CO_2/C=44/12= 3.667. (1)
C_{weight}	=	The conversion factor from kg to ton, 1kg=0.001 ton. (1)
$Q_{biobased\ product\ i}$	=	The quantity of the biobased building product which is either 1) sold by the building product manufacturer, or 2) used by the constructor, depending on the nature of the project.
$\frac{FU_{lifetime}}{LCA/PCF_{lifetime}}$	=	The service time correction factor. See Equation 1.

Equation 4 - Total GHG emissions reduction and removal: This equation will be used to calculate the total impact of the project

$$E_{total} = \sum_{i=1}^{n}((R_{removal} + E_{reduction}) \times UF)$$

Where:

E_{total}	=	The total tonnes CO_2eq of GHG reduced and removed due to the project. (ton CO_2e)
$R_{removal}$	=	Stored carbon in the total quantity of biobased building products. (ton CO_2e)
$E_{reduction}$	=	The total tonnes CO_2eq of GHG reduced due to the use of the total quantity of building products. (ton CO_2e)
UF	=	Uncertainty factor in %
n	=	The years of the project. (year)

Note: When biobased products are used in the project scenario, the claiming of the total impact can be classified between GHG reduction and GHG removals or as a total.

Note: Typically, a Buffer Pool is applied in GHG projects. This acts as a reserve of Carbon credits established to cover potential losses in GHG Projects, ensuring the integrity of emissions reductions or removals over time. The size of the Buffer Pool is aligned with the level of reversal risks associated with the GHG Project. The Project Developer should identify any such potential reversal risks and then include them as part of the POD in the form of a Buffer Pool.

3.5.1 Uncertainty

Uncertainty is an inherent aspect of LCA/PCF reports, as they include variability in emissions related to the activities assessed. However, other relevant uncertainties must also be addressed in the Project Design (POD). One significant source of uncertainty is the assumption regarding the duration of carbon storage in materials. While this duration can be estimated using the best available information and supporting evidence, it is impossible to predict with certainty the fate of the material decades into the future. For that reason an uncertainty factor should be applied to the final Total GHG emissions reduction and removal.

To calculate the Uncertainty Factor, the tool[24] developed by the GHG Protocol Initiative can be used. This Excel-based tool automates the aggregation steps for developing a basic uncertainty assessment for GHG inventory data, following the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National GHG Inventories. The tool is supplemented by a guidance document[25], which describes the functionality of the tool and gives a better understanding of how to prepare, interpret, and utilize uncertainty assessments. The Project Developer must quantify and document all uncertainties concerning assumptions, data measured, tooling involved for both static and dynamic baselines

4. Monitoring, Reporting, and Verification (MRV)

MRV refers to a structured approach used to measure, quantify, track, report, and verify GHG emissions, GHG reductions, and carbon storage potential associated with the use of low-carbon building products in construction projects. The purpose of MRV approach is to ensure accurate,

[24] https://ghgprotocol.org/calculation-tools-and-guidance
[25] https://ghgprotocol.org/sites/default/files/2023-03/ghg-uncertainty.pdf

consistent, and credible measurement and reporting of emissions over time, facilitating the issuance of high-quality carbon credits

4.1 Monitoring

While the PCF reports provide a comprehensive overview of the product's lifecycle emissions, certain components of the report—such as data and relevant information on specific lifecycle phases (e.g., raw material extraction, transportation, manufacturing, etc), must also be reported separately. These details ensure transparency and enable Validation and Verification Bodies (VVBs) to review and confirm the accuracy of the calculations.

Table 1: Parameters related to the life cycle stages of the building product

Category name	Description	Proof required for baseline (commonly used building products)	Proof required for project intervention (low-carbon building product)	Frequency of reporting
Raw material supply	Quantity of raw materials harvested * and delivered (e.g., biomass or fiber crops)	Specific information retrieved from PCF/LCA reports	• Documentation of past harvest * • Contracts and invoices indicating the tons of raw material delivered	During each purchase of the certain quantity of low-carbon building products intended for use in a construction project
Production /Manufacturing figures	The input of raw materials corresponds to the output of final products, accounting for waste	Specific information retrieved from PCF/LCA reports	• Production/Manufacturing records • The weight-to-weight (w/w) ratio of the biobased material in the final product * • Waste ratio records	During each purchase of the certain quantity of low-carbon building products intended for use in a construction project
Market distribution and use	Evidence of the quantity of low-carbon products sold in the market and their intended use in a construction	Specific information retrieved from PCF/LCA reports	• Invoices and purchase orders that detail the quantity of the product sold and its intended use in specific construction projects (construction blueprints) • Formal contract that explicitly outlines the constructor's	During each purchase of the certain quantity of low-carbon building products intended for use in a construction project

			commitment to use the purchased quantities as specified.	
Transportation	List of modes of transportation of raw materials and low-carbon building products	Specific information retrieved from PCF/LCA reports	Documentation of emissions related to the transportation of raw materials and final products, including distances, modes of transport, and energy consumption	During each purchase of the certain quantity of low-carbon building products intended for use in a construction project
Usage	Emissions, carbon sequestration, durability, and material performance throughout the product's functional life, including GHG emissions from chemical processes, maintenance, repair, replacement, refurbishment, and operational energy demand.	Specific information retrieved from PCF/LCA reports or industry-standard scenarios for material degradation, repair frequency, and operational energy demand.	Scientific based scenarios and assumptions regarding the usage stage based on relevant performance parameters (e.g., durability, degradation rates, insulation efficiency, fire resistance, structural integrity, maintenance cycles, repair frequency, replacement rate, refurbishment potential, and operational energy consumption). The parameters are determined based on the nature and purposes of the products in the scope of the intervention. Supporting documents may include technical specifications, durability studies, maintenance records, or industry benchmarks.	During each purchase of a certain quantity of low-carbon building products intended for use in a construction project
End-of-life scenarios	Emissions and processes related to the disposal, recycling, reuse, or degradation of building products at the end of their lifecycle	Specific information retrieved from PCF/LCA reports Default scenarios based on industry standards or literature regarding landfill, incineration, or recycling rates.	Scientific based scenarios and assumptions regarding emissions from the product's disposal, recycling, or reuse, ensuring proper alignment with carbon footprint calculations	During each purchase of the certain quantity of low-carbon building products intended for use in a construction project

* For products that contain biobased materials

4.2 Reporting

Monitoring reports must include the following:

- General project description: A summary of the project, including the geographical location of construction projects, fields, or production facilities where the baseline data was established and low-carbon building products are utilized.
- Monitoring roles and responsibilities: A description of the roles and responsibilities of individuals involved in the monitoring and data collection processes, specifying who is responsible for each activity.
- Monitoring period documentation: The time period covered by monitoring activities must be clearly indicated in every report.
- Data collection process: Details of the data collection methods, frequency of monitoring, and procedures for data archiving, as described above.
- Proof of product use: A recordkeeping plan that includes documentation such as invoices, purchase orders, delivery receipts, and other proof that demonstrates the application or use of low-carbon building products in the construction project.
- Access to reports: All monitoring reports must be readily accessible for review by the Validation and Verification Bodies (VVB) during validation and verification procedures.

4.3 Verification

An accredited Validation and Verification Body (VVB)[26] must be selected to execute the verification process based on the monitoring plan and reports to confirm that all the requirements are met, ensuring the accuracy of the calculated GHG reductions and carbon storage resulting from the use of low carbon building products. VVBs should conduct their procedures in accordance with the guidelines outlined in the dedicated document for validation and verification processes. (This document is currently under development)

5. Issuance of credits

Credits are issued at the stage that the low carbon building product is sold to the constructor. This is the point when the product, from being a manufactured building product, is decided/scheduled to be a component of a sustainable construction project. This moment is chosen because:

[26] Please refer to the Proba Standard for more details on VVB requirements

- All project emissions can be calculated at this stage, providing a complete and accurate assessment.
- Carbon storage potential of the biobased product (if it is used) is fully determined at this point.
- Guaranteed use: The sale to the constructor confirms the product’s intended application in a sustainable construction project, reducing uncertainties about its final use.
- VVB verification procedures can take place, ensuring that all claims meet the requirements for carbon benefits as per this methodology.

As indicated in the Section 11 Monitoring, Reporting, and Verification (MRV) invoices must clearly detail the specific quantities sold and the exact intended use of the product in the construction should be documented based on the blueprints of the construction. Additionally, there must be a formal contract in place that explicitly stipulates the constructor's commitment to utilize the purchased quantities as specified. Each step from product development to its application must be documented

Appendix 1

The Carbon Footprint of a Product (PCF) is quantified by evaluating the entire lifecycle of a product, encompassing raw material acquisition, design, production, transportation, usage, and end-of-life treatment. At the core of every PCF lies a systematic framework based on Life Cycle Assessment (LCA) stages. For that reason the LCA stages are described below.

1.1 Description of LCA stages (e.g. for biobased products)

Throughout the **production stage** of the biomass or fiber crops that will be used for the production of biobased products, a range of emissions will occur from ongoing activities, which need to be calculated separately for each activity. During the cultivation, emissions can occur due to the soil preparation and tilling, planting machinery, fertilizer applications, maintenance activities. During the manufacturing process, emissions from chemical input into the processing (e.g. volatile organic compounds), energy usage, binders production, packaging will be considered. Additionally, emission from transporting crops, primary products, secondary products, and packaging will be included in the LCA.

Throughout the **construction stage**, several activities can lead to GHG emissions. Considering the logistics, GHG would emit from installation machinery like forklifts, excavators, loaders, and cranes. Transporting the insulating panels within the construction site should also be considered.

Throughout the **use stage**, activities related to maintenance, energy, replacement, et al. can lead to GHG emissions. Machinery for maintenance, replacement activities can emit GHGs when powered by fossil fuels. Additional energy demands for the electrical appliance, ventilation system, heating needs, moisture control, and mold management in the building can also contribute to the GHG emissions. The application of chemical treatments to biobased materials to enhance their durability or fire resistance can also involve GHG emissions. The declaration of the reference service life (see section below) is imperative for EPDs or LCA reports covering the complete use stage (modules B1-B7), or if a use stage scenario is described, which refers to the lifetime of the product

Throughout the **end-of-life stage**, machinery used for deconstruction, demolition can produce GHG emissions. The energy used for waste processing, shredding, cleaning, and incineration also produce GHG emissions.

In the **recycling stage**, biobased materials may degrade and release stored carbon back into the atmosphere. The activities of recovering usable materials from waste, such as separating biobased materials from other waste streams, can involve significant energy use and associated GHG emissions. The possibilities of re-use, recycling, and energy recovery must be described.

1.2 System boundaries

This includes analyzing all lifecycle stages from modules A to D[27] as outlined in ISO 14067 and EN 15804. Module D should be incorporated only when sufficient data are available (for both baseline and project product's). The life cycle stages included in an LCA of low-carbon building products and commonly used building products are listed in Table 1. Each stage includes certain activities and associated GHG emissions and/or carbon sequestration that must be assessed to provide a comprehensive evaluation.

Table 3: *This table provides a detailed breakdown of the system boundaries for a Life Cycle Assessment (LCA) focused on building products, using biobased products as a primary example of a project's intervention. The activities and related emissions listed highlight key differences and environmental impacts at each stage:*

Life cycle stage	Process	Baseline	Project
Product Stage	Raw material supply (A1)	• Blasting and drilling for limestone mining • Excavation and loading of raw materials. • Storage of raw materials	• Cultivation of fiber/biomass crops • Farming activities • Harvesting • Carbon sequestration (biogenic carbon) • Storage of biomass
	Transport (A2)	• Transportation of raw materials to processing facilities • Emissions from diesel and fuel consumption.	• Transportation of harvested biomass to processing facilities • Emissions from diesel and fuel consumption
	Manufacturing (A3)	• Use of industrial equipment • Grinding and mixing raw materials • High energy consumption and fossil fuels combustion from machinery use	• Processing biomass into construction products (e.g. insulation panels) • Grinding, mixing, and forming biomass materials • Energy consumption from machinery use
Construction	Transport (A4)	• Transportation of	• Transportation of biobased

[27] Module A (Product stage), Module B (Construction stage), Module C (Use stage-End -of-life stage), Module D (Benefits and loads beyond the system boundary)

Stage		conventional building materials (e.g. cement, steel, etc.) to the construction site • Emissions from diesel and fuel consumption	materials (e.g. insulation panels) to construction sites. • Emissions from diesel and fuel consumption
	Construction/Installation (A5)	• Use of cranes, mixers, and other heavy machinery • Emissions from diesel engines and electricity usage	• Installation of biobased construction materials • Emissions from diesel engines and electricity usage • Material waste and associated emissions
Use Stage	Use（B1)	• Minimal GHG emissions from chemical processes in conventional materials	• Carbon sequestration maintained in biobased materials • Minimal GHG emissions during use
	Maintenance (B2)	• Regular maintenance involving painting, repairs, etc • Emissions from maintenance activities and use of equipment	• Regular treatment may be needed to prevent degradation (e.g. pest treatment) • Emissions from maintenance activities and use of equipment
	Repair (B3)	• Emissions from repairing materials and equipment	• Emissions from repairing activities and equipment • Repairs may be needed more frequently due to biobased material properties
	Replacement (B4)	• Emissions from producing and installing replacement materials	• Emissions from producing and installing replacements • They may require more frequent replacement depending on their application
	Refurbishment (B5)	• Use of refurbishment equipment and materials	• Use of refurbishment equipment and materials
	Operational Energy (B6)	• Indirect emissions from electricity and fuel use for heating and cooling	• Indirect emissions from electricity and fuel use for heating and cooling

		• Importance of thermal resistance (R value)	• Importance of thermal resistance (R value)
End-of-Life Stage	Deconstruction/Demolition (C1)	• Use of demolition machinery (e.g. wrecking balls, excavators) • Emissions from fuel combustion in machinery	• Emissions from deconstruction of biobased materials • Typically lower emissions due to easier processes
	Transport (C2)	• Transportation of waste to landfill or recycling facilities • Emissions from diesel and fuel consumption	• Transportation of biobased waste materials to landfill or recycling facilities • Emissions from diesel and fuel consumption
	Waste Processing (C3)	• Emissions from waste processing equipment (e.g. crushers, sorters)	• Emissions from processing biobased materials for composting or recycling
	Disposal (C4)	• Emissions from landfill operations	• Lower emissions due to higher potential for composting and natural degradation of biobased materials
Benefits and loads (Optional)	Supplementary information for future reuse, recycling and energy recovery	• Potential benefits from recycling materials • Emissions from processing recycled materials	• Potential benefits from recycling or composting biobased materials • Emissions from processing recycled or composted materials • Potential savings from energy recovery and material reuse

Note: The initially defined system boundary may need to be refined based on the specifics of the chosen baseline and the project intervention. Consequently, the monitoring and verification procedures should be adjusted accordingly.

1.2 Reference Service Life

Reference Service Life (RSL) is crucial to be determined in an LCA report of building products, especially when focusing on reducing GHG emissions through the use of low-carbon building products. RSL indicates the duration for which building components and materials are expected to serve their intended purpose effectively.

It ensures that the environmental benefits, such as reduced GHG emissions and carbon sequestration from biobased or recycled materials, are realized over the expected service life of the product.

Permanence refers to the duration that carbon sequestration benefits are maintained without being reversed. In the context of building products, this means the carbon stored or emissions avoided must be secure for a significant period

Appendix 2

2.1 Proposed databases

2.1.1 Databases for LCA reports

It is important to note that each LCA database is developed by an organization based in a specific country or territory, with processes modeled according to the local manufacturing characteristics. As a result, using an LCA database from another country may lead to inaccurate results.

The EPD is an ISO type III Environmental Declaration complying with ISO 14025 standard.

To accurately assess the environmental impact and carbon sequestration potential of low-carbon building products compared to the commonly used like cement or steel, Project Developers need reliable LCA data. There are two primary databases that can be utilized for this purpose and are related to Option 1 of the Lice cycle inventory analysis chapter:

Environmental Product Declarations (EPD) Database[28]

Scope: The EPD database is widely used across European countries. It contains standardized LCA data for various construction materials, adhering to the European standard EN 15804. This

[28] https://www.environdec.com/library

database includes information on the environmental impacts of both conventional and biobased construction materials throughout their life cycles.

Usage: For projects within Europe, the EPD database serves as an essential resource. It provides comparable and transparent environmental data that can be used to evaluate the sustainability of construction materials and specifically the GHG emissions related to them.

Advantages: The EPD database ensures that environmental assessments are consistent with European standards. It supports cross-border projects by providing harmonized data, facilitating compliance with EU regulations and certification schemes.

National Environmental Database (NMD)[29]

Scope: The NMD is a comprehensive database used primarily in the Netherlands. It provides detailed LCA data for a wide range of building products and construction materials.

Usage: Project Developers undertaking projects in the Netherlands can leverage the NMD to obtain specific environmental impact data. The database includes EPDs that detail the life cycle impacts of products, ensuring consistency and reliability in environmental assessments.

Advantages: The NMD is tailored to the Dutch regulatory and environmental context, making it particularly relevant for projects within this country. It provides localized data that can help in meeting national environmental standards and regulations.

Categories of NMD

Category 1 comprises crop-product reports that are developed based on externally evaluated Life Cycle Assessments (LCAs) for a particular product, such as a substitute for concrete or a biobased insulation panel. These reports are typically prepared at the request of entrepreneurs so that they can use this data to demonstrate the environmental performance of a building.

Category 2 comprises crop-product combinations that are aggregated for an industry. The reports in this category are more generalized compared to the product-specific reports in Category 1. Similar to the reports in this category, they undergo evaluation by external specialists.

Category 3 comprises LCA reports for crops and products that have not undergone evaluation by external specialists. To prevent overestimation, the NMD employs a conservative estimation by applying a 30 percent surcharge on the environmental performance. Particularly, utilizing this category leads to a reduction of 30% in the estimated amount of carbon sequestration.

[29] https://milieudatabase.nl/en/environmental-data-lca/my-product-in-nmd/

A project may utilize crop-product reports belonging to Category 1. If the project already has the necessary report, it can utilize it for a fee in order to assess the amount of carbon sequestration achieved by the project.

If there is no existing report for the specific combination of crop and product in Category 1 of the project, the company conducting the project has the option to build one using the LCA approach that is presented in this methodology. The responsibility for developing an LCA is assigned by the project developer and must be executed by a certified LCA specialist.

2.1.2 Databases for extraction of raw data

This section highlights databases[30] crucial for obtaining raw data necessary for Option 2 of the LCI analysis. These databases offer vital data that supports the execution of detailed and accurate LCAs specifically tailored to building products.

Ecoinvent[31]

Ecoinvent is a widely-used database for LCA that provides high-quality, transparent, and consistent LCI data. The Ecoinvent database has extensive data coverage and includes thousands of datasets covering a wide range of industries and sectors, such as energy, materials, transport, chemicals, waste management, and agriculture.

LCA software integration: Ecoinvent is accessible via mainstream LCA software platforms, allowing users to pinpoint and extract specific datasets relevant to building products.

Process selection: The project developer can select the specific processes or products for which they need GHG emissions data. Ecoinvent provides detailed inventory data for each process, including the emissions of different greenhouse gasses such as CO_2, CH4, N2O, etc.

Impact assessment methods: LCA software tools integrate Ecoinvent data with various impact assessment methods (e.g., IPCC, ReCiPe, CML). These methods can calculate the overall GHG emissions (often expressed in CO_2-equivalents) based on the individual emissions provided in the dataset.

[30] https://www.sciencedirect.com/science/article/pii/S1364032115016263
[31] https://ecoinvent.org/

Appendix 3

3.1 Baseline identification

Although it may be difficult to determine with certainty which product should be used specifically as a baseline, it can be said with a high degree of certainty what the average mix of the specific type of building materials in a European country is commonly used and that can serve as a baseline. Where national data is available, it should always be preferred.

<u>Average retrieved from multiple commonly used products:</u>

If multiple products are used in the construction process, the project developer should calculate and provide an average impact for these materials as the baseline. This approach ensures a more comprehensive and representative comparison between the commonly used and low-carbon materials. This approach considers the market share of each material along with its emission data. Weighted emissions of each material are calculated based on market prevalence allowing for the establishment of an average emission factor for the construction materials.

Product	R(m2k/w	λ(W/mk)	ρ(kg/m3)	CI spec ($kgCO_2$/kg)	CI total (CO_2/m2)	Marketshare	Weighted emissions ($kgCO_2$/m2)
Rockwool	4.5	0.0368	48	1.42	11.6	22%	2.32
Glasswool	4.5	0.034	25	1.76	6.7	22%	1.34
EPS	4.5	0.04	15	4.64	12.5	22%	2.5
PIR	4.5	0.023	33	4.58	15.6	11%	1.56
PUR	4.5	0.025	33	4.58	17	12%	1.7
Resol Foam (PF)	4.5	0.02	41	4.78	17.6	11%	1.76
Average							**11.468**

CIspec: Specific climate impact per unit mass of the product, measured in kilograms of CO_2 equivalent per kilogram of material. It quantifies the direct greenhouse gas emissions associated with producing one kilogram of the material.

CItotal: Total climate impact per unit area of the product, measured in kilograms of CO_2 equivalent per square meter. This value is calculated by integrating the specific climate impact with the material's density and thermal conductivity, providing a comprehensive measure of emissions for a given area of material used

3.2 Calculations example

This section is used as a demonstration of how the calculation should be done by the project developer. It indicates to project developers how to apply the equations of the methodology using real-life LCA data. The example is based on data from the LCA report from Mouton et al. (2023), which evaluated the environmental impact of both conventional and bio-based external wall assemblies. The numbers for each module are extracted from this LCA report.

Wall Types Compared

1. **Baseline (conventional):** Clay brick wall with stone wool insulation (referred as MMG04 in the LCA report)
2. **Project (bio-based):** Timber frame wall with blown-in straw insulation (referred as EW09.1 in the LCA report)

Functional unit (FU) is reported to be 1 m2 of the respective building element with U = 0.15 W/m²K

Assume a project installing **10,000 m² of wall per year** for **10 years**, totaling **100,000 m²**.

Equation 1 - GHG emissions of building products

Variable	Description	Value	Justification
$E_{Module\ A-D,\ product\ i}$	Emissions per functional unit (kg CO_2e/m^2)	127.81 (baseline) / 71.03 (project)	Taken from LCA results in the "1_GWP-all" sheet of the LCA report
$FU_{lifetime}$	Functional unit lifetime (years)	60	Typical service life assumption for walls in residential buildings
$PCF/LCA_{lifetime}$	Lifetime used in the LCA/PCF reports (years)	60	From the methodology and confirmed in the MMG-LCA model documentation
$Q_{material\ i}$	Quantity of product used (m²)	100,000	Based on assumed project: 10,000 m² per year over 10 years.

Equation 1:

$$\frac{FU_{lifetime}}{PCF/LCA_{lifetime}} = \frac{60}{60} = 1 \rightarrow E_{product\ i} = E_{Module\ A-D,\ product\ i} \times Q_{material\ i}$$

Values used:

$$E_{external\ wall,\ baseline} = 127.81 \times 100,000 = 12,781,000\ kg\ CO_2e = 12,781\ tCO_2e$$

$$E_{external\ wall,\ project} = 71.03 \times 100,000 = 7,103,000\ kg\ CO_2e = 7,103\ tCO_2e$$

Equation 2 - The total GHG emissions reduction

$$E_{reduction} = E_{product,\ baseline} - E_{product,\ project} = 12,781 - 7,103 = 5,678\ tCO_2e$$

Equation 3 - Carbon storage in low-carbon building product :

Variable	Description	Value	Justification
$C_{biobased\ product}$	The kilograms of carbon stored in one functional unit of biobased product [kgC/m²]	20.87	Taken from Table 4 in the LCA report
$Q_{material\ i}$	Quantity of product used (m²)	100,000	Based on assumed project: 10,000 m² per year over 10 years

Equation 3:

$$R_{removal} = R_{storage} = C_{biobased\ product} \times C_{carbon} \times C_{weight} \times Q_{biobased\ material\ i} \times \frac{FU_{lifetime}}{LCA/PCF_{lifetime}}$$

$$R_{removal} = R_{storage} = 20.87 \times 3.667 \times 0.001 \times 100,000 \times 1 = 7,653.03\ tCO_2e$$

Equation 4 - Total GHG emissions reduction and removal:

Variable	Description	Value	Justification
$E_{reduction}$	Total GHG emissions reduction (tCO_2e)	$5,678$	Results from equation 2
$R_{removal}$	Total GHG emissions removal (tCO_2e)	$7,652.83$	Results from equation 3

UF	Uncertainty factor	0.9	No uncertainty reported in the paper; conservative assumption of 10% applied

$$E_{total} = (R_{removal} + E_{reduction}) \times UF = (5,678 + 7,653.03) \times 0.9 = 11,997.93\ tCO_2e$$

References

Cabeza, L. F., Rincón, L., Vilariño, V., Pérez, G., & Castell, A. (2014). Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. Renewable and Sustainable Energy Reviews, 29, 394–416. https://doi.org/10.1016/j.rser.2013.08.037

EPD International. (n.d.). EPD Library. Retrieved November 12, 2024, from https://www.environdec.com/library

European Commission. (n.d.). Buildings and construction. Single Market Economy. Retrieved November 12, 2024, from https://single-market-economy.ec.europa.eu/industry/sustainability/buildings-and-construction_en

European Commission. (n.d.). Carbon removals and carbon farming. Climate Action. Retrieved November 12, 2024, from https://climate.ec.europa.eu/eu-action/carbon-removals-and-carbon-farming_en

European Union. (2011). Regulation (EU) No 305/2011 laying down harmonized conditions for the marketing of construction products (CPR). Official Journal of the European Union. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011R0305

Hoxha, E., Passer, A., Saade, M. R. M., Trigaux, D., Shuttleworth, A., Pittau, F., Allacker, K., & Habert, G. (2020). Biogenic carbon in buildings: A critical overview of LCA methods. Buildings and Cities, 1(1), 504–524. https://doi.org/10.5334/bc.46

Invidiata, A. (2017). Atti LCA Invidiata. Politecnico di Milano. Retrieved from https://re.public.polimi.it/bitstream/11311/1050549/1/2017%20Atti%20LCA%20Invidiata.pdf

IPCC. (2022). Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Retrieved from https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter09.pdf

IPCC National Greenhouse Gas Inventories Programme. (2000). Good practice guidance and uncertainty management in national greenhouse gas inventories. Retrieved from https://www.ipcc-nggip.iges.or.jp/public/gp/english/6_Uncertainty.pdf

ISO. (2013). ISO 14064-3:2013: Greenhouse gases—Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions. International Organization for Standardization. Retrieved from https://www.iso.org/standard/66454.html

Cabeza, Luisa F., et al. "Embodied Energy and Embodied Carbon of Structural Building Materials: Worldwide Progress and Barriers through Literature Map Analysis." Energy and Buildings, Nov. 2020, p. 110612, https://doi.org/10.1016/j.enbuild.2020.110612.

Milieu Database. (n.d.). My product in NMD. Retrieved November 12, 2024, from https://milieudatabase.nl/en/environmental-data-lca/my-product-in-nmd/

Ruyssenaars, P., et al. (2020). CO_2-vastlegging in de bodem op minerale landbouwgronden (zand, klei en löss). Wageningen University & Research. Retrieved from https://edepot.wur.nl/640116

United Nations. (n.d.). Sustainable Development Goals. Retrieved November 12, 2024, from https://sdgs.un.org/goals

Van Gulck, L., Wastiels, L. & Steeman, M. How to evaluate circularity through an LCA study based on the standards EN 15804 and EN 15978. Int J Life Cycle Assess 27, 1249–1266 (2022). https://doi.org/10.1007/s11367-022-02099-w

Wang, X., Yang, H., Liu, H., & Zhang, W. (2020). Sustainable approaches to carbon sequestration. Journal of Cleaner Production, 110612. https://doi.org/10.1016/j.jclepro.2020.110612

World Resources Institute. (2023). Quantifying and managing uncertainty in GHG inventories and assessments. GHG Protocol. Retrieved from https://ghgprotocol.org/sites/default/files/2023-03/ghg-uncertainty.pdf

Mouton, L., Allacker, K., & Röck, M. (2023). Bio-based building material solutions for environmental benefits over conventional construction products–Life cycle assessment of regenerative design strategies (1/2). Energy and Buildings, 282, 112767.