SCORE LCA

Study N°2023-01

Biogenic GHGs accounting

Summary

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SCORE LCA is an association that has been created to financially support collaborative research on LCA and related topics. It aims to promote and organize cooperation between companies, institutional and scientists in order to support the evolution of LCA methods and its practical implementation at European and international level.

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- The views and recommendations expressed in this publication are those of the authors and do not necessarily reflect, unless otherwise stated, the views of all members of SCORE LCA.
- The information and conclusions presented in this document were established on the basis of scientific and technical data and regulatory and normative framework in force at the date of the publication of documents.

1. Context and objective of the study

In Life Cycle Assessment (LCA), the accounting for biogenic carbon is much debated, but little harmonized. Different, even contradictory, approaches are found in current guides, standards and regulations for different sectors of the economy (biofuel, bio-based plastics, construction, etc.).

This study meets the following objectives:

- Establish the state of the art of methodological issues identified in the scientific literature for the accounting for biogenic carbon in LCA;
- Summarize regulatory and standards requirements, as well as the positions of a number of stakeholders, and shed light on the development of standardization in this area;
- Take a more operational look at the various methodological issues in a case study;
- Issue recommendations for standard-setting bodies, stakeholders and LCA practitioners to improve the understanding of the benefits and limitations of biogenic carbon accounting;
- Disseminate the results of this work to different audiences.

This document is a summary of the complete study available online on the ScoreLCA website (in French):

SCORE LCA, Comptabilisation des GES biogéniques, 2024, 128 pages, n°01-2023.

2. State of the art

2.1 Background and definition of terms

A carbon atom is said to be biogenic when it has been absorbed from the atmosphere by **biomass** through the process of **photosynthesis** and remains within the **short carbon cycle**. The term 'biogenic' refers specifically to the **mechanism** by which a carbon atom is absorbed from the atmosphere into the biosphere. This carbon atom is **identical to a fossil carbon atom**, and GHG emissions, whether of fossil or biogenic origin, have the **same effect on radiative forcing and climate change**.

Three categories of elementary flows may contain biogenic carbon in LCA.

- **CO_2 flows captured during photosynthesis** (sequestration). CO_2 captured during biomass growth and subsequently stored in soils is accounted for as a biogenic carbon flows caused by land use and land use change (see below).
- **Biogenic carbon flows (CO_2, CH_4 or CO) derived from the carbon content of biomass**, generally emitted to the atmosphere during biomass combustion and degradation stages (composting, landfill, etc.).
- **Biogenic carbon flows (CO_2, CH_4 or CO) caused by land use and land use change (LULUC)**. These flows are linked to the impact of human activities requiring land to be occupied and/or transformed for an activity.

GHG flows, whether of fossil or biogenic origin, have an **identical influence on climate change**. Thus, the inventory flows listed **contribute to the impact on climate change**.

2.2 Description of the main accounting approaches

The four main biogenic carbon accounting approaches are described and critically analyzed to highlight their methodological and operational advantages and disadvantages in the Table 2-1. These accounting methods **do not affect** biogenic carbon flows caused by **land use and land change**, which are detailed in a separate section.

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Table 2-1: Summary table of biogenic carbon accounting approaches, their advantages and disadvantages

	Inventory = 0/0	**FC=0/0**	**FC=-1/+1**	**Dynamic approaches**
Description	CO_{2bio} flows not inventoried, not characterized	CO_{2bio} flows inventoried, characterized with a zero characterization factor	CO_{2bio} flows inventoried, characterized as fossil flows	CO_{2bio} flows and their chronology inventoried, characterized as fossil flows
	Other GHG_{bio} flows inventoried, characterized as fossil fuels	Other GHG_{bio} flows inventoried, adjusted characterization factor	Other GHG_{bio} flows inventoried, characterized as fossil flows	Other GHG_{bio} flows and their chronology inventoried, characterized as fossil flows
Methodological issues	● Environmental impact overestimated if emissions in non-CO forms2 (CH_4, CO)	● Non-CO_2 emissions (CH_4, CO) taken into account by adjusted characterization factors	● Non-CO_2 emissions (CH_4, CO) taken into account by fossil characterization factors	● Non-CO_2 emissions (CH_4, CO) taken into account by fossil characterization factors
	● Permanent storage not accounted for	● Permanent storage not accounted for	● Permanent storage accounted for	● Permanent storage accounted for
	● Time dimension not considered	● Time dimension not considered	● Time dimension not considered	● Time dimension considered
	● Failure to maintain process mass balance	● Maintenance of mass balance	● Maintenance of mass balance	● Maintenance of mass balance
	● Impact calculation not influenced by potential choices or errors in accounting for CO_{2bio} flows , but influenced for other GHG_{bio} flows ,	● Impact calculation not influenced by potential choices or errors in accounting for CO_{2bio} flows, but influenced for other GHG_{bio} flows.	● Impact calculation influenced by potential choices or errors in accounting for carbon flows	● Impact calculation influenced by potential choices or errors in accounting for carbon flows

	Inventory = 0/0	FC=0/0	FC=-1/+1	Dynamic approaches
Operational challenges	● No data collection step for biogenic CO_2 flows	● Data collection required for biogenic CO_2 flows	● Data collection required for biogenic CO_2 flows	● Data collection required for biogenic CO_2 flows and addition of the time dimension for all inventory flows
	● Sensitivity analysis with other accounting methods not possible	● Sensitivity analysis with other accounting methods possible	● Sensitivity analysis with other accounting methods possible	● Sensitivity analysis with other accounting methods possible
	● Distorted contribution analysis	● Distorted contribution analysis	● Non-distorted contribution analysis	● Non-distorted contribution analysis
	● No particular attention to be paid to modelling carbon flows (system boundaries, multifunctionality, traceability (*mass-balance*))	● No particular attention to be paid to modelling carbon flows (system boundaries, multifunctionality, traceability (*mass-balance*))	● Particular attention to be paid to the modelling of carbon flows (system boundaries, multifunctionality, traceability (*mass-balance*))	● Particular attention to be paid to carbon flow modelling (system boundaries, multifunctionality, traceability (*mass-balance*))

Colored dots indicate whether the listed feature is more of an asset (green dot), a disadvantage (red dot) or neither (orange dot) relative to the other methods.

2.3 Methodological issues

2.3.1 Carbon flows

Biogenic carbon accounting issues linked to the choice of system boundaries, multifunctionality and traceability (*mass-balance*) arise when the FC=-1/+1 accounting approach is used.

- **Choice of system boundaries**: LCAs that do not include all life-cycle stages (particularly the stages during which biogenic carbon is sequestered and emitted) may result in a distorted interpretation of the results. Results obtained with a "cradle-to-gate" or "gate-to-grave" LCA may respectively underestimate or overestimate a product's impact on climate change.
- **Multifunctionality** :
    - An allocation of co-products **not based on the biogenic carbon content** of the products **disturbs the balance of biogenic carbon** at the process level: the quantity of biogenic carbon entering, allocated according to the chosen allocation method, is not equal to the quantity of biogenic carbon leaving. These balances can be **corrected** manually for foreground processes, and in databases for background processes.
    - The ***cut-off*** approach attributes the impacts of biogenic carbon flows from incoming or outgoing by-products and waste to the **product systems respectively upstream or downstream** of the product system under consideration. By excluding processes in the product system that could potentially sequester or emit biogenic carbon, the **balance of biogenic carbon flows** is **disturbed** at system level. These balances can also be corrected, both manually and by default in the databases.
- **Traceability (*mass-balance*)** :
    - There are four chain-of-custody models for linking inputs to an outgoing final product. In the *mass-balance* and *book-and-claim* models, traceability does not always reflect the "real", or physical, carbon content of the product.
    - The use of a certified carbon content in a model does not necessarily reflect the actual biogenic carbon content of the product, but it does reward the choices and efforts of the stakeholders involved.
    - Any model can be implemented, but **transparency**, **standardization** of practices and **control by independent entities** are necessary to ensure that the chain runs smoothly.

2.3.2 Time/dynamic and storage

Calculating the impact on climate change depends in particular on two parameters:

- **the time horizon** chosen to account for emissions and calculate impacts. In static LCA, this is generally set at 100 years;
- **the time at which the elementary flow** is emitted or absorbed. In static LCA, all elementary flows are assumed to be emitted or absorbed at t=0.

In addition, two main issues are more specifically linked to the dynamics of accounting for biogenic carbon flows in LCA:

- the dynamics **between carbon capture and emission**, linked to the biomass growth cycle. The slower the biomass grows, the longer the sequestration, the more carbon remains in the atmosphere and has an impact;
- the question of carbon **storage** (temporary or permanent) in materials and products. **Temporary carbon storage** means keeping carbon out of the atmosphere for a certain period of time. It is sometimes associated with an environmental credit (impact avoided). **Permanent storage** corresponds to an emission that takes place beyond the chosen time horizon and is

therefore not considered in the LCA.

Several **dynamic** methods exist to take into account time and storage aspects.

- Some methods, referred to in this study as "**selective dynamic accounting approaches"**, allow dynamic aspects specifically linked to biogenic carbon flows to be taken into account, and are combined with static LCA, but present inconsistencies from a methodological point of view.
- **Dynamic accounting approaches** consider all dynamic parameters for the entire inventory (biogenic and non-biogenic flows) but require additional data collection effort and the use of specific tools. Dynamic approaches make it possible to visualize changes in impact over time. The results obtained are not easily comparable with those of static approaches but provide additional information for decision-making.

In general, practitioners do **not consider dynamic approaches in LCA** due to the lack of consensus as to which approach to adopt, the difficulty of their implementation and the complexity of their interpretation. **With the exception of temporary storage,** which is **sometimes considered** with selective dynamic approaches.

2.3.3 Land use and land use change

Biogenic carbon stored in soil and vegetation is affected by **land use and land use change** (**LULUC**).

- Two types of activity are differentiated: **land occupation** (maintaining an activity at a certain intensity for a certain time) and **land use change (LUC)**, which includes land assignment change (converting land from one use to another) and land management change (changing agricultural or forestry practices).
- Two types of LUC are differentiated: **direct LUC** (dLUC, caused directly by land that is occupied and/or transformed by the product system under study) and **indirect LUC** (iLUC, caused outside the system under study by market mechanisms). Of the two, **only the dLUC are generally taken into account**.
- LULUC influence climate change, soil quality and biodiversity. The issue of accounting for LULUC emissions for climate change impact is linked to the **quantification of emissions at the inventory level**. These emissions then contribute to the impact on climate change in the same way as other emissions in the inventory.
- Most models for quantifying LULUC emissions are based on the IPCC Tier 1 approach. However, another approach is recommended by the Life Cycle Initiative (GLAM): the Müller-Wenk and Brandão approach.

This issue remains an ongoing research topic requiring further development for harmonized operationalization.

3. State of the art of biogenic carbon accounting requirements and practices

The Table 3-1 provides an overview of regulatory and standards requirements and the positioning of public and private players in the field of biogenic GHG accounting.

Table 3-1 : Table summarizing regulatory and normative requirements and the positioning of public and private stakeholders for biogenic GHG accounting.

Issues		Standards response
Accounting approach	**Inventory**	Often **mandatory** monitoring of biogenic carbon flows. Nomenclature: flow explicitly identified by "biogenic" in its name. Product Category Rules (PCRs) often require tracking of biogenic carbon flows **between modules** (EN 15 804 and derived PCRs).
	Characterization method	**FC=0/0 approach:** mandatory **in PEF** (2018) (factor adjusted for CH_4, unless contraindicated by a PCR), sometimes possible (e.g. in the ILCD Handbook (2010) which does not give a specific method to follow). **FC=-1/+1 approach**: generally recommended (GHG Protocol (2011), PAS 2050 (2011), EN 15804+A2 (2019), EN16485, EN 16760, ISO 14067 (2018)...).
Multifunctionality	**General hierarchy**	In general, ISO 14040-44 hierarchy.
	Specific to carbon flows	In general, biogenic carbon must be **allocated according to the reality of physical flows, regardless of the choice of allocation**.
Time/dynamic and storage	**Dynamic LCA**	Not mentioned except in ISO 14 067, general method proposed to take into account temporal aspects.
	Storage	● **Temporary storage:** - Not considered (EN 15804+A2 (2019), PEF (2018)) - Not considered unless specified in the objectives of the study (ILCD Handbook (2010)) - Can be calculated, but must be declared separately (ISO 14 067, GHG Protocol (2011)) - Must be taken into account (PAS 2050 (2011)) If taken into account, calculation methods are : - Simplified Lashof method (ILCD Handbook (2010), EN 16760) - Multiplication factor (PAS 2050 (2011)) - Simplified Levasseur method (RE2020) ● **Permanent storage :** - Not considered (ISO 14067 (2018), EN 15 804) - Taken into account (carbon considered to be

Issues		Standards response
		stored indefinitely if emitted after 100 years) (PEF (2018), PAS 2050 (2011))
Land use and transformation (LULUC)	**dLUC**	To be included for all standards and guidelines, but sometimes to be reported separately - Often, 20-year amortization and IPCC Tier 1 method for calculating emissions (PAS 2050 (2011), PEF (2018)) - Müller-Wenk and Brandão method (ILCD Handbook (2010)) LULUC flows from old-growth forests are sometimes accounted as fossil emissions dLUC are usually included
	iLUC	Not generally considered, due to lack of consensus in calculating them The ILCD Handbook (2010) allows quantification if justified by the study objective (consequential approach)

4. Case study

The aim of this case study is to **illustrate how the methodological issues mentionned are operationalized** in an LCA database and software. Different materials used in the **construction of a building** (concrete, wood and bamboo) are compared. Using SimaPro software and the *ecoinvent* version 3.9.1 database, this study tests the **FC=0/0**, **FC=-1/+1** and several **dynamic approaches**, and proposes an example of adapting biogenic flows linked to **land use and land use change** to the context of the study.

The FC=0/0 and FC=-1/+1 approaches give different impact scores, mainly due to an **imbalance in the biogenic carbon mass balance at system level**. This imbalance is mainly caused by **permanent carbon storage** (notably through landfilling), **co-product allocation** and ***cut-off***. The **corrections** made in the *ecoinvent* database*, as* well as those recommended to practitioners, are discussed in detail. This case study highlights the **complexity of tracking biogenic carbon flows** in the system with currently available software.

The selective dynamic approaches tested include the **tonne-year** approach **adapted by the ILCD Handbook** and the **GWPbio** approach, which add an environmental credit or impact to the results obtained with static approaches. Despite their relative ease of implementation, these approaches do not treat all inventory flows exhaustively and consistently. In addition, the **dynamic Levasseur approach** is evaluated, offering the possibility of tracking the evolution of the impact on climate change over time, which complements the static results for decision-making. All calculation steps are explained to facilitate their implementation by practitioners.

Finally, the integration of the climate change impact of **land use and land use change** into *ecoinvent* is detailed. The example of oil palm cultivation is used to demonstrate the importance of **adapting the calculation** of the impact of land use and land use change on climate change **to the context of the study**, particularly for agricultural and forestry products where this impact can be significant.

5. Conclusions and recommendations

Summary of recommendations

Accounting approach

General recommendations

As biogenic carbon is the same atom and has the same impacts as fossil carbon, it should not be treated differently in LCA.

- Always prioritize the FC=-1/+1 approach.
- The FC=0/0 approach can be used for systems where biobased products are not the focus of the study, or where biogenic carbon flows do not contribute significantly to the final impact.

Recommendations for practitioners

- Ensure that the inventory of biogenic carbon flows is complete.
- Adjust the biogenic carbon balance in case of imbalance, prioritizing the foreground and the most contributing processes.
- Use databases that include all biogenic carbon flows (sequestration and biogenic GHG emissions).
- Use disaggregated databases to access (and possibly correct) biogenic carbon flows in processes.

Recommendations for databases

- Include all biogenic carbon flows (conservation of mass).

Summary of recommendations

Carbon flows: choice of system boundaries, multifunctionality and traceability (*mass-balance)*

General recommendations

- The treatment of multifunctionality must be adjusted for biogenic carbon (allocation according to biogenic carbon content or correction).
- The choice of traceability method does not affect the final carbon balance. However, flow traceability and documentation are required to calculate these balances.

Recommendations for practitioners

- Consider all life cycle stages involving biogenic carbon sequestration or emissions. Failing that, explicitly highlight the influence of the choice of system boundaries on the results and their interpretation.
- Calculate and verify the biogenic carbon balance.
- Use databases that correct allocation problems (co-products and *cut-offs*).
- Manually adjust imbalances resulting from multifunctionality (co-products and *cut-offs*).
- In the case of boundary expansion, consider all life-cycle stages involving sequestration or emissions for the substituted system.
- The use of actual or certified biogenic carbon content must be transparently documented throughout the product value chain.

Recommendations for databases

- Include biogenic carbon content for all flows.
- Include correction flows for the background (co-product allocation and *cut-off*).
- Parameterize processes according to the biogenic carbon content of incoming or outgoing flows.
- Facilitate the monitoring of biogenic carbon in the system (e.g. enable material flow analysis of biogenic carbon).

Summary of recommendations

Time/dynamic and storage

General recommendations

- Carry out a dynamic LCA only if relevant in the context of the study (e.g. in the case of significant temporary storage or long biomass rotation cycles).
- Prioritize dynamic approaches over selective dynamic approaches, which maintain consistency across all inventory flows.
- Continue to develop and update characterization factors, approaches and dynamic LCA tools.

Recommendations for practitioners

- Determine the relevance of the approach with a contribution analysis and an estimation of temporarily stored carbon.
- Build a dynamic inventory (which emission at which time) in an iterative way to find the balance between the level of detail and the time spent on modeling.
- Present separately the contributions obtained using selective dynamic methods (tonne.year, GWPbio).
- Present and interpret the results obtained using dynamic approaches without comparing them with those of static LCA.

Recommendations for databases

- Integrate temporal information on flows when relevant (lifespan, biomass rotation period, chronology of flows, etc.).
- Develop specific data on biomass growth dynamics (particularly for wood).
- Build a dynamic inventory.
- Integrate the ability to perform dynamic LCAs directly within LCA software.

Summary of recommendations

Land use and land use change

General recommendations

- If possible, include the impacts of land use and land use change on climate change.
- Choose the most appropriate tool for identifying LUCs, based on the resources allocated to the study.
- If possible, include land management changes when assessing LUC impacts.
- Include iLUCs if required, depending on the study context.

Recommendations for practitioners

- Use databases that include LUC emissions.
- Use disaggregated databases to adapt processes to the study context.
- If possible, adapt database processes with data specific to the study.

Recommendations for databases

- Parameterize and disaggregate data to calculate LUC emissions, and document them clearly.
- Follow the evolution of research on iLUC calculation and inclusion.