Comparative carbon footprint of uses of wood residues and low-grade roundwood

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Summary and key Drax take-aways undertaken by:
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Summary

This report evaluates the climate impact of different end-uses of wood residues and low-grade roundwood (pulpwood) using lifecycle assessment (LCA).

It calculates greenhouse gas (GHG) emissions from 'forest gate' to product end-of-life for bioenergy, bioenergy with carbon capture and storage (BECCS), biochar, sustainable aviation fuel (SAF), pulp and paper, and oriented strand board (OSB, a type of wood panel). The assessment includes emissions from the production and use of the wood products and potential avoided emissions from substitution for non-wood product alternatives.

Drax commissioned the report, Anthesis Consultants wrote it, and third-party experts for conformity to International Organization for Standardization (2018)* independently peer reviewed it.

Key Drax take-aways

1. LCA results
   - All considered uses and feedstocks deliver climate benefits by offering a reduction in carbon emissions relative to the products they replace.
   - Among all considered uses of forest residues, BECCS provides the greatest climate benefits. The next best use is unabated bioenergy, followed closely by biochar.
   - Among all considered uses of manufacturing residues and pulpwood, OSB provides the greatest climate benefits, followed by BECCS, then bioenergy. Therefore, BECCS (and all other considered uses) should try to avoid displacing OSB production.
   - For all considered feedstocks, BECCS ranks best or second best in the merit order for delivering climate impact. Although unabated bioenergy delivers lower climate impact than BECCS, it delivers greater climate benefits than some other pathways, including biochar (similar), SAF, pulp and paper.
   - Rankings are insensitive to the geographical context (i.e. US versus Europe). Therefore, the benefits of BECCS and bioenergy hold true even when feedstocks are transported/shipped long distances from the US to Europe.
2. Policy implications
   - This LCA study suggest that BECCS and bioenergy are among the best uses of (low grade) wood feedstocks for delivering climate benefits. However, sustainability criteria like the European Renewable Energy Directive (REDIII) use a cascading principle for determining best use of (low grade) wood, based primarily on product longevity, which positions BECCS and bioenergy at the bottom of the merit order.
   - The results suggest that future iterations of REDIII should incorporate LCA techniques more fully, to develop a more holistic view of the environmental outcomes of different wood feedstocks and end uses.

*Greenhouse gases—Carbon footprint of products – Requirements and guidelines for quantification (ISO 14067:2018).

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Comparative Carbon Footprint of Uses of Wood Residues and Low Grade Roundwood

According to ISO 14067

Version 1.3
January 6, 2025

Study Undertaken on Behalf of:

Drax

Author:

Caroline Gaudreault

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Anthesis Group is a global leader in sustainability consulting, established in 2013, with a mission to guide organizations toward sustainable performance. The company leverages its extensive expertise in science-based advisory services, the development of high-quality carbon removal projects, purpose-driven storytelling, backed by digital solutions to help clients navigate the complexities of sustainability. With a team of over 1,400 experts, Anthesis focuses on creating value through innovative strategies that align profit with purpose. Anthesis emphasizes the importance of positive impact for both clients and the planet, addressing the challenges of sustainable compliance and performance. With in a presence in 23 countries, Anthesis continues to expand its global footprint while maintaining a commitment to excellence in sustainability practices.

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Executive Summary

Background

Drax is committed to achieving a positive economic, social, and environmental impact and to creating long-term value. Limiting global warming to 1.5 degrees Celsius requires fundamental change across all sectors of the economy and society. *Principally, fossil fuels and fossil fuels-based products must be phased out and replaced with sustainable, renewable alternatives. In this context,* Drax wanted to understand how using various wood feedstocks, including forest residues, wood processor residues, and pulpwood for bioenergy compares to other uses of wood from a carbon perspective.

Drax has commissioned Anthesis LLC ("Anthesis") to compare the carbon emissions of using different wood feedstocks at the point of generation of electricity generation with BECCS to other uses of wood.

Goal & Scope Definition

The specific objective of this study is to compare the carbon emissions of using different wood feedstocks at the point of generation of electricity with BECCS to other uses.

Feedstocks included in this study include harvest residues, wood processor residues, and low-grade roundwood (roundwood that does not meet sawmill-grade) for electricity generation.

The study strives to apply the best practices from ISO 14067.

In consequence, the goal of this study is not to calculate precise carbon savings associated with the use of wood for producing electricity but rather to get an understanding of the magnitude of these savings, if any, in contrast to that of other uses of wood. The scope of this study does not include sawlogs as a feedstock, but instead focuses on lower grade wood types that are most likely to be used for electricity generation.

Drax intends to use these results both internally and externally (e.g., upload to Drax' 'Evidence Hub', a public facing web page for sharing Drax-commissioned peer reviewed evidence and drafting of a white paper summarising results for policymakers) for the purpose of informing debate on the relative merits of bioenergy and BECCS compared to other uses of wood feedstocks.

The system boundary of this LCA study is from the generation of the wood feedstock to the end-of-life of the product from this use. This includes the transport of the feedstock, manufacturing processes, transport to customer/client, use of the product and final disposal. In the case of use of wood for energy, the system boundaries finish at the point of energy production. In addition, the system boundaries are expanded to include the avoided production of the secondary function.

The functional unit for this study, which describes the function provided by the product system and serves as a basis of comparison between systems, is defined as:

"The use of one dry tonne of wood feedstock."

Each different use of wood feedstock will generate a secondary function that will need to be addressed through allocation.

Uses of woody biomass and reference flows as well as data used to derived these are presented in Table 1.

Table 1. Uses of Wood Feedstocks and Reference Flows

Use Pathway	Rationale	Reference flow
Electricity in the US (from chips, w/o BECCS)	In this study we do not attempt to identify the actual source of electricity that is substituted. Instead, we assume that the average national electricity mix minimizes the uncertainty around what type of electricity is displaced. We use the residual mixes to be consistent with ISO 14067 requirements.	1 t
Electricity in the US (from chips, w/ BECCS)		1 t
Electricity in the UK (from pellets, w/o BECCS)		0.96 t
Electricity in the UK (from pellets, w/ BECCS)		0.96 t
Use	**Rationale**	**Reference flow**
PE-coated paperboard plates	One important use of wood residues is for making wood pulp. Pulp can be used for many types of products. Here, to be conservative, we chose a use of pulp that would typically results in lower GHGs than its main substitute (plastic plates).[1]	0.49 t
Sustainable aviation fuel (SAF)	Direct substitution.	0.036 t
Biochar	Biochar is a carbon-rich soil amendments that can be used as the replacement material for other materials such as straw and compost. Here the substituted product was based on one study comparing the performance of these materials (data availability).	0.16 t
OSB	The substitutes for OSB are not obvious. For instance, US-made OSB might substitute Chinese OSB. To be conservative, we used a published study which assumed OSB, MgO board and fibre cement can all be used for sheeting with various thicknesses for structural equivalence.	0.83 t

This study has been undertaken according to the requirements of ISO 14067 for product carbon footprints (CFPs) and ISO 14026 for communication of footprint information.

[1] NCASI. 2020. Review of Life Cycle Assessments Comparing Paper and Plastic Products. NCASI White Paper. https://www.ncasi.org/wp-content/uploads/2020/11/WP-20-09_Plastic_vs_Paper_LCA_Review_Nov2020.pdf

Data Collection

In this study, primary data were collected for all processes under the operational control of Drax. For each process, a representative facility was selected. Data was collected for one year of production. All other processes were modelled using secondary data including ecoinvent v3.10 allocation cut-off by classification, US LCI, and various literature sources. Although the version of US LCI implemented in SimaPro is rather old, it was still preferred over ecoinvent for most fossil fuels to avoid converting from physical to energy units. The SimaPro v9.6.0.1 software was used to conduct the LCA.

Quantification of the Carbon Footprint

The CFP of the product(s) is calculated by applying the 2023 100-year GWP from IPCC AR6. Removals[2] of CO_2 into biomass are characterized in the LCIA as −1 kg CO_2e/kg CO_2 in the calculation of the CFP when entering the product system. Emissions of biogenic CO_2 are characterized as +1 kg CO_2e/kg CO_2 of biogenic carbon in the calculation of the CFP.

Note that a carbon footprint is one of many environmental indicators, and it cannot be used to the only basis for discussing the overall environmental preferability.

Critical Review

The critical review intends to ensure consistency between the CFP study and the principles and requirements of ISO 14067. For this study, a two-reviewer critical review was undertaken:

- Pakarat Promyu, First Environment, and
- Reid Miner, Independent consultant.

Mrs. Promyu was responsible for reviewing the study against the requirements of ISO 14067, while Mr. Miner emphasis was on the technical aspects and assumptions made in comparing the various uses of wood feedstocks.

Results

Carbon Footprint Results

It is evident from the results as shown in Table 2, that all use pathways result in carbon benefits relative to their substitutes. Among all the use pathways studied, the use pathway of OSB that displaces MgO board results in the greatest carbon benefits (-4104 kgCO_2e/t). Secondly, for producing electricity with carbon capture using the wood feedstocks in the form of chips and pellets leads to carbon benefits of -2304 kgCO_2e/t (US) and -2107 kgCO_2e/t (UK), respectively, which is in the same order of magnitude of using OSB to displace fibreboard (-2686 kg CO_2e/t). The use of wood feedstock for paper plates and SAF production leads to the smaller carbon benefits, which can be attributed to the use of fossil fuels involved in these use pathways as well as the relatively low carbon footprint of producing the substitute.

[2] In this report, “removal” refers to, consistently with ISO 14067, the removal of carbon from the atmosphere and not to the removal of wood from the forest.

Table 2. Detailed CFP results (kg CO_2e/t)

Use pathway	Fossil GHGs	Biogenic GHGs*		Biogenic CO_2 uptake*	Net
		CO_2	CH_4		
	kg CO_2e/t				
Electricity in the US (from chips, w/o BECCS)	-694	1833	4.6	-1833	-689
Electricity in the US (from chips, w/ BECCS)	-568	91.7	4.6	-1833	-2304
Electricity in the UK (from pellets, w/o BECCS)	-579	1833	0.4	-1833	-578
Electricity in the UK (from pellets, w/ BECCS)	-447	172	0.4	-1833	-2107
PE-coated paperboard plates	-1227	1648	1116	-1833	-295
Sustainable aviation fuel (SAF)	-48.9	1833	0	-1833	-48.6
Biochar	-38	1407	0	-1833	-464
OSB – Fibre cement board	-1691	485**	353**	-1313**	-2686
OSB – MgO board	-3451	805	375	-1833	-4104

NOTE: Differences between number in this table and carbon balances in the figures are due to rounding and background processes. *CO_2 emissions and uptake from biofuels other than from the feedstock are excluded from the analysis. **This pathway is the only one not showing the same net carbon uptake and for which the emission of biogenic GHGs cannot be directly derived from the figures because fibreboard (the substituted product) is partly made from wood pulp.

Sensitivity Analyses

Sensitivity analyses were undertaken on parameters that includes pre-processing of wood feedstock (electricity pathways), location of production of PE-coated paperboard plates, carbon intensity of jet fuel (SAF pathway), and various sensitivity analysis on the OSB Pathway that are likely to affect the results of the analysis.

Pre-Processing of Wood Feedstock (Electricity Pathways)

The implication of additional pre-processing for electricity processing is assessed in this sensitivity analysis. It is observed from the sensitivity analysis that the assumption to neglect pre-processing of wood feedstocks had little effect on the results.

Location of Production of PE-Coated Paperboard Plates

This sensitivity analysis assessed that the paperboard plate is produced in Europe rather than in the US. Results show that the location of production of paperboard plates is relatively insensitive to the location of production.

Carbon Intensity of Jet Fuel (SAF Pathway)

This sensitivity analysis assessed the implications of assumed carbon intensity for jet fuel for the performance of the SAF pathway. The results shows that the assumption about the carbon intensity of jet fuel production, while having significant implications for the results of this pathway, does not affect the ranking of SAF within the various use pathways.

OSB Pathway

If OSB substitutes for OSB from China and not for fossil fuel-based alternative, the carbon benefits of using wood feedstocks in OSB are much lower. MgO board has much shorter reported lifetime than OSB. If we assume that MgO board has half as long of a lifetime than OSB, the benefits from avoiding MgO board production will double, which will not change the ranking of options. Assuming that a product can be credited for temporary carbon storage increases the benefits of using wood feedstocks in long-lived product over short-lived. Finally, producing OSB in Europe instead of in the US has marginal implications for the results.

Conclusion and Recommendations

The following conclusions can be drawn from the study:

- All use pathways resulted in carbon benefits compared to their substitution.
- The use of wood feedstocks for producing electricity with BECCs, although not leading to the greatest observed benefits, still ranked relatively high and consistently with that of producing OSB (in some substitution scenarios).
- The use of wood feedstocks for producing electricity without BECCs produced lower carbon benefits, but these were still higher than carbon benefits of some other pathways.
- Rankings are insensitive to the geographical context (i.e., US versus Europe).

Limitations

The results within this report are mainly limited by the fact that primary data was only available for the electricity pathways. Secondary data was used to model all other pathways and results showed to be relatively variable. As such, results of this study cannot be used to make precise quantitative claims. In addition, the study compares the carbon impacts of static and independent systems and does not evaluate the dynamic implications of moving the wood feedstock from one use to the other. The results do not, therefore, reveal the overall effects of, for instance, increasing the competition for woody biomass where bioenergy and wood product systems are relying on common sources of raw materials. Where changes in raw material availability and cost are imposed, bioenergy and forest product systems would likely respond differently.

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Abbreviations and Acronyms

BECCS	Bioenergy with carbon capture and storage
CCS	Carbon capture and storage
CFP	Carbon footprint of product
CO_2	Carbon dioxide
dLUC	Direct land use change
GHG	Greenhouse gas
GWP	Global warming potential (in general in g or kg of CO_2e)
iLUC	Indirect land use change
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
kWh	Kilowatt-hour
LCA	Life cycle assessment
LCI	Life cycle inventory
LUC	Land use change
MgO	Magnesium oxide
OSB	Oriented strandboard
PE	Polyethylene
SAF	Sustainable aviation fuel
SBP	Sustainable Biomass Program

Definitions

Material	Definition in this study	Closest equivalent in SBP[3]	SBP definition
Harvest residues	Tree-tops, branches, small stems.	Forest residues	A forest residue is a feedstock directly generated in the forest for which there is no alternative use. These residues do not include residues from related industries or processing. Examples include feedstock comprising branch wood, diseased wood, and storm salvage from natural disturbances, end of life timber plantations, or treetops.
Low grade roundwood	Pulpwood (roundwood suitable for pulp mills) and other roundwood that does not meet sawmill-grade due to size, straightness, and other quality issues.	Low grade stemwood	Wood from the stem of a tree (i.e., excludes branches, stumps and roots) that is not merchantable as sawtimber in local markets. This excludes salvage trees, end-of-life trees, and trees removed for nature conservation.
Sawlogs	Sawmill-grade (high-grade) roundwood.	High grade stemwood	Wood from the stem of a tree (i.e., excludes branches, stumps, and roots) that is merchantable as sawtimber in local markets. This also excludes salvage trees, end of life trees, and trees removed for nature conservation.

[3] Sustainable Biomass Program (SBP). 2023. Glossary of Terms and Definitions. Version 2.0. https://sbpcert.wpenginepowered.com/wp-content/uploads/2023/05/SBP_Standards_Glossary_v2.0_final.pdf

Material	Definition in this study	Closest equivalent in SBP[3]	SBP definition
Wood processor residues	Wood processor / sawmill residues such as such as bark, sawdust, chips, or off-cuts.	Processing residues/Wood industry or sawmill residues	Feedstock such as bark, sawdust, slab wood, or residues arising from a primary or secondary wood processor; any wood rejected by a sawmill. Sawdust, shavings produced during the processing of wood at the sawmill/wood industry. Chips, offcuts produced during the processing of wood at the sawmill / wood industry, that may include small offcuts or also bark that has been stripped from the wood.

1 Goal of the Study

1.1 Background

Drax is committed to achieving a positive economic, social, and environmental impact and to creating long-term value. Limiting global warming to 1.5 degrees Celsius requires fundamental change across all sectors of the economy and society. Principally, fossil fuels and fossil fuels-based products must be phased out and replaced with sustainable, renewable alternatives. We need more timber in construction to replace steel and carbon; and we need sustainable, renewable technologies in our power system too. This means renewable power generation must be maximised. Investment in technologies such as sustainable biomass, energy storage, and hydrogen can balance and stabilise the electricity grid and enable more intermittent renewables, such as wind and solar, to come online. Alongside carbon emission reductions, negative emissions technologies and techniques are needed to remove carbon from the atmosphere. These technologies will be critical to help decarbonise harder-to-abate sectors such as agriculture and aviation so we can meet net zero by 2050 faster, and even go beyond it – helping to lower the carbon concentration in the atmosphere. In this context, Drax was interested in understanding how using wood, including pulpwood, forest residues and wood processor residues, for bioenergy compares to other uses of wood from a carbon perspective.

1.2 The Life Cycle Carbon Footprint Approach

A carbon footprint (CFP) is the sum of GHG emissions and GHG removals[4] in a product system expressed as CO_2 equivalents and based on a life cycle assessment (LCA) using the single impact category of climate change. LCA is a decision support tool that allows quantitative environmental profiles to be generated for different products systems. The methods employed in this study are consistent with the international standards for LCA (ISO 14040/44[5,6]) and follow the required four-stage iterative process below (and represented in Figure 1).

1. **Goal and scope definition:** The first stage of LCA is to define the goal and scope of study to understand the objectives and intended applications, the boundaries of what is being assessed, and the performance requirement that the product fulfils.
2. **Inventory analysis:** The second stage is inventory analysis, in which an inventory of flows to and from nature is created, usually using a combination of primary and secondary data collected for each unit process of the product system.
3. **Impact assessment:** The third stage is impact assessment, through which inventory data are applied to characterization factors to generate the main results and determine the environmental impacts.
4. **Interpretation:** The final stage is interpretation, when conclusions are drawn, sensitivity and uncertainty analyses are performed, and recommendations made.

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[4] In this report, "removal" refers to, consistently with ISO 14067, the removal of carbon from the atmosphere and not to the removal of wood from the forest.

[5] ISO. 2006. Environmental Management – Life Cycle Assessment – Principles and Framework. ISO 14040.

[6] ISO. 2006. Environmental Management – Life Cycle Assessment – Requirements and Guidelines. ISO 14044.

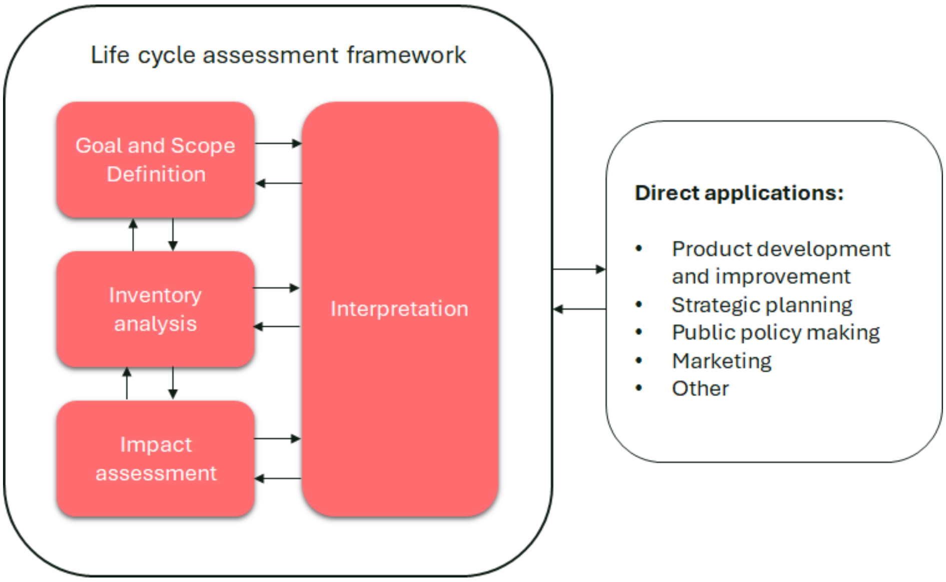

Figure 1: The four stages of LCA as defined by ISO 14040

In addition, this study has been undertaken according to the requirements of the ISO 14067 Standard[7] for product carbon footprints (CFPs) and the ISO 14026 Standard[8] for communication of footprint information.

The following LCA practitioners from Anthesis were involved in this project:

- Nydia Lynch, Ph.D., Principal Consultant;
- Carol Hee, Ph.D., MBA, Principal Consultant; and
- Caroline Gaudreault, Ph.D., Director and LCA Services Lead.

1.3 Objective of the Study

The objective of this study is to compare the carbon emissions of using different wood feedstocks at the point of generation of electricity generation with BECCS to other uses of wood. By "at the point of generation," we mean that the study looks at existing feedstocks (not additional) and compares the carbon emissions of different pathways for these feedstocks, with no implication for forest management. Feedstocks included in this study includes harvest residues, wood processor residues, and low grade roundwood.

The scope of this study does not include sawlogs as a feedstock, but instead focuses on lower grade wood types that are most likely to be used for electricity generation. However, there are documented carbon benefits of wood products compared to fossil-fuel based alternatives (e.g.,

[7] ISO. 2018. Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification. ISO 14067.

[8] ISO. 2017. Environmental Labels and Declarations – Principles, Requirement and Guidelines for Communication of Footprint Information. ISO 14026.

Leskinen et al. 2018[9], Sarthre and O'Connor 2010[10]) which provide interesting contextual information to this study. Hence, the results obtained here will also be discussed in this context.

The study uses primary data to produce energy from Drax, but secondary data from a mix of literature and life cycle inventory databases. In addition, end uses for products derived from wood feedstocks and the products they potentially substitute for are numerous. In consequence, the objective of this study is not to calculate precise carbon savings associated with the use of wood for producing electricity, but rather to get an understanding of the magnitude of these savings, if any, in contrast to that of other uses of wood. At the same time, the study strives to apply the best practices from ISO 14067.

Table 3. Uses of wood considered in this study

Feedstock categories	Use pathways
Harvest residues	Electricity in the US (from chips, w/ and w/o BECCS) Electricity in the UK (from pellets, w/ and w/o BECCS) Sustainable aviation fuel (SAF) Biochar
Wood processor residues	Electricity in the US (from chips, w/ and w/o BECCS) Electricity in the UK (from pellets, w/ and w/o BECCS) PE-coated paperboard plates (from pulp) Sustainable aviation fuel (SAF) Biochar OSB
Low grade roundwood	Electricity in the US (from chips, w/ and w/o BECCS) Electricity in the UK (from pellets, w/ and w/o BECCS) PE-coated paperboard plates (from pulp) Sustainable aviation fuel (SAF) Biochar OSB

NOTE: Some specific feedstocks within a feedstock category may not be suitable for a given use. In this study, we assumed that solely the proper feedstock would be used.*

[9] Leskinen, P., Cardellini, G., Gonzalez-Garcia, S., Hurmekoski, E., Sathre, R., Seppala, J., Smyth, C., Stern, T. Verkerk, J. 2018. Substitution Effects of Wood-Based Products in Climate Change Mitigation. From Science to Policy 7. European Forest Institute. https://efi.int/sites/default/files/files/publication-bank/2019/efi_fstp_7_2018.pdf

[10] Sathre, R., O'Connor, J. 2010. Meta-Analysis of Greenhouse Gas Displacement Factors of Wood Product Substitution. *Environmental Science & Policy*. 13(2). pp. 104-114.

1.4 Intended Application and Audience

Drax intends to use these results both internally and externally (e.g., upload to Drax' "Evidence Hub," a public facing web page for sharing Drax-commissioned peer reviewed evidence and drafting of a white paper summarising results for policymakers) for the purpose of informing debate on the relative merits of bioenergy and BECCS compared to other wood-uses. Note that this debate also needs consideration of the carbon impacts of potential dynamic competition for raw materials which are not addressed by this report.

Communication is made in accordance with ISO 14067 and ISO 14026. A footprint addresses a specific area of concern. As such, it does not cover overall environmental performance and cannot form the only basis of a comparative assertion. A comparative footprint communication shall not be regarded as a comparative assertion.

2 Scope of the Study

2.1 Functional Unit

The functional unit for this study is defined as:

"The use of one dry tonne of wood feedstock."

Each different use of wood feedstock will generate a secondary function that will need to be addressed through allocation. This is further discussed in Section 2.4.1.

2.2 System Boundaries

2.2.1 Physical Boundary

As depicted in Figure 2, the system boundary of this LCA study is from the generation of the wood feedstock to the end-of-life of the product from this use. This includes the transport of the feedstock, manufacturing processes, transport to customer/client, use of the product, and final disposal. In the case of use of wood for energy, the system boundaries finish at the point of energy production. In addition, the system boundaries are expanded to include the avoided production of the secondary function. See details in Section 2.4.1.

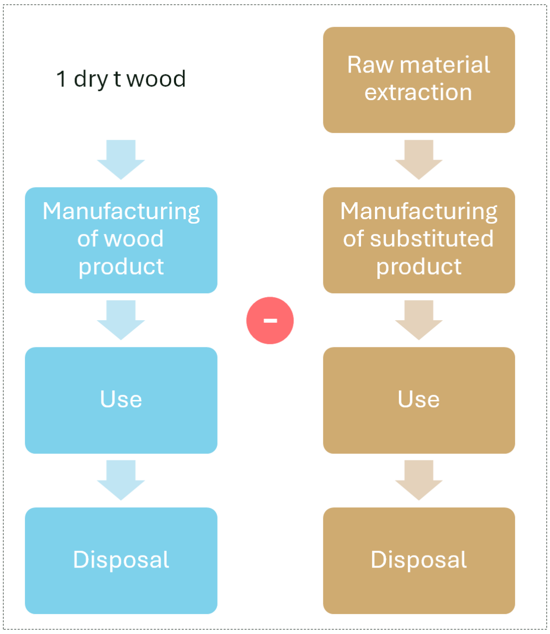

Figure 2: Simplified system boundaries

2.2.2 Geographical Scope

The wood feedstocks are produced in the US. Wood pellets are shipped to the UK for electricity production. Other uses of wood are assumed to be in the US where the wood feedstocks are derived from, but where possible, sensitivity analyses are undertaken for the European market.

2.2.3 Time Boundary

Primary data is representative of 2023.

All GHG emissions and removals have been calculated as if released or removed at the beginning of the assessment period without considering the effect of delayed GHG emissions and removals. A sensitivity analysis that accounts for time in storage was also undertaken.

2.3 Exclusions and Cut-Off Criteria

No cut-off was applied.

Activities included and excluded from the system boundary are listed in Table 4.

Table 4. Activities included and excluded from system boundary

Included	Excluded
✓ Transportation of raw material inputs ✓ Product manufacturing incl. energy use, auxiliaries, and emissions ✓ Transport and disposal of manufacturing waste	× Packaging × Capital equipment, construction, and maintenance × Human labour and employee commute × Product development, prototyping, research, administration × Product packaging

2.4 Allocation

2.4.1 Secondary Functions

The use of wood feedstocks results in a secondary function which is different for each type of uses. Hence, to be able to compare all uses based on 1 dry tonne of feedstock, it is necessary to apply an allocation approach to handle the secondary function. In this study, we applied system expansion. The product system is expanded to include additional functions related the product system that is substituted by the co-product. In practice, the co-products are compared to other substitutable products, and the environmental burdens associated with the substituted product(s) are subtracted from the product system under study (see example in Figure 2).[11] The application of system expansion involves an understanding of the market for the co-products. In this study, some uses of wood feedstocks can substitute for a wide variety of products. In general, substituted products were selected based on three criteria:

- Likelihood;
- Conservativeness (in the context of the objective of the study); and
- Data availability.

[11] ISO. 2020. Environmental Management – Life Cycle Assessment – Requirements and Guideline. ISO 14044 Amendment 2.

Table 5. Uses of wood, secondary functions and reference flows

Use pathway	Reference flow	Secondary function	Quantity	Substituted product	Reference flow	Rationale
Electricity in the US (from chips, w/o BECCS)	1 t	Electricity	1.55 MWh	Residual US grid mix	1.55 MWh made from a mix of fuels	In this study we do not attempt to identify the actual source of electricity that is substituted. Instead, we assume that the average national electricity mix minimizes the uncertainty around what type of electricity is displaced. We use the residual mixes to be consistent with ISO 14067 requirements.
Electricity in the US (from chips, w/ BECCS)	1 t	Electricity	1.29 MWh	Residual US grid mix	1.29 MWh made from a mix of fuels	
Electricity in the UK (from pellets, w/o BECCS)	0.96 t	Electricity	1.99 MWh	Residual UK grid mix	1.99 MWh made from a mix of fuels	
Electricity in the UK (from pellets, w/ BECCS)	0.96 t	Electricity	1.70 MWh	Residual UK grid mix	1.70 MWh made from a mix of fuels	

(Table continued on next page.)

Table 5. (Cont'd)

Use	Reference flow	Secondary function	Quantity	Substituted product	Reference flow	Rationale
PE-coated paperboard plates	0.49 t	Plates	29747 plates	Polystyrene plates	0.32 t	One important use of wood residues is for making wood pulp. Pulp can be used for many types of products. Here, to be conservative, we chose a use of pulp that would typically results in lower GHGs than its main substitute (plastic plates).[12]
Sustainable aviation fuel (SAF)	0.036 t	Energy for aviation	3103 MJ[13]	Jet fuel	0.072 t	Direct substitution.
Biochar	0.16 t	Soil enrichment	116 kg C, 3.2 kg N, 1.1 kg P, 2.8 kg K	Farmyard manure compost	0.64 t	Biochar is a carbon-rich soil amendments that can be used as the replacement material for other materials such as straw and compost. Here the substituted was based on one study comparing the performance of these materials (data availability).
OSB	0.83 t	Sheeting for house	15.6 m^3	Fibre cement MgO board	1.42 t 1.10 t	There are few obvious non-wood-based substitutes for OSB. US made OSB might substitute Chinese OSB. To be conservative, we used a published study which assumed OSB, MgO board and fibre cement can all be used for sheeting with various thicknesses for structural equivalence.

[12] NCASI. 2020. Review of Life Cycle Assessments Comparing Paper and Plastic Products. NCASI White Paper. https://www.ncasi.org/wp-content/uploads/2020/11/WP-20-09_Plastic_vs_Paper_LCA_Review_Nov2020.pdf
[13] Assuming 50% blend.

2.4.2 Other Co-Products

In addition to the secondary function delivered by the products made from wood feedstocks, the manufacturing of these products might result in co-products (for instance, manufacturing of OSB results in residues that are sold). In these cases, mass allocation was applied to avoid the multiple system expansions and to align with the study objective.

2.4.3 Recycling

Recycling was not a focus of his study hence a cut-off approach was applied.

2.5 Quantification of the Carbon Footprint

2.5.1 IPCC Methods and Category of Emissions Included

The potential climate change impact of each GHG emitted and removed by the product system(s) is calculated by multiplying the mass of GHG released or removed by the 100-year GWP (AR6)[14] in units of kg CO_2e per kg emission (with carbon feedbacks, according to IPCC). The GWPs used in this study are documented in Table 6.

Table 6. GWPs used in this study (kg CO_2e/kg)

CO_2 (fossil and biogenic)	CH_4 (fossil and biogenic)	N_2O	CO_2 carbon uptake
1	29.8	273	-1

ISO 14067 requires that various components of a CFP are reported differently. Table 7 lists the requirements of ISO 14067 as well as how each emission/removal category is handled in this study. Fossil GHG emissions refer to GHG emissions from fossilized material. Biogenic GHG emissions refer to GHG emissions from biomass. Land use change (LUC) is a conversion of one land use type to another as a result of human activity. LUC has impacts on soil properties (e.g., carbon content or compaction), nutrients leaching, N_2O emissions, biodiversity, biotic production, and on other environmental aspects such as landscape, albedo, and evapotranspiration.

There are direct and indirect LUC: Direct LUC (dLUC) is a direct change in the piece of land occupied by the human activity; whereas indirect LUC (iLUC) is a change that appears in a different area than the direct land use as an indirect consequence (e.g., increase of soybean production in Brazil forces cattle production to deforest).

Note that a carbon footprint is one of many environmental indicators and it cannot be used to discuss the overall environmental preferability.

[14] In limited cases, the GHG of some uses were taken directly from the literature and hence might not have been from AR6. These cases are clearly underlined in the life cycle inventory section.

Table 7. CFP calculation and documentation

GHG emission or removal category	Treatment in the Calculated CFP			Documentation	
	Shall be included	Should be included	Should be considered for inclusion	Shall be documented separately	Shall be documented separately if calculated
Fossil and biogenic GHG emissions and removals	X			X	
GHG emissions and removals occurring as a result of dLUC	X Not relevant			X Not relevant	
GHG emissions and removals occurring as a result of iLUC			X Not relevant		X Not relevant
GHG emissions and removals from land use		X Not relevant			X Not relevant
Biogenic carbon in products					X
Aircraft GHG emissions	X			X Not reported separately as not very relevant	

NOTE: "Xs" identify which column(s) is(are) relevant to each of the GHG emission or removal categories.

2.5.2 Biogenic CO_2

Consistent with the ISO 14067 requirements, removals of CO_2 into biomass are characterized as −1 kg CO_2e/kg CO_2 in the calculation of the CFP when entering the product system. Emissions of biogenic CO_2 are characterized as +1 kg CO_2e/kg CO_2 of biogenic carbon in the calculation of the CFP. The amount of CO_2 taken up in biomass and the equivalent amount of CO_2 emissions from the biomass at the point of complete oxidation results in zero net CO_2 emissions integrated over time except when biomass carbon is converted into CH_4 or permanently stored.

In this study, the carbon removal associated with all use scenarios is the same:

$$1\ t\ wood \times \frac{0.5\ t\ C}{t\ wood} \times \frac{44\ t\ CO_2}{12\ t\ C} \times -1 = -1.83\ t\ CO_2$$

Because it is the same for all compared scenarios, it could have been ignored; however, its inclusion facilitates interpretation in the context of fossil-based substitutes.

Some scenarios might be using wood-based fuels beyond the 1 t of wood feedstocks. It has been assumed for these that the carbon removed was equal to the carbon released with the intention to focus on the fate of the carbon in the feedstock.

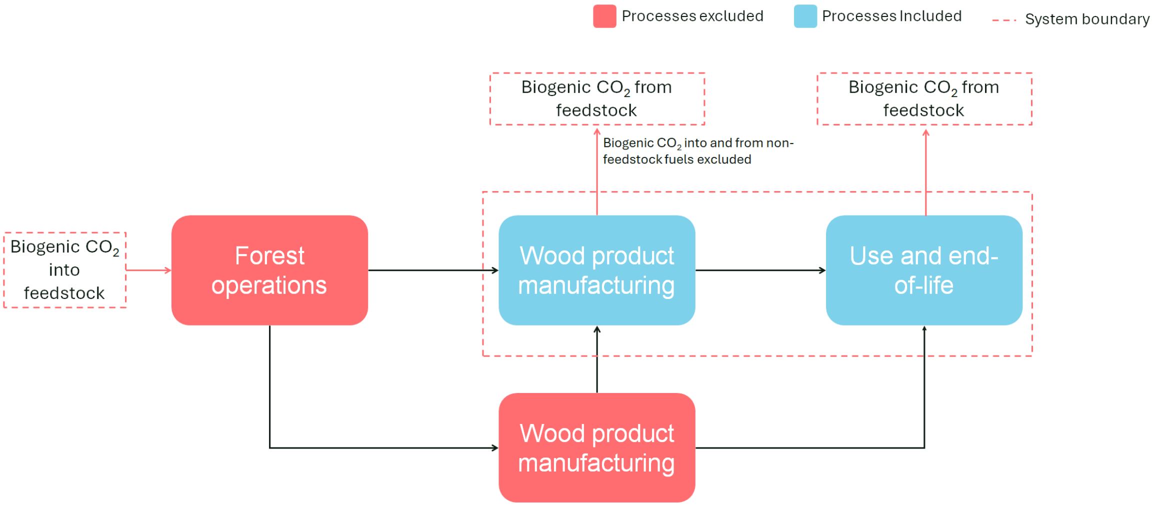

Figure 3: System boundaries in relation to biogenic carbon

2.6 Critical Review

The critical review intends to ensure consistency between the CFP study and the principles and requirements of ISO 14067. For this study, a two-reviewer critical review was undertaken:

- Pakarat Promyu, First Environment; and
- Reid Miner, Independent consultant.

Pakarat Promyu has over 8 years of diverse global experience as an environmental engineer and technical expert in wastewater and water management, as well as an expert assistant for decarbonization roadmaps, GHG inventories, and Climate Action Plans for local governments. She has organized and conducted numerous independent ISO critical reviews for the plastics and chemical industries, packaging, agricultures, and pavement coatings for First Environment, Inc.

Reid Miner, an Emeritus Senior Fellow at NCASI, has worked on greenhouse gas and carbon accounting issues for over 25 years. He directed the development of the first set of forest product industry GHG accounting tools for the original GHG Protocol and participated in the Revision Working Group assembled by WRI and WBCSD to develop the Revised GHG Protocol issued in 2004. His publications address GHG accounting issues ranging from forest carbon accounting considerations in energy policy to national and global industry carbon footprints.

Mrs. Promyu was responsible for reviewing the study against the requirements of ISO 14067, while Mr. Miner emphasis was on the technical aspects and assumptions made in comparing the various uses of woody biomass.

3 Life Cycle Inventory

3.1 Data Collection and Validation

In this study, primary data were collected for all processes under the operational control of Drax (see Table 8). For each process, a representative facility was selected. Data was collected for one year of production. All other processes were modelled using secondary data including ecoinvent v3.10 allocation cut-off by classification, US LCI, and various literature sources. Although the version of US LCI implemented in SimaPro is rather old, it was still preferred over ecoinvent for most fossil fuels to avoid converting from physical to energy units.

Data validation was made mainly from mass balances.

The SimaPro v9.6.0.1 software was used to conduct the LCA.

Table 8. Primary data collection sources

Process	Facility from which data was collected
Electricity production from chips in the US	Drax US design data
CCS in the US	Drax US design data
Pellet production	Amite Pellet Plant
Electricity production from pellets in the UK	Drax Power Station (Selby)
CCS in the UK	Drax Power Station (Selby) design data

3.2 Description of the Product Systems and Main Assumptions

3.2.1 Electricity in the US (from Chips, w/o BECCS)

In this pathway, the wood feedstock is transported from their point of generation to the electricity generation by truck. In some cases, wood would already be in the form of chips (e.g., from sawmills); in other cases, it would have to be processed (e.g., chipped) prior to being burned. In this project, we assumed that the level of processing would be the same for all uses of wood feedstocks hence it was ignored. However, in practice, different uses of wood might require different levels of processing. For this reason, processing was checked in sensitivity analyses. On arrival, the chips are screened to remove any foreign objects, stored in a silo, then burned in a boiler. Once in the boiler, the fuel is burned to generate high-pressure steam which is used to power turbines that are connected to the generators to generate electricity.

Figure 4 presents a flow diagram for this process and Table 9, the full life cycle inventory.

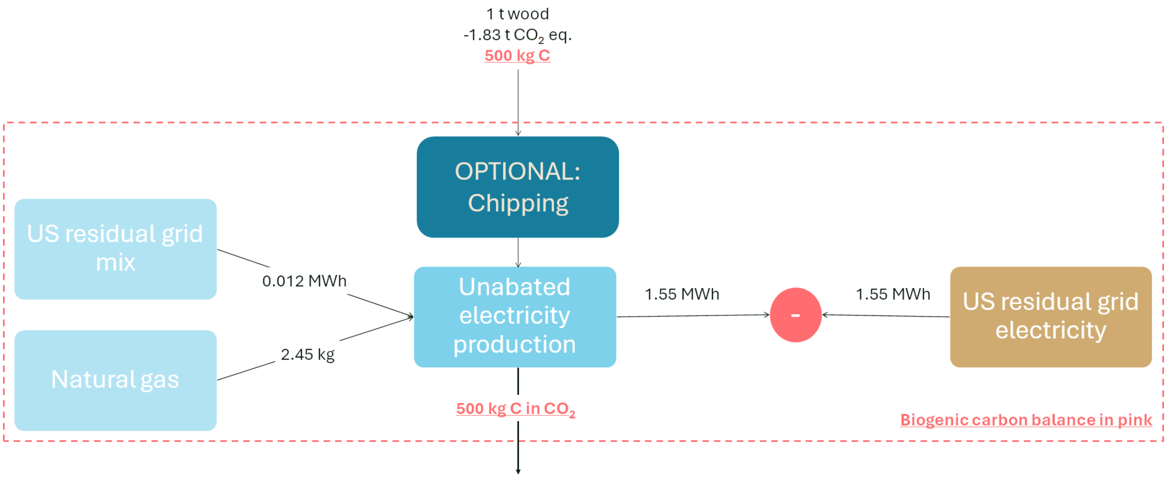

Figure 4: Flow diagram for unabated electricity production from wood chips in the US

Table 9. Life cycle inventory for unabated electricity production from wood chips

Product	Quantity	Unit	Assumption/Secondary dataset used
Electricity	2 380 000	MWh	
Input	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Wood chips	1 530 000	Dry t	
Electricity	19 029	MWh	Electricity, low voltage {US-SERC}| market for electricity, low voltage (ecoinvent) – Corrected for residual mix (see Section 3.3).
Natural gas	4 710 000	m^3	Natural gas, combusted in industrial equipment/RNA (US LCI).
Diesel	4 053 000	L	For chipping (applied only in sensitivity analyses). 3.01 L/dry t, average value from Johnson et al. (2012)[15] Diesel, combusted in industrial equipment/US (US LCI).
Wood chip transportation by truck	100	tkm	Assuming 51% water. Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified (ecoinvent).
Outputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
CO_2, biogenic	2 805 000	t	Based on carbon balance.
CH_4, biogenic	213	t	126 g/short ton, EPA 2024.[16]
N_2O, biogenic	106	t	63 g/short ton, EPA 2024[16].
Wood ash to landfill	122 400	t	Assumed 8% of wood input.

[15] Johnson, L., Lippke, B. Oneil, E. 2012 Modeling Biomass Collection and Woods Processing Life-Cycle Analysis. *Forest Products Journal*. 62(4): 258-272.

[16] https://www.epa.gov/climateleadership/ghg-emission-factors-hub

Table 10. (Cont'd)

Outputs	Quantity	Unit	Assumption/Secondary dataset used
Wood ash transportation by truck	6.12E6	tkm	Assuming 0% water and 50 km. Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified (ecoinvent).
Substituted product	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
US residual mix of electricity	2 380 000	MWh	Electricity, high voltage {US}, production mix – Corrected for residual mix – Corrected for residual mix (ecoinvent, see Section 3.3).

3.2.2 Electricity in the US (from Chips, w/ BECCS)

In this use pathway, the electricity produced from chips (see Section3.2.1) goes through a carbon capture storage process. As there is currently no CCS in the US, the UK process (see Section 3.2.4) was used as a proxy. Figure 5 presents a flow diagram for this process and Table 10, the full life cycle inventory.

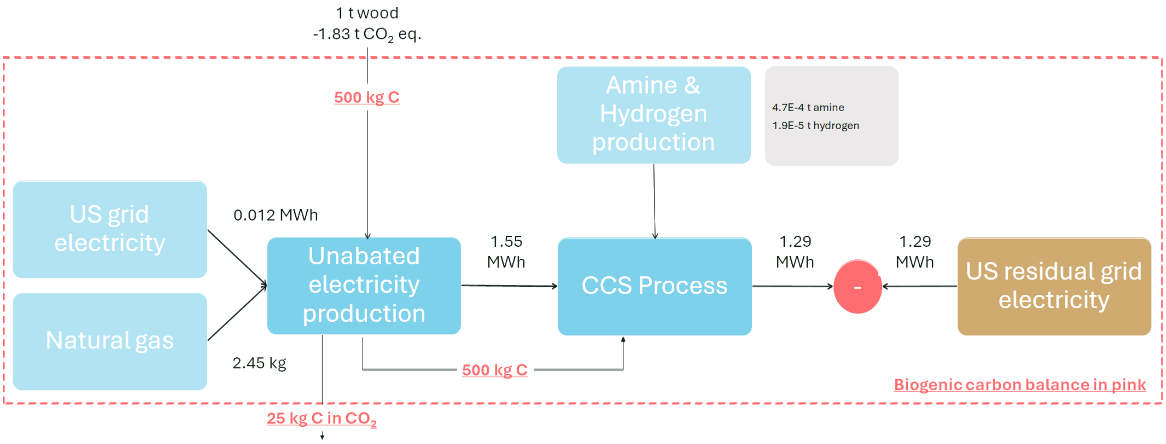

Figure 5: Flow diagram for abated electricity production from wood chips in the US

Table 10. Life cycle inventory for abated electricity production from wood chips (CCS)

Product	Quantity	Unit	Assumption/Secondary dataset used
Electricity	1	MWh	N/A
Input	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Unabated electricity from chips	1.2	MWh	Primary data.
Amine capture solvent	0.331	kg	Triethanolamine {GLO}| market for triethanolamine (ecoinvent).

(Table continued on next page.)

Table 10. (Cont'd)

Product	Quantity	Unit	Assumption/Secondary dataset used
Hydrogen	0.0134	kg	Hydrogen, gaseous {GLO}| market for hydrogen, gaseous (ecoinvent).
Chemicals transportation by truck	100	km	Assuming 0% water. Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified (ecoinvent).
CO_2, biogenic, captured	1.74	t	CO_2 is assumed to be released in the electricity generation process and captured in the CCS process with an efficiency of 95%.
Substituted product	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
US residual mix of electricity	1	MWh	Electricity, high voltage {US}, production mix – Corrected for residual mix – Corrected for residual mix (ecoinvent, see Section 3.3).

3.2.3 Electricity Production in the UK (from Pellets w/o BECCS)

In this use pathway, wood pellets are used to produce electricity in the UK.

First, woody feedstocks are delivered to the pellet mill by truck where it is stored in the wood yard or directly processed. Low-grade roundwood is debarked and chipped. Although this processing would need to happen irrespective of wood use pathway, energy for doing so was included in the system boundary because it is part of the pellet mill operations and could not be split. The bark is then use as fuel in the furnace during the drying stage later in the manufacturing process. Other wood feedstocks do not require processing because they are already in the form of chips, sawdust or shavings. Wood chips are screened for quality and waste, such as sand, bark, or stones are removed. Next, the wood chips are fed into a dryer, powered by the bark, to remove moisture. Once dry, they are fed into a hammer mill where they are shred into a fine powder. The powder is then forced at very high pressure through a grate with small holes - known as a die. The pressure creates heat which helps bind the powder into compressed pellets. The pellets are then sent to rest and cool before being loaded onto a rail car which transports the pellets to a port facility ready to be shipped overseas.

Wood pellets are delivered by train to Drax power plant. On arrival, the pellets are screened to remove any foreign objects and stored in silo. Pellets are extracted into the fuel pellet pipes, blown down the pipes by an air blower, and conveyed to the boiler house waiting to be fed to hollow balls where they are crushed into a fine powder and blown into a boiler. Once in the boiler, the fuel is burned to generate high-pressure steam, which is used to power turbines that are connected to generators that produce electricity.

Figure 6 presents a flow diagram for this use of wood, and Table 11 and Table 12, the full life cycle inventory for each of the processes involved in this use pathway.

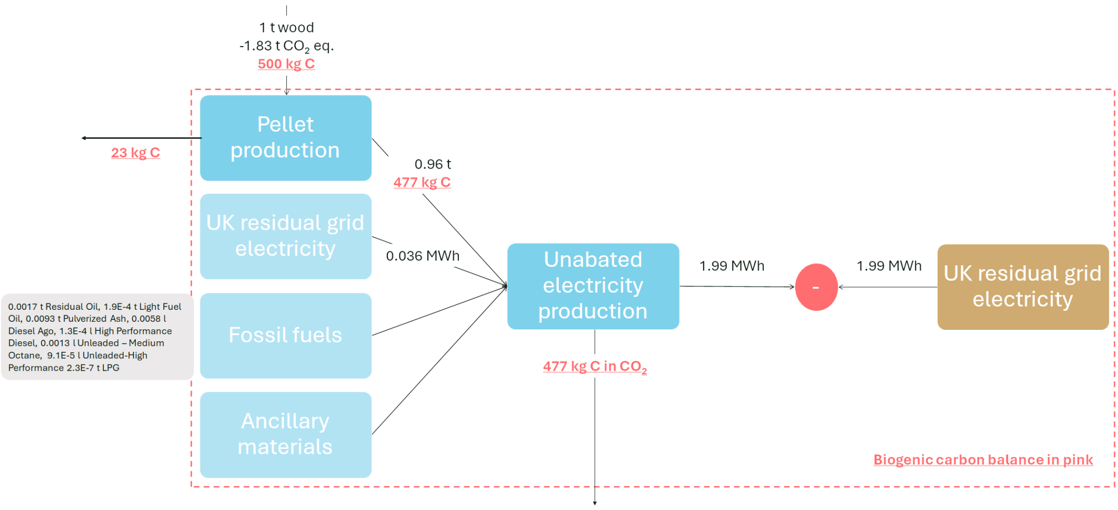

Figure 6. Flow diagram for unabated electricity production from wood pellets in the UK

Table 11. Life cycle inventory for the production of wood pellets

Product	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Wood pellets	467,327	Dry t	7% water. Primary data.
Inputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Wood chips	72,870	Dry t	
Low-grade roundwood	188,838	Dry t	
Shavings	112,090	Dry t	
Dust	115,038	Dry t	
Self-generated hogged fuel	21,509	Dry t	Comes from wood inputs listed above. Hog fuel, self-gen., combusted in ind. boiler, at pulp and paper mill (EXCL.)/kg/RNA (ecoinvent).
Forest residues	2,011	Dry t	Wood waste, unspecified, combusted in industrial boiler/US (US LCI). Forest residue, preprocessed, at conversion facility/ton/RNA (US LCI) – Includes transportation.
Purchased bark	21,509	Dry t	Wood waste, unspecified, combusted in industrial boiler/US (US LCI). Bark, at sawmill, US SE/kg/US.
Natural gas	175,540,243	MJ HHV	Heat, district or industrial, natural gas {RoW}| heat production, natural gas, at boiler condensing modulating >100kW. A factor of 1.11 was used to convert from HHV to LHV in ecoinvent.
Diesel	62,359	L	Diesel, combusted in industrial boiler/US (US LCI).

(Table continued on next page).

Table 11. (Cont'd)

Inputs	Quantity	Unit	Assumption/Secondary dataset used
Electricity	93,300,000	kWh	Electricity, low voltage {US-SERC}| market for electricity, low voltage (ecoinvent) – Corrected for residual mix (see Section 3.3).
Wood chip transportation by truck (same assumed for bark)	44.28 (97%); 74.83 (3%)	km	50% water. Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified (ecoinvent).
Roundwood transportation by truck	42.04 (97%); 44.74 (3%)	km	50% water. Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified (ecoinvent).
Shavings transportation by Truck	153.83 (99.6%); 309.94 (0.4%)	Km	10% water. Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified (ecoinvent).

Table 12. Life cycle inventory for the production of unabated electricity from wood pellets in the UK

Product	Quantity	Unit	Assumption/Secondary dataset used
Electricity	11,690,513	MWh	
Inputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Wood pellets	5,622,052	Dry t	7% water. Primary data.
Electricity	24,861	MWh	Electricity, low voltage {GB}| electricity, low voltage, residual mix (ecoinvent).
Residual fuel oil	11,131	t	Density: 0.98 kg/L. Residual fuel oil, combusted in industrial boiler/US (US LCI).
Pulverized fuel ash	63,182	t	Bituminous coal, combusted in industrial boiler/US (US LCI).
Diesel	39,635	L	Diesel, combusted in industrial boiler/US (US LCI).
Gasoline	9,650	L	Gasoline, combusted in equipment/US (US LCI).
Distillate fuel oil	1,333	t	Density: 0.98 kg/L
LPG	1,581	t	Density: 0.86 kg/L
Transportation of pellets by rail – Leg 1	270	km	Drax US to Gulf Port. Transport, freight train {US}| market for transport, freight train (ecoinvent).
Transportation of pellets by boat	8938	km	Gulf Port to Hull Port. Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship.
Transportation of pellets by rail – Leg 2	53	km	Hull Port to Drax. Transport, freight train {RER}| market group for transport, freight train.
Outputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
CO_2, from HVAC	142	t	Excludes CO_2 from fuel combustion processes listed above.
CO_2, biogenic	10,307,095	t	Corrected to match carbon in wood assumed.
CH_4, biogenic	59.6	t	
N_2O, biogenic	0.27	t	
Substituted product	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
UK residual mix of electricity	11,690,513	MWh	Electricity, high voltage {GB}, production mix.

3.2.4 Electricity Production in the UK (from Pellets w/ CCS)

In this use pathway, the electricity produced from pellets (see Section 3.2.3) go through a carbon capture storage process. Some electricity is needed to run the process. The carbon capture process is depicted in Figure 7 for which the total efficiency (including potential leakage) is 95%.

Figure 8 presents a flow diagram for this process and Table 13, the full life cycle inventory.

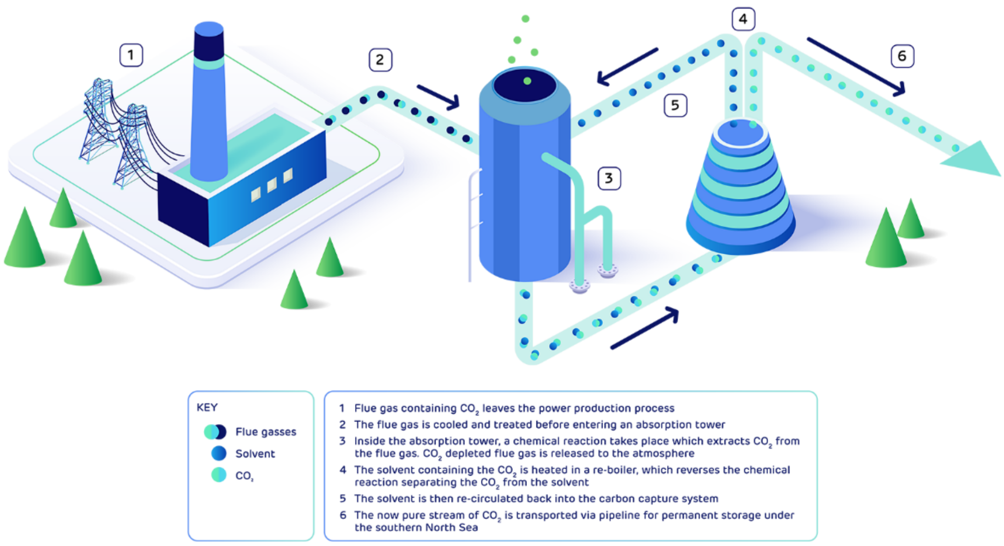

Figure 7: How carbon is captured from an emission source

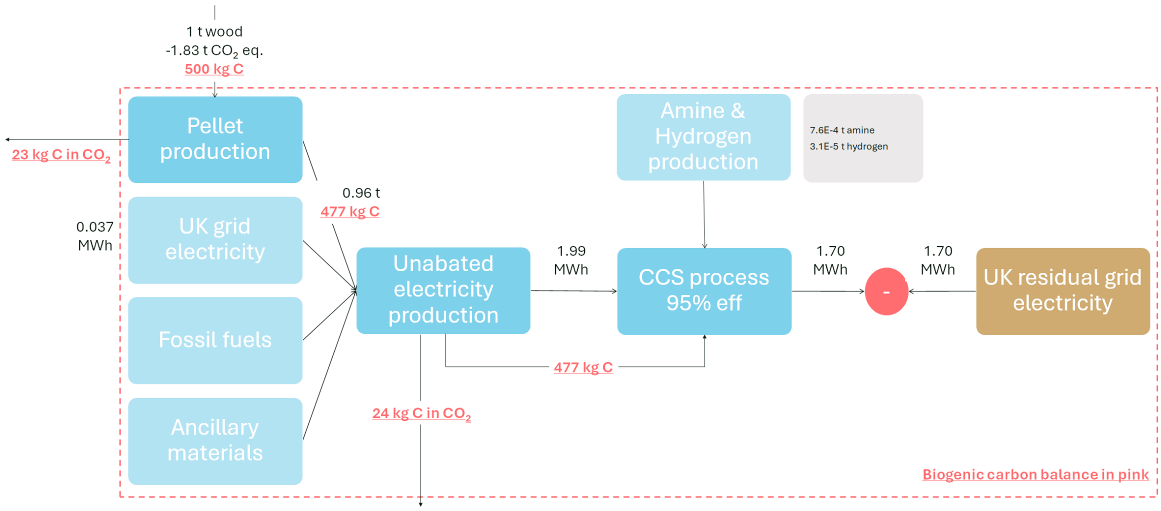

Figure 8: Flow diagram for abated electricity production from wood pellets in the UK

Table 13. Life cycle inventory for abated electricity production from pellets (CCS)

Product	Quantity	Unit	Assumption/Secondary dataset used
Electricity	1	MWh	N/A
Inputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Unabated electricity from chips	1.17	MWh	Primary data.
Amine capture solvent	0.331	kg	Triethanolamine {GLO}| market for triethanolamine (ecoinvent).
Hydrogen	0.0134	kg	Hydrogen, gaseous {GLO}| market for hydrogen, gaseous (ecoinvent).
Chemicals transportation by truck	100	km	Assuming 0% water. Transport, freight, lorry, unspecified {GLO}| market group for transport, freight, lorry, unspecified (ecoinvent).
CO_2, biogenic, captured	1.74	t	CO_2 is assumed to be released in the electricity generation process and captured in the CCS process with an efficiency of 95%.
Substituted product	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
UK residual mix of electricity	1	MWh	Electricity, low voltage {GB}| electricity, low voltage, residual mix (ecoinvent).

3.2.5 PE-Coated Paperboard

In this pathway, wood is used to produce pulp that is then used to produce paper plates which can substitute for polystyrene plates. The quantity of paperboard produced from 1 t of wood is estimated using the ecoinvent solid bleached and unbleached board carton. The difference between the wood input and the paperboard produced is assumed to be in energy with the CO_2 released. The number of plates produced, the equivalent quantity of polystyrene, and the carbon footprint of paper and polystyrene plates are derived from a study from Franklin Associates (FAL, 2011).[17] Both plates are assumed to be sent to disposal (no recycling) with average landfill to incineration ratio that is based on US EPA (2020)[18].

Figure 9 presents a flow diagram for this process and Table 14, the full life cycle inventory.

[17] Franklin Associates (FAL). 2011. Life Cycle Inventory of Foam Polystyrene, Paper-Based and PLA Foodservices Products. Prepared for the Plastic Foodservice Packaging Group. https://www.plasticfoodservicefacts.com/wp-content/uploads/2017/12/Peer_Reviewed_Foodservice_LCA_Study-2011.pdf

[18] US EPA (2020). Advancing Sustainable Materials Management: 2018 Tables and Figures Assessing Trends in Materials Generation and Management in the United States. https://www.epa.gov/sites/default/files/2021-01/documents/2018_tables_and_figures_dec_2020_fnl_508.pdf

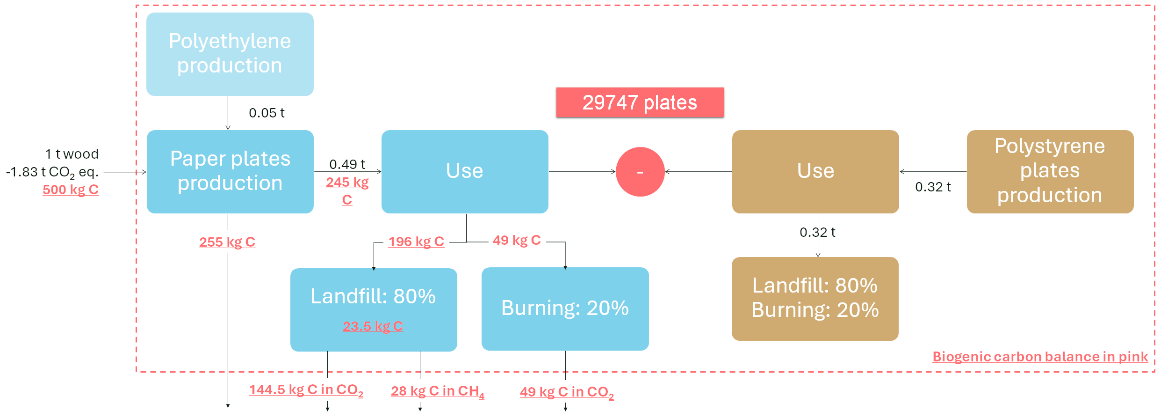

Figure 9: Flow diagram for the PE-coated paperboard plate use pathway

Table 14. Life cycle inventory for the PE-coated paperboard plates use pathway

Product	Quantity	Unit	Assumption/Secondary dataset used
PE-coated paperboard plates	1	plate	N/A
Inputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
PE-coated paperboard	0.54	Dry t	0.49 dry t of fibre inputs and 0.05 dry tons of PE.
Outputs			
CO_2, fossil from production	0.0326	kg	Based on FAL (2011).
CO_2, biogenic from production	0.0314	kg	From mass balances.
Fiber fraction of paperboard plate to end-of-life	16.56	g	80% landfill, 20% incineration. Biogenic CO_2 and CH_4 based on NCASI carbon storage calculator[19]. Carbon content: 50%, non-degradable carbon: 12%, fraction of degradable carbon converted to gas: 100%, fraction landfill CH_4 collected and burned: 64%, fraction of landfill CH_4 oxidized: 10%.
PE-coating to end-of-life	1.84	g	80% landfill, 20% incineration. Waste polyethylene {RoW} treatment of waste polyethylene, sanitary landfill. Waste polyethylene {GLO} treatment of waste polyethylene, municipal incineration.
Substituted product	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Polystyrene	10.8	g	
CO_2, fossil	0.047	kg	For polystyrene plate production, based on FAL (2011).

(Table continued on next page.)

[19] NCASI. NCASI Tool to Calculate Carbon Storage in Forest Products.

Table 14. (Cont'd)

Substituted product	Quantity	Unit	Assumption/Secondary dataset used
Polystyrene plate to end-of-life	10.8	g	80% landfill, 20% incineration. Waste polystyrene {GLO}| treatment of waste polystyrene, municipal incineration (ecoinvent). Waste polystyrene {RoW}| treatment of waste polystyrene, sanitary landfill (ecoinvent).

3.2.6 Sustainable Aviation Fuel (SAF)

The carbon intensity of producing SAF from wood residues is based on a study by Ringsred et al. (2021).[20] Wood residues are pre-treated and dried prior to undergoing fast pyrolysis followed by steam reforming and distillation which produce gasoline, SAF, and diesel. As the carbon content of these three products is similar, the wood input was allocated based on mass. Based on this study, the carbon intensity of SAF varies from 25.7 to 26.1 g CO_2/MJ (25.9 used in this study). The following assumptions were made:

- SAF would be burned in a 1:1 ratio with jet fuel;
- Energy content of jet fuel/SAF is 43.2 MJ/kg; and
- GHG emissions from burning jet fuel and SAF are the same.

Figure 10 presents a flow diagram for this process and Table 15, the full life cycle inventory.

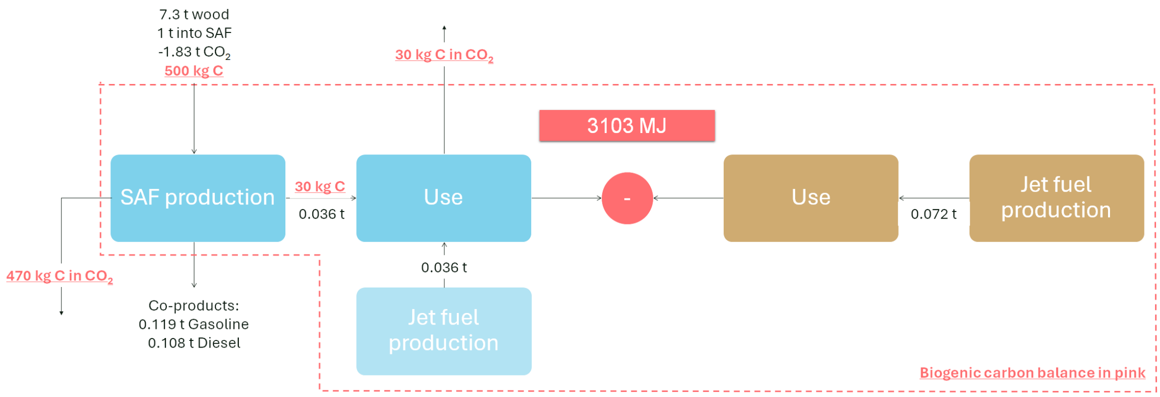

Figure 10: Flow diagram for the SAF use pathway

[20] Ringsred, Anna. Van Dyk, Susan. Saddler John (Jack). 2021. Life-Cycle Analysis of Drop-In Fuel Produced from British Columbia Forest Residues and Wood Pellets Via Fast Pyrolysis. *Applied Energy*. 287: 116587.

Table 15. Life cycle inventory for the SAF Pathway

Product	Quantity	Unit	Assumption/Secondary dataset used
Energy from SAF	3103	MJ	N/A
Inputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
SAF combustion	0.036	t	Transport, freight, aircraft, long haul {GLO}| transport, freight, aircraft, dedicated freight, long haul (ecoinvent, excluding the production of kerosene, 1 tkm = 0.0201 kg fuel).
Jet fuel combustion	0.036	t	Transport, freight, aircraft, long haul {GLO}| transport, freight, aircraft, dedicated freight, long haul (ecoinvent, including the production of kerosene, 1 tkm = 0.0201 kg fuel).
Outputs			
Carbon dioxide, fossil	80.4	kg	From production of SAF, 25.9 g CO_2/MJ.
Carbon dioxide, biogenic	1833	kg	From the production of SAF, from mass balances assuming SAF is 86% carbon and from combustion.
Substituted product	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Jet fuel	0.072	t	Transport, freight, aircraft, long haul {GLO}| transport, freight, aircraft, dedicated freight, long haul (ecoinvent, including the production of kerosene, 1 tkm = 0.0201 kg fuel).

3.2.7 Biochar

In this use pathway, wood feedstock is used to produce biochar. The carbon intensity of biochar production was derived from a study from Puettmann et al. (2020a).[21] In the Puettmann et al. study, the system boundary for the LCA of biochar begins with the harvesting of biomass and ends with marketable biochar. It includes seven biochar production systems. In this study, we used the average of carbon intensity of the seven production systems from which we subtracted the contribution from forest operations and pre-processing. The product substituted from biochar is based on another study from Siedt et al. (2021).[22] Note however that the carbon content of biochar in Puettmann et al. (2020a) is different than that in Siedt et al. (2021) which might imply the substituted product is not exactly functionally equivalent. The carbon content being lower means that less compost would be displaced, hence the results presented will be conservative. Figure 11 presents a flow diagram for this process and Table 16, the full life cycle inventory.

[21]Puettmann, M., Sahoo, K., Wilson, K., Oneil, E. 2020a. Life Cycle Assessment of Biochar Produced from Forest Residues Using Portable Systems. *Journal of Cleaner Production*. 119564. 10.1016/j.jclepro.2019.119564.

[22] Siedt, M., Schäfferm A., Smith, K.E.C., Nabel, M., Rob-Nickoll, M., van Dongen, J.T. 2021. Comparing Straw, Compost, and Biochar as Agricultural Soil Amendments to Affect Soil Structure, Nutrient Leaching Microbial Communities, and the Fate of Pesticide.

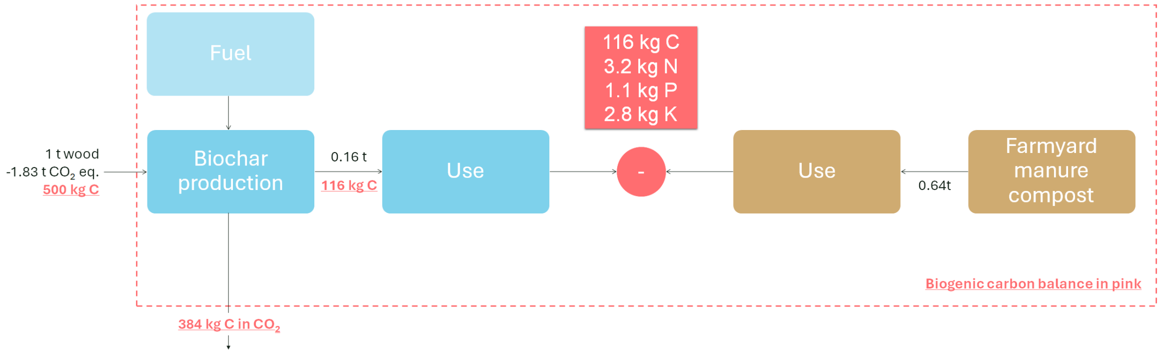

Figure 11: Flow diagram for the biochar use pathway

Table 16. Life cycle inventory for the biochar pathway

Product	Quantity	Unit	Assumption/Secondary dataset used
Soil enrichment	C: 116, N: 3.2, P: 1.1, K: 2.8	kg	
Inputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Biochar	0.28	t	Based on Puettmann et al. (2020b).
Outputs			
Carbon dioxide, fossil	23.6	kg	Based on Puettmann et al. (2020b), excluding harvesting and pre-processing.
Carbon dioxide, biogenic	1408	kg	Based on Puettmann et al. (2020b), remaining carbon fixed in the biochar.
Substituted product	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Farmyard manure compost	0.64	t	From Siedt et al. (2021).
Carbon dioxide, fossil	104	kg	From Siedt et al. (2021).

3.2.8 Oriented Strandboard (OSB)

In this use pathway, wood feedstock is used to produce OSB, and the life cycle inventory is based on data from CORRIM.[23] The product substituted are based on a study Gorbunov (2022).[24] Gorbunov assumes that all materials have sufficient lifetime to be used throughout the lifetime of the building. Figure 11 presents a flow diagram for this process and Table 17, the full life cycle inventory.

[23] Puettmann, M., Kaestner, D. Taylor, A. 2020b. CORRIM Report: Life Cycle Assessment for the Production of Oriented Strandboard Production. https://corrim.org/wp-content/uploads/2020/12/CORRIM-AWC-OSB-Final.pdf

[24] Gorbunov. I. 2022. Comparative Life Cycle Assessment of a Sustainable Modular Tiny-House. University of Twente. Civil Engineering. S2355116. https://essay.utwente.nl/93535/1/Gorbunov-Ilya.pdf

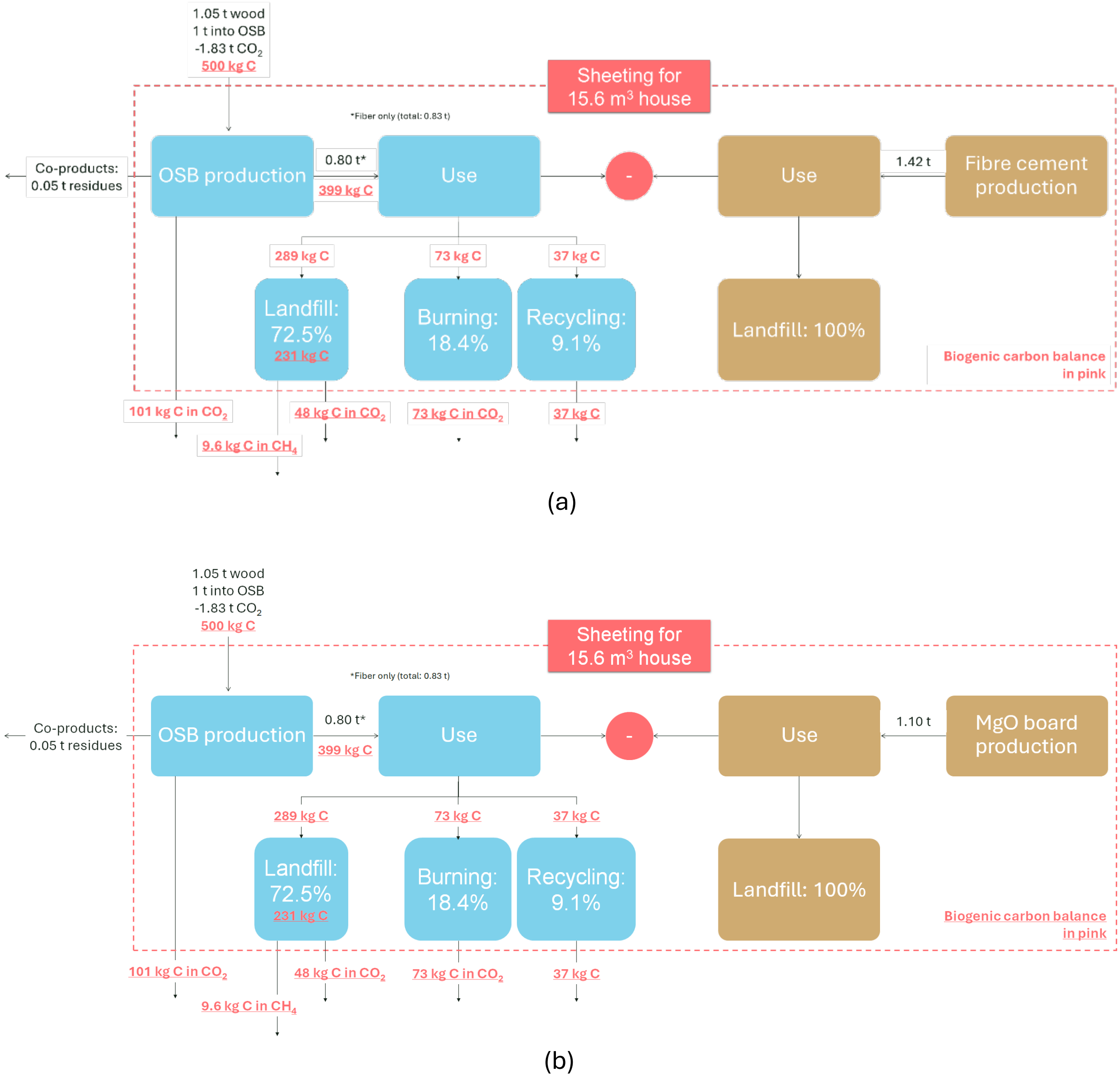

Figure 12: Flow diagram for the OSB use pathway a) fibre cement substitution, b) MgO board substitution

Table 17. Life cycle inventory for the OSB pathways

Product	Quantity	Unit	Assumption/Secondary dataset used
Housing (sheeting part)	15.6	m³	The volume of house modelled in this study is 15.6 m³. This volume results from downscaling the house modelled in Gorbunov so that the house modelled here requires an amount of OSB produced from 1 tonne feedstock.
Inputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
OSB	0.83	t	Based on Puettmann et al. (2020b). Weight of wood fibre: 0.80, resins: 0.03 t.
Outputs			
Carbon dioxide, fossil	325	kg	Based on Puettmann et al. (2020b).

(Table continued on next page.)

Table 17. (Cont'd)

Outputs			
Carbon dioxide, biogenic	354	kg	Based on Puettmann et al. (2020b), feedstock only.
OSB to end-of-life (fibre)	0.80	t	End-of-life split based on US EPA (2020). Biogenic CO_2 and CH_4 based on NCASI carbon storage calculator. Carbon content: 50%, non-degradable carbon: 80%, fraction landfill CH_4 collected and burned: 64%, fraction of landfill CH_4 oxidized: 10%.
OSB to end-of-life (resins)	0.03	t	Waste plastic, mixture {CH}| treatment of waste plastic, mixture, sanitary landfill. Waste plastic, mixture {GLO}| treatment of waste plastic, mixture, municipal incineration.
Substituted product 1	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Fibre cement	1.42	t	Gorbunov (2022). Fibre cement facing tile, large format {RoW}| fibre cement facing tile production, large format (ecoinvent) – Data modified for US (grid and cement production).
Fibre cement to end-of-life	1.42	t	Assumed 100% landfilled. Waste concrete {RoW}| treatment of waste concrete, inert material landfill (ecoinvent).
Substituted product 2	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
MgO board	1.10	t	Substitution ratio from Gorbunov (2022). Life cycle inventory from Alonso Soto (2021)[25]. A1-A3 and C4. Data is for Europe.
MgO board to end-of-life	1.10	t	Assumed 100% landfilled.

3.2.9 Sawtimber

This use pathway is presented solely for providing context to the results as sawtimber does not use the wood feedstocks described in this study. Instead, sawtimber would be made from sawlogs. To make sure the contextual information is framed in the same manner as the other use of wood feedstocks, however, we modelled two sawtimber pathways: one in which sawtimber displaces steel in a portal frame, and one in which it displaces concrete (see Figure 13). Wood, steel, and concrete are used in each of the portals whether it is wood-based, steel-based, or concrete based. Hence, the results are based on a net wood input (for instance, if the wood portal contains 2 kg of wood, and the steel portal contains 0.5 kg of wood, only 1.5 kg of wood is considered. The quantity of wood, steel, and concrete in each of the portals is based on

[25] Alonso Soto, A.M. 2021. Life Cycle Assessment of Magnesium Oxide Structural Insulated Panels. Master's Final Degree Project. Kaunas University of Technology Institute of Environmental Engineering Faculty of Mechanical Engineering and Design.

a study by Hegeir et al. (2022).[26] The data from modelling sawtimber was derived from a study from CORRIM.[27] Life cycle inventory is presented in Table 18.

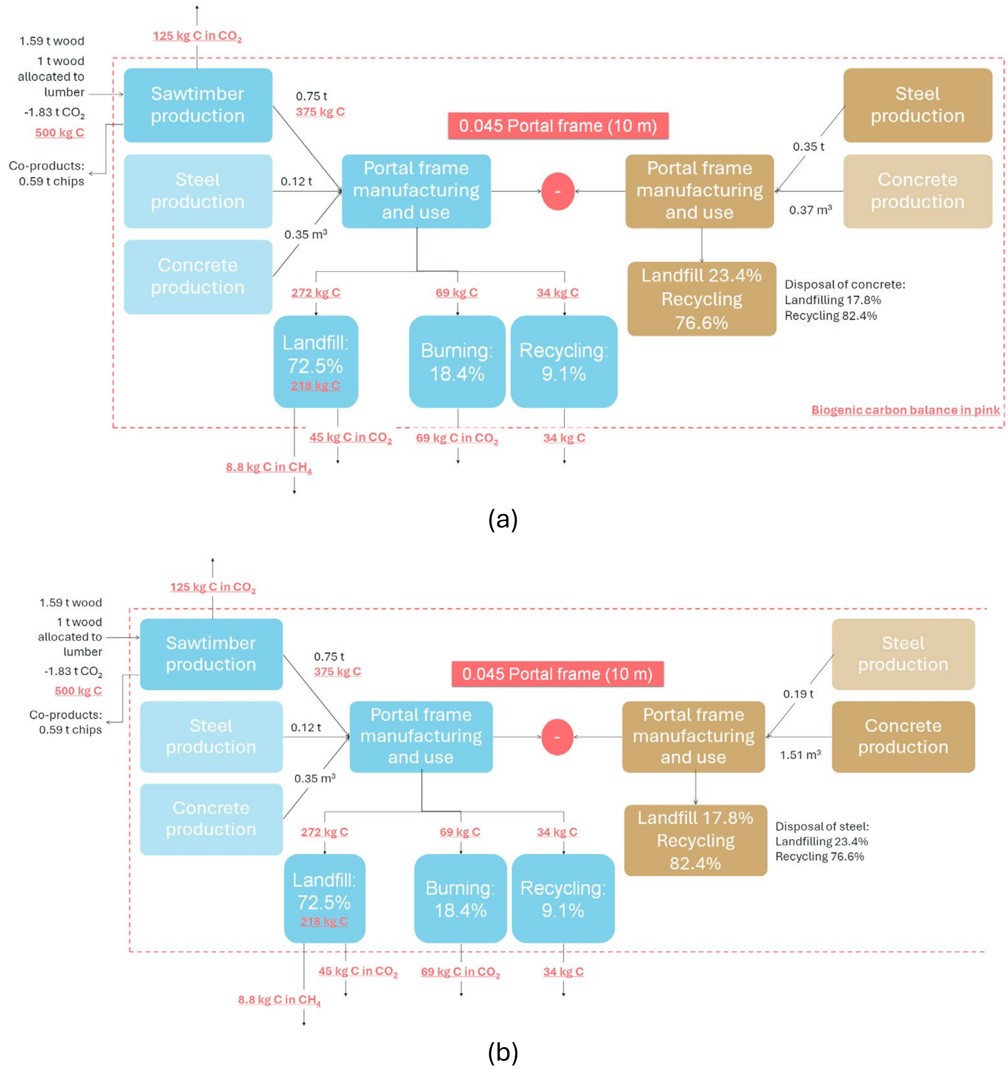

Figure 13: Flow diagram for the sawtimber portals a) steel substitution, b) concrete substitution

[26] Hegeir, O.A., Kvande, T., Stamatopoulos, H. Bohne, R.A. 2022. Comparative Life Cycle Analysis of Timber, Steel, and Reinforced Concrete Portal Frames: A Theoretical Study on a Norwegian Industrial Building. Buildings. 12:573.

[27] Milota, M. 2020. Life Cycle Assessment for the Production of Southeastern Softwood Lumber. CORRIM. https://corrim.org/wp-content/uploads/2020/06/CORIRM-AWC-SE-Lumber.pdf

Table 18. Life cycle inventory for the sawtimber portal pathways

Product	Quantity	Unit	Assumption/Secondary dataset used
Portal	0.045	portal	
Inputs	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Sawtimber	0.75	Dry t	Based on Milota (2020).
Steel	0.12	t	Reinforcing steel {RoW}| reinforcing steel production (ecoinvent).
Concrete	0.35	m^3	Concrete, 35MPa {North America without Quebec}| concrete production, 35MPa, for civil engineering, for exterior use, with cement, Portland (ecoinvent).
Outputs			
Carbon dioxide, fossil	96.9	kg	From sawtimber production, based on Milota (2020).
Carbon dioxide, biogenic	454	kg	From sawtimber production, based on Milota (2020), feedstock only.
Sawtimber to end-of-life	0.75	t	End-of-life split based on US EPA (2020). Biogenic CO_2 and CH_4 based on NCASI carbon storage calculator. Carbon content: 50%, non-degradable carbon: 80%, fraction landfill CH_4 collected and burned: 64%, fraction of landfill CH_4 oxidized: 10%.
Steel to end-of-life	0.12	t	End-of-life split based on US EPA (2020). Disposal, building, reinforcement steel, to recycling (ecoinvent). Disposal, steel, 0% water, to inert material landfill (ecoinvent).
Concrete to end-of-life	0.35	m^3	End-of-life split based on US EPA (2020). Disposal, building, concrete, not reinforced, to recycling (ecoinvent). Waste concrete {RoW}| treatment of waste concrete, inert material landfill.
Substituted product – steel	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Steel	0.35 t	t	From Hegeir et al. (2022). Same data as above for production and EOL.
Concrete	0.37	m^3	From Hegeir et al. (2022). Same data as above for production and EOL.
Substituted product - concrete	**Quantity**	**Unit**	**Assumption/Secondary dataset used**
Steel	0.19	t	From Hegeir et al. (2022). Same data as above for production and EOL.
Concrete	1.51	m^3	From Hegeir et al. (2022). Same data as above for production and EOL.

3.3 Assumptions about Electricity Production

This study does not intend to cover a particular set of operations but rather to get general understanding. ISO 14067 requires that when information on supplier specific electricity is not available, GHG emissions associated with the relevant electricity grid from which the electricity is obtained shall be used. The relevant grid shall reflect the electricity consumption of the related region, excluding any previously claimed attributed electricity (i.e., the residual grid mix).

In this study, we applied the residual grid mix to all primary data and to secondary data where possible. Deviations from the residual grid mix and potential implications for the results are discussed.

The life cycle inventory for residual electricity was derived from ecoinvent 3.10, which includes no data for the US residual electricity. For this case, we compared the national 2022 Green-e® Residual Mix Emissions Rates (2020 Data)[28] to the 2020 eGrid data[29] and determined that the residual mix would produce 7.7% more emissions than the average mix. Hence a 1.077 factor was applied to life cycle data. Note that neither Green-e nor eGrid includes pre-combustion emissions, hence this factor has limitations.

[28] https://www.green-e.org/2022-residual-mix

[29] https://www.epa.gov/egrid/data-explorer

4 Carbon Footprint Results

This section presents the results from this study. Results comprise a comparative assessment wherein the environmental profile of each use pathway is compared and environmental hotspot analyses where key areas of impact in the lifecycle of each product system are examined and the key drivers of each hotspot are identified. All results are presented in terms of the functional unit, which is defined as **"The use of one dry tonne of wood feedstock"** and covers all processes included within system boundary.

Detailed CFP results are presented in Table 18 while Figure 14 presents a visual representation of the net impacts. It can be seen that all use pathways result in carbon benefits relative to their substitutes. The use of OSB that displaces MgO board results in the greatest carbon benefits. Using the wood feedstocks for producing electricity with carbon capture leads to carbon benefits that are in the same order of magnitude of using OSB to displace fibreboard. The use of wood feedstock for paper plates and SAF production leads to the smaller carbon benefits due to the use of fossil fuels involved in these pathways as well as the relatively low carbon footprint of producing the substitute.

Table 19. Detailed CFP results

Use pathway	Fossil GHGs	Biogenic GHGs*		Biogenic CO_2 uptake*	Net
		CO_2	CH_4		
	kg CO_2e/t				
Electricity in the US (from chips, w/o BECCS)	-694	1833	4.6	-1833	-689
Electricity in the US (from chips, w/ BECCS)	-568	91.7	4.6	-1833	-2304
Electricity in the UK (from pellets, w/o BECCS)	-579	1833	0.4	-1833	-578
Electricity in the UK (from pellets, w/ BECCS)	-447	172	0.4	-1833	-2107
PE-coated paperboard plates	-1227	1648	1116	-1833	-295
Sustainable aviation fuel (SAF)	-48.9	1833	0	-1833	-48.6
Biochar	-38	1407	0	-1833	-464
OSB – Fibre cement board	-1691	485**	353**	-1313**	-2686
OSB – MgO board	-3451	805	375	-1833	-4104

NOTE: Differences between number in this table and carbon balances in the figures are due to rounding and background processes. *CO_2 emissions and uptake from biofuels other than from the feedstock are excluded from the analysis. **This pathway is the only one not showing the same net carbon uptake and for which the emission of biogenic GHGs cannot be directly derived from the figures because fibreboard (the substituted product) is partly made from wood pulp.

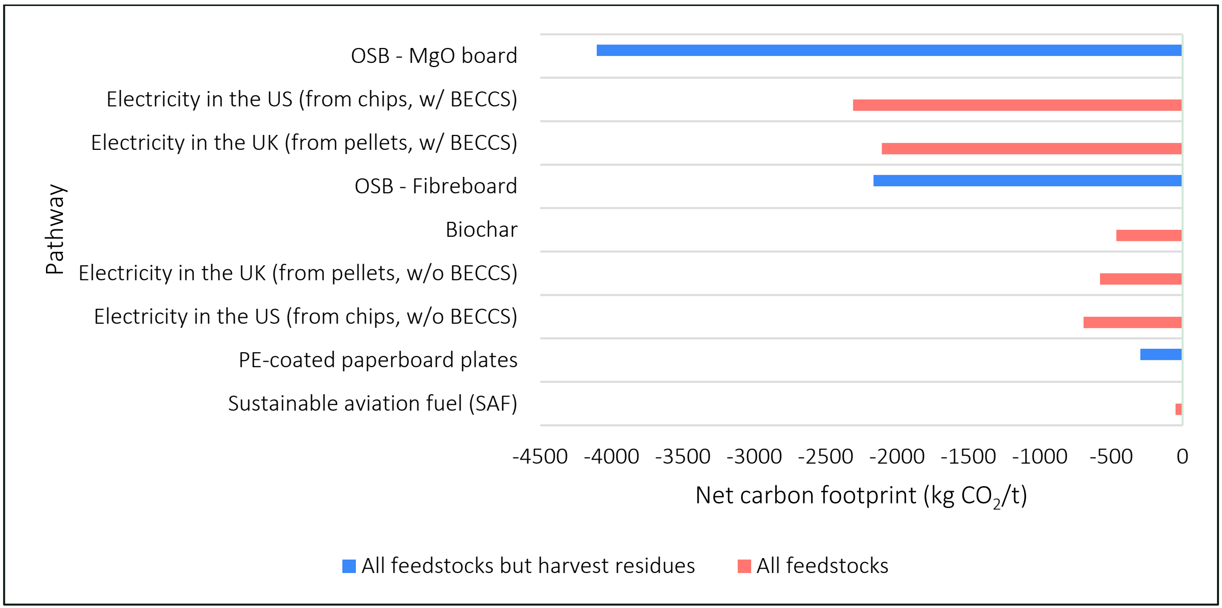

Figure 14: Net carbon impact of the different use pathways

Although wood products such as lumber do not use the same feedstocks as the one covered in this study, they have been extensively studied in terms of their carbon benefits relative to fossil-based alternatives. Table 20 compares substitution factor (kg CO_2 eq./kg C in product) for various wood products in this study and in the literature. The results obtained in this study are inline with that found in the literature. Electricity from wood feedstocks led to carbon benefits inline with that of wood products when considering carbon storage. When considering fossil fuels only, results show that substitution benefits are extremely variable for wood products.

Table 20. Magnitude of carbon benefits of using wood feedstocks for electricity comparatively of typical benefits of using sawtimber for wood products

Author	Use pathway	Geographical context	Substitution factor*	Substitution factor (fossil and biogenic CH_4 only) *
			kg CO_2e/kg C in product** (kg CO2e/t wood)	
This study	Electricity in the US (from chips, w/o BECCS)	US	-1.4 (-689)	-1.4 (-689)
This study	Electricity in the US (from chips, w/ BECCS)	US	-4.6 (-2304)	-1.1 (-563)
This study	Electricity in the UK (from pellets, w/o BECCS)	UK	-1.2 (-578)	-0.9 (-446)
This study	Electricity in the UK (from pellets, w/ BECCS)	UK	4.4 (-2107)	-1.2 (-567)
This study	Sawtimber – Steel	US	-3.0 (-1120)	-0.44 (-166)
This study	Sawtimber - Concrete	US	-3.1 (-1164)	-0.56 (-209)
Leskinen et al.	Construction products - Structural	Global	N/Av	-4.8***, -20.2 to +3.3
Leskinen et al.	Construction products – Non structural	Global	N/Av	-5.8***, -17.2 to +0.7

*For consistency with this study, a negative indicates a carbon benefit of the wood product compared to the fossil alternative.
**Note change in units to be comparable to the literature.
***Average value.

5 Interpretation

Interpretation of CFP results above is carried out in this section, comprising:

- A **sensitivity analysis**, which tests the effect of uncertainty in the data, assumptions and methodological choices on overall results and conclusions;
- An **uncertainty analysis**, which highlight the significance of the results in the comparative analysis;
- The **completeness check,** which verifies whether information from the phases of a life cycle assessment is sufficient for reaching conclusions in accordance with the goal and scope definition;
- The **consistency check**, which verifies that the assumptions, methods and data are consistently applied throughout the study; and
- A data quality assessment, that verifies that data quality criteria were met.

5.1 Sensitivity Analyses

Sensitivity analyses are undertaken on parameters that are likely to affect the results of the analysis.

5.1.1 Pre-Processing of Wood Feedstock (Electricity Pathways)

Above, we assumed that the same level of pre-processing of wood feedstocks would be required for the different pathways of a same feedstock. In this sensitivity analysis, we assess the implication of additional pre-processing for electricity processing, and we assume that 3.01 L/dry t of wood feedstock would be required. Results in Table 21 show that the assumption to neglect pre-processing of wood feedstocks had little effect on the results.

Table 21. Sensitivity Analysis on Wood Feedstocks Pre-Processing

Use pathway	Base case	Additional processing	Min*	Max*
	kg CO_2e/t			
Electricity in the US (from chips, w/o BECCS)	-689	-679	-49.0 (SAF)	-4104 (OSB – MgO board)
Electricity in the US (from chips, w/ BECCS)	-2304	-2294		
Electricity in the UK (from pellets, w/o BECCS)	-578	-568		
Electricity in the UK (from pellets, w/ BECCS)	-2107	-2097		

*For comparison purposes.

5.1.2 Location of Production of PE-Coated Paperboard Plates

In this sensitivity analysis we test the sensitivity of the results to assuming the paperboard plates are produced in Europe (i.e., using European data) rather than in the US. To do this, we replaced the data for paperboard production by:

- Folding boxboard carton {RER}| folding boxboard carton production (ecoinvent); and
- Packaging film, low density polyethylene {RER}| packaging film production, low density polyethylene (ecoinvent).

Results in Table 22 show that the results of for the paperboard plates pathway are relatively insensitive to the location of production.

Table 22. Sensitivity analysis on location of production of paperboard plates

Use pathway	US	Europe
	kg CO_2e/t	
PE-coated paperboard plates	-296	-290

5.1.3 Carbon Intensity of Jet Fuel (SAF Pathway)

In this study, we used US LCI to model the production of jet fuel (kerosene used as a proxy) which resulted in 12.4 g CO_2e/MJ. Kerosene production in ecoinvent is 21.0 g CO_2e/MJ for Europe while Ringsred et al. report 89.8 g CO_2e/MJ for jet fuel (Canada). This sensitivity analysis assesses the implications of assumed carbon intensity for jet fuel for the performance of the SAF pathway. The result in Table 23 shows that the assumption on the carbon intensity of jet fuel production while having significant implications does not affect the ranking of SAF within the various use pathways.

Table 23. Sensitivity analysis on the carbon intensity (CI) of jet fuel production

Use pathway	CI = 12.4	CI = 21.0	CI = 89.8
	kg CO_2e/t		
SAF Pathway	-49.0	-62.3	-169

5.1.4 Various Sensitivity Analysis on the OSB Pathway

Here we undertook the following sensitivity analysis on the OSB use pathway:

- Production of OSB in Europe;
- OSB substituting for OSB produced in China instead of fibreboard or MgO board;
- Lifetime of MgO board; and
- Consideration of temporary carbon storage.

For the production of OSB in Europe, we used the "Oriented strand board {RER}| oriented strand board production" dataset from ecoinvent.

For the production of OSB in China, we used the "Oriented strand board {RoW}| oriented strand board production" dataset from ecoinvent where we replaced the electricity mix from Chinese. We assumed transportation from China to Southeast US by boat and rail.

MgO board has much shorter reported lifetime (Gorbunov (2022)[30]) than OSB. In this sensitivity analysis we look at the results if we assume that the lifetime of MgO board is half of that of OSB, meaning that we would displace twice as much as MgO board.

Lastly, it can be argued that long-lived products such as OSB temporary store carbon with benefit for climate change. In this analysis, we credited OSB with a temporary carbon storage benefit by applying dynamic LCA of 100-year. The emission profile was calculated using NCASI carbon storage tool[31] using the parameters depicted in Figure 15. Then, the total impact from biogenic CO_2 and CH_4 was calculated by apply the DynCO_2 calculator[32] where the emission profile was entered assuming a carbon removal of -1833 kg CO_2 in year 0. Dynamic LCA was not applied to the fibreboard substitution because fibreboard also includes a portion of wood fibre material which would have complexified the interpretation.

User Input Parameters:

0.83	Quantity of product (dry metric tons produced in year of interest)
0.5	Fraction of carbon per dry mass of product (fraction between zero and one, default value is 0.5)
80	Half life of product in use (see table of default values in "Default Parameters" tab). Enter zero if no carbon is stored in product-in-use phase (carbon immediately flows to end of life disposition).
0.184	Fraction of product burned or incinerated (versus other end of life fates) as it is removed from service (fraction between zero and one)
0.091	Fraction of product recycled (versus other end of life fates) as it is removed from service (fraction between zero and one)
0.725	Fraction of product sent to landfill (versus other end of life fates) as it is removed from service (fraction between zero and one)
OKAY	Error Check: Each end of life disposition entry must be a fraction between zero and one, and sum of three entries cannot exceed 1
1	What fraction of the landfilled material will be disposed of in anaerobic landfills (i.e., versus dumps or composting facilities, fraction between zero and one)?
0.8	What fraction of the carbon is non-degradable under anaerobic conditions (also known as carbon storage fraction (CSF), fraction between zero and one, see table of default values in "Default Parameters" tab)?
0.0239	Rate constant for decay in landfill ($year^{-1}$, see table of default values in "Default Parameters" tab)
0.5	Fraction of carbon in generated landfill gas from anaerobic landfills that is methane (remainder assumed to be carbon dioxide, default is 0.5)
0.1	Fraction of generated methane in landfill gas that is "naturally" oxidized in landfill cover (default is 0.1)
0.64	Fraction of methane in landfill gas, after natural oxidation, that is captured and destroyed or otherwise not emitted (see table of default values in "Default Parameters" tab).
29.8	GWP of methane (kg CO2E/kg CH4; IPCC 1996: 21, IPCC 2006: 25, IPCC 2014: 28)

Figure 15: Input parameters to NCASI carbon storage tool

Results of sensitivity analyses on OSB are presented in Table 24. It can be seen that if OSB substitutes for OSB from China and not for fossil fuel-based alternative, the carbon benefits of using wood feedstocks in OSB are much lower. Assuming that a product can be credited for temporary carbon storage increases the benefits of using wood feedstocks in long-lived product over short-lived. Finally, producing OSB in Europe instead of in the US has marginal implications for the results.

[30] Gorbunov. I. 2022. Comparative Life Cycle Assessment of a Sustainable Modular Tiny-House. University of Twente. Civil Engineering. S2355116. https://essay.utwente.nl/93535/1/Gorbunov-Ilya.pdf.

[31] https://www.ncasi.org/resource/tool-to-calculate-carbon-stored-in-forest-products/.

[32] https://ciraig.org/index.php/project/dynco2-dynamic-carbon-footprinter/.

Table 24. Sensitivity analysis on OSB

Location of production of OSB	Substituted Product Fibreboard	 MgO board	 Chinese OSB
	kg CO_2e/t		
US	-2686	-4104	-520
Europe	-2020	-3959	-389
US – Dynamic LCA		-4672	
For comparison purposes			
Electricity in the US (from chips, w/o BECCS)	-689		
Electricity in the US (from chips, w/ BECCS)	-2304		
Electricity in the UK (from pellets, w/o BECCS)	-578		
Electricity in the UK (from pellets, w/ BECCS)	-2107		

5.2 Completeness and Consistency Checks

The completeness check is the process of verifying whether information from the phases of a life cycle assessment is sufficient for reaching conclusions in accordance with the goal and scope definition. The consistency check is the process of verifying that the assumptions, methods, and data are consistently applied throughout the study and are in accordance with the goal and scope definition performed before conclusions are reached. In this study, most assumptions and methodological choices have been applied consistently. Sensitivity analyses were performed on methodological choices, on the parameters with relatively large uncertainty, and on potential inconsistencies. These allowed clear definition of the conditions for which the main conclusions remain valid. Hence, consistency in modelling systems in the study is considered sufficient to achieve the objectives. There were no significant data gaps, hence the completeness of the study is considered adequate in relation to its objectives.

5.3 Uncertainty Analysis

The objective of this study was not to make precise claims about the comparative carbon benefits of the different use pathways but rather to gain a general understanding of the magnitude of using wood feedstocks for electricity production compared to other pathways for using these feedstocks. Therefore, no formal quantitative uncertainty analysis was performed. However, uncertainty is important in understanding the significance of the results obtained, especially when comparisons are performed. For this reason, a qualitative analysis was undertaken. Any difference lower than 10% is unlikely to be significant (Franklin Associates 2004[33], Humbert et al. 2009[34]). The results are summarized in Table 25.

Table 25. Ranking of use pathways considering 10% uncertainty threshold

Rank (largest benefit to lowest)	Use pathways
1	OSB – MgO board
2	OSB – Fibre cement board
3	Electricity in the US (from chips, w/ BECCS) Electricity in the UK (from pellets, w/ BECCS)
4	Electricity in the US (from chips, w/o BECCS)
5	Electricity in the UK (from pellets, w/o BECCS)
6	Biochar
7	PE-coated paperboard plates
8	Sustainable aviation fuel (SAF)

5.4 Data Quality Assessment

Data Quality criteria and assessment are presented in Table 26.

[33] Franklin Associates. 2004. Life cycle inventory of packaging options for shipment of retail mail-order soft goods. Final peer-reviewed report. Prairie Village, KS.
[34] Humbert, S., Rossi, V., Margni, M., Jolliet, O. and Loerincik, Y. 2009. Life cycle assessment of two baby food packaging alternatives: glass jars vs. plastic pots. *The International Journal of Life Cycle Assessment*. 14(2):95-106.

Table 26. Data quality assessment

Aspect	Criteria	Assessment
Time-related coverage	General data represent the current situation of the date of study, or as close as possible. Collected data represent conditions and operations as of 2023.	Primary data is from 2023. The latest ecoinvent data was used. US LCI data available in SimaPro is relatively dated but still judged more representative than European data where used. Most data around substitute are from the 2020s, which is judged acceptable for the purpose of this study.
Geographical coverage	Data are representative of US and Europe.	Primary data was taken from the various location covered in this study. For BECCs, UK data was used as a proxy for US by adapting the grid mix.
Technology coverage	Data are representative of the technology used in the specified locations	Data was taken from described technologies.
Consistency	Consistent assumptions and modelling choices are applied across the product systems (e.g., allocation approach, transportation included, waste disposal included).	Consistent assumptions were applied and where not possible, conservative assumptions were made. Although different allocation methods are used in different databases, compared system uses consistent allocation methods.
Completeness	Simple validation checks (e.g., mass balances) are performed.	Primary data was checked through mass balanced.
Representativeness	The data fulfil the defined time-related, geographical and technological scope.	Data is representative of geography and scope as defined above.
Precision	Data that are as representative as possible are used. A sensitivity analysis is used to determine the influence of variability in key parameters on the study conclusions.	See sensitivity analysis in Section 4.1.
Reproducibility	Information about the method and data (reference source) are provided.	See list of references.
Sources of the data	Data derived from credible sources, and references are provided.	Data was taken from consistent data sources were possible and through credible data sources.

6 Conclusions and Limitations

6.1 Conclusions

The following conclusions can be drawn from the study:

- All use pathways resulted in carbon benefits compared to their substitution.
- The use of wood feedstocks for producing electricity with BECCs although not leading to the greatest observed benefits still ranked relatively high and consistently with that of producing OSB (in some substitution scenarios).
- The use of wood feedstocks for producing electricity without BECCs produced lower carbon benefits, but these were still higher than carbon benefits of some other pathways.
- Rankings are insensitive to the geographical context (i.e., US versus Europe).

6.2 Limitations

The results within this report are mainly limited that primary data was only available for the electricity pathways. Secondary data was used to model all other pathways and results showed to be relatively variable. As such, results of this study cannot be used to make precise quantitative claims. In addition, the study compares the carbon impacts of static and independent systems and does not evaluate the dynamic implications of moving the wood feedstock from one use to the other. The results do not, therefore, reveal the overall effects of, for instance, increasing the competition for woody biomass where bioenergy and wood product systems are relying on common sources of raw materials. Where changes in raw material availability and cost are imposed, bioenergy and forest product systems would likely respond differently.

7 Critical Review Statement

Critical review statement, reviewers' self-declarations and detailed comment are provided in the next pages.

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January 7, 2025

Attest Verification Report: Comparative Carbon Footprint of Uses of Wood Residues and Low Grade Roundwood, Prepared by Anthesis Group – January 6, 2025

Anthesis Group commissioned an external ISO peer review by First Environment, Inc. to perform an external independent ISO critical review of the Comparative Carbon Footprint of Uses of Wood Residues and Low Grade Roundwood, Prepared by Anthesis Group – January 6, 2025.

The goal of this review was to demonstrate that the product carbon footprint meets the International Organization for Standardization. (2018). *Greenhouse gases—Carbon footprint of products – Requirements and guidelines for quantification* (ISO 14067:2018)

The independent third-party verification was conducted by the following experts:

Reid Miner
an Emeritus Senior Fellow at NCASI

Pakarat Promyu, CLE
Environmental Scientist
First Environment, Inc.

REVIEW SCOPE

The intent of this review was to provide an independent third-party external verification of the Product Carbon Footprint (PCF) for the Comparative Carbon Footprint of Uses of Wood Residues and Low Grade Roundwood in conformance with the aforementioned ISO standards. This review excluded an in-depth assessment of both the life cycle inventory (LCI) model and individual datasets.

REVIEW PROCESS

The review process involved the verification of all requirements set forth by the applicable ISO standards cataloged in the comprehensive review table along with editorial comments.

A preliminary draft report was submitted for review on October 07, 2024. There were three rounds of comments by the reviewers submitted to Anthesis Group in the form of comprehensive review matrices. Responses by Anthesis Group to each issue raised were resolved and acknowledged by the reviewers to have been satisfactorily addressed. A final revised report date was issued on January 6, 2025.

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VERIFICATION STATEMENT

Based on the independent verification objectives, the final report, Comparative Carbon Footprint of Uses of Wood Residues and Low Grade Roundwood, Prepared by Anthesis Group – January 6, 2025, was determined to be ***in conformance*** with the applicable ISO standards. The quality and accuracy of the carbon footprint of a product - based data and supporting information are confirmed.

As the external reviewer, I confirm that I have sufficient technical knowledge and experience of the material contents of this study and the applicable ISO standards to carry out this verification.

VCS VERIFIED CARBON STANDARD A Global Benchmark for Carbon

Sincerely,

CR Verification Body

Pakarat Promyu

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Pakarat Promyu
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Self-Declaration of Reviewer Independence and Competencies (ISO/TS 14071)

Report Title: Comparative Carbon Footprint of Uses of Wood Residues and Low Grade Roundwood
Report Date: January 6, 2025

I, the signatory, hereby declare that:

- ☒ I am not a full-time or part-time employee of the commissioner or practitioner of the LCA study (external reviewers only).
- ☒ I have not been involved in defining the scope or carrying out any of the work to conduct the LCA study at hand, i.e., I have not been part of the commissioner's or practitioner's project team(s).
- ☒ I do not have vested financial, political, or other interests in the outcome of the study.

My competencies relevant to the Critical Review at hand include knowledge of and proficiency in:

- ☒ ISO 14040 and ISO 14044
- ☒ LCA methodology and practice, particularly in the context of LCI, (including data set generation and data set review, if applicable)
- ☒ Critical Review practice
- ☒ The scientific disciplines relevant to the important impact categories of the study.
- ☒ Environmental, technical. and other relevant performance aspects of the product system(s) assessed
- ☒ Language used for the study

I declare that the above statements are truthful and complete. I will immediately notify all parties involved (commissioner of the critical review, practitioner of the LCA study, fellow reviewer(s)), as applicable, if the validity of any of these statements changes during the course of the review process.

Signature: *Pakarat Promyu*

Name: Pakarat Promyu

Date: January 7, 2025

Anthesis

Self-Declaration of Reviewer Independence and Competencies (ISO/TS 14071)

Report Title:
Report Date:

I, the signatory, hereby declare that:

☒ I am not a full-time or part-time employee of the commissioner or practitioner of the LCA study (external reviewers only).

☒ I have not been involved in defining the scope or carrying out any of the work to conduct the LCA study at hand, i.e., I have not been part of the commissioner's or practitioner's project team(s).

☒ I do not have vested financial, political, or other interests in the outcome of the study.

My competencies relevant to the Critical Review at hand include knowledge of and proficiency in:

☐ ISO 14040 and ISO 14044

☐ ISO 14067

☐ LCA methodology and practice, particularly in the context of LCI, (including data set generation and data set review, if applicable)

☐ Critical Review practice

☒ The scientific disciplines relevant to the important impact categories of the study.

☐ Environmental, technical. and other relevant performance aspects of the product system(s) assessed

☐ Language used for the study

I declare that the above statements are truthful and complete. I will immediately notify all parties involved (commissioner of the critical review, practitioner of the LCA study, fellow reviewer(s)), as applicable, if the validity of any of these statements changes during the course of the review process.

Signature:________________________________

Name: Reid Miner

Date: January 9, 2025

Critical Review Matrix for use by panel members to provide comments in accordance with the ISO 14067 standards **Date:** 10/7/2024
Document: Comparative Carbon Footprint of Uses of Wood Residues and Low Grade Roundwood
Reviewers: Reid Miner and First Environment, Inc (Pakarat Promyu)

Comment #	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/ Note (e.g. Table 1)	ISO 14067 - Methodology for quantification of the CFP and partial CFP	Reviewer Comments	Practioner Response	Reviewer Comments	Practioner Response	Status
14067-1			**ISO 14067 6.1 General** A CFP study in accordance with this document shall include the four phases of LCA, i.e. goal and scope definition (see 6.3), LCI (see 6.4), LCIA (see 6.5) and life cycle interpretation (see 6.6), for CFP or partial CFP. The unit processes comprising the product system shall be grouped into life cycle stages, e.g. acquisition of raw material, design, production, transportation/delivery, use (see 6.3.7) and end-of-life (see 6.3.8). GHG emissions and removals from the product's life cycle shall be assigned to the life cycle stage in which the GHG emissions and removals occur. Partial CFPs may be added together to quantify the CFP, provided that they are performed according to the same methodology for the same timeframe and that no gaps or overlaps exist. An organization may develop a CFP systematic approach. If it does, it shall be developed in accordance with Annex C.	Requirement Met				Closed
14067-2			**ISO 14067 6.2 Use of CFP–PCR** Where relevant PCR or CFP–PCR exist, they shall be adopted. PCR or CFP–PCR are relevant provided: — they have been developed in accordance with ISO/TS 14027, or a relevant sector-specific International Standard that applies the requirements of ISO 14044; — they conform to the requirements of this clause, 6.3, 6.4 and 6.5; — they are considered proper (e.g. for system boundaries, modularity, allocation and data quality) by the organization applying this document and are in accordance with the principles in Clause 5. Note: Examples of organizations that apply this document are providers of goods and services, practitioners and commissioners of the CFP study. If more than one set of relevant PCR or CFP–PCR exist, the relevant PCR or CFP–PCR shall be reviewed by the organization applying this document (e.g. for system boundaries, modularity, allocation, data quality). The choice of the PCR or CFP–PCR adopted shall be justified. When all requirements in this subclause are met by PCR, those PCR are equivalent to the CFP–PCR. If CFP–PCR are adopted for the CFP study, the quantification shall be conducted according to the requirements in these CFP–PCR. Where no relevant CFP–PCR exist, the requirements and guidance of other internationally agreed sector-specific documents, related to specific product or material categories, should be adopted if they conform to the requirements of this document and are considered appropriate by the organization applying this document.	Requirement Met				Closed
14067-3	1.4		**ISO 14067 6.3.1 Goal of a CFP study** The overall goal of conducting a CFP study is to calculate the potential contribution of a product to global warming expressed as CO2e by quantifying all significant GHG emissions and removals over the product's life cycle or selected processes, in line with cut-off criteria (see 6.3.4.3). NOTE 1 This quantification supports a range of objectives and applications, including, but not limited to, individual studies, comparative studies in accordance with Annex B and performance tracking over time, and is intended for a range of audiences. In defining the goal of a CFP study, the following items shall be unambiguously stated: — the intended application; — the reasons for carrying out the CFP study; — the intended audience; — the intended communication, if any, of the CFP or partial CFP information, in accordance with ISO 14026. NOTE 2 This subclause is adapted from ISO 14044:2006, 4.2.2.	*Regarding the intention to inform "the debate on the relative merits of bioenergy..."* I would note that this debate is almost always in the context of potential dynamic competition for raw material. This study does not address such situations. Instead, it compares static and independent systems. Where there is competition for raw material, understanding the carbon implications requires understanding how each system responds. In these situations, it cannot be assumed that (a) the systems will respond the same or (b) there will be no impact on forest carbon. This is an important caveat that should be highlighted in communicating the results of this study.	Caveat added to section 1.4.	1. The caveat added to Section 1.4 needs to be changed from "Note that this debate also needs consideration of potential dynamic competition for raw materials, which is not addressed by this report." to "Note that this debate also needs consideration of **the carbon impacts** of potential dynamic competition for raw materials, which **are** not addressed by this report." 2. This same caveat (as edited above) needs to be added to the "Limitations", located immediately before the Table of Contents 3. The functional unit description in Goal and	Done.	Closed
14067-4	6.2		**ISO 14067 6.3.2 Scope of a CFP study** The scope of a CFP study shall be consistent with the goal of the CFP study (see 6.3.1). In defining the scope of the CFP study, the following items shall be considered and clearly described, taking into account the requirements and guidance given in the relevant subclauses of this document: a) the system under study and its functions; b) the functional or declared unit (see 6.3.3); c) the system boundary, including the geographical scope of the system under study (see 6.3.4); d) data and data quality requirements (see 6.3.5); e) the time boundary for data (see 6.3.6); f) assumptions, especially for the use stage and the end-of-life stage (see 6.3.7 and 6.3.8); g) allocation procedures (see 6.4.6); h) specific GHG emissions and removals (see 6.4.9), e.g. due to LUC (see 6.4.9.5); i) methods to address issues occurring with specific product categories (see 6.4.9); j) the CFP study report (see Clause 7); k) the type of critical review, if any (see Clause 8); l) limitations of the CFP study (see Annex A). If a comparison is undertaken, the requirements in Annex B shall be followed. In some cases, the scope of the CFP study may be revised due to unforeseen limitations, constraints or as a result of additional information. Such modifications, together with their explanation, shall be documented. NOTE This subclause is adapted from ISO 14044:2006, 4.2.3.1.	As noted above, another important limitation is that the study compares static and independent systems. The results do not, therefore, reveal the overall effects of, for instance, increasing the competition for woody biomass where bioenergy and wood product systems are relying on common sources of raw materials. Where changes in raw material availability and cost are imposed, bioenergy and forest product systems would likely respond differently, and in ways that would violate the assumption, applied in this study, that feedstock operations are not affected. Therefore, dynamic impacts on forest carbon would likely need to be considered.	Added to limitations in Section 6.4.			Closed
			ISO 14067 6.3.3 Functional or declared unit A CFP study shall clearly specify the functional or declared unit of the system under study. The functional or declared unit shall be consistent with the goal and scope of the CFP study. The primary purpose of a functional or declared unit is to provide a reference to which the inputs and outputs are related. Therefore, the functional or declared unit shall be clearly defined and measurable. The declared unit shall only be used in a partial CFP. When CFP–PCR are adopted, the functional or declared unit used shall be that defined in the CFP–PCR. Having chosen the functional or declared unit, the associated reference flow shall be defined.	Typo identified. Change, "The use of wood dry tonne of wood feedstock" to "The use of one dry tonne of wood feedstock".				

14067-5	2.1	Table 5	When a comparison is done between product systems, it shall be made on the basis of the same functional unit(s). Comparisons based on partial carbon footprint (declared unit) are permitted if the omitted life cycle stages are identical (see Annex B). Comparison based on the declared unit may only be used for business-to-business purposes. If additional functions of any of the product systems are not taken into account in the comparison of functional units, then these omissions shall be explained and documented. As an alternative to this approach, systems associated with the delivery of these functions may be added to the boundary of the other product system to make the product systems more comparable. In these cases, the processes selected shall be explained and documented. NOTE 1 The choice of the functional or the declared unit and the associated reference flow require special attention, e.g. in order to allow comparisons without bias (see also Annex B).	Section 2.4.1 Secondary functions Table 5 Quantity of paperboard plates This should be 29747 plates. Table 5 Reference flow for polystyrene plates Table 13 indicates that each plate weighs 10.8 grams. 29747 plates would weigh 0.32 metric tons, not 0.29 metric tons. Table 5 Rationale for OSB I suggest changing "there are few obvious substitutes for OSB" to "there are few obvious non-wood-based substitutes	Typos corrected. And changed made.			Closed
14067-6			**ISO 14067 6.3.4 System boundary** **6.3.4.1 General** The system boundary shall be the basis used to determine which unit processes are included within the CFP study. Where CFP–PCR are used (see 6.2), their requirements on the processes to be included shall also apply. The selection of the system boundary shall be consistent with the goal of the CFP study. The criteria, e.g. cut-off criteria (see 6.3.4.3), used in establishing the system boundary shall be identified and explained. Decisions shall be made regarding which unit processes to include in the CFP study and to which level of detail these unit processes shall be studied. The exclusion of life cycle stages, processes, inputs or outputs within the system under study is only permitted if they do not significantly change the overall conclusions of the CFP study. Any decisions to exclude life cycle stages, processes, inputs or outputs shall be clearly stated and the reasons and implications for their exclusion shall be explained. The threshold for significance shall be stated, e.g. as cut-off criteria (see 6.3.4.3), and justified. EXAMPLE Capital goods can be excluded in accordance with the goal and scope if their exclusion is not expected to significantly alter the conclusions according to specified criteria. Decisions made regarding which unit processes, inputs and outputs shall be included and the level of detail of the quantification of the CFP shall be clearly stated. NOTE 1 The first five paragraphs of this subclause are adapted from ISO 14044:2006, 4.2.3.3. The CFP and the partial CFP shall not include carbon offsetting. NOTE 2 GHG removals that are not linked to carbon offsetting can occur within the system boundary of the product system.	Requirement Met				Closed
14067-7			**ISO 14067 6.3.4.2 Setting the system boundary** Quantification carried out in accordance with this document shall include all GHG emissions and removals of those unit processes that are part of the product system that have the potential to make a significant contribution to the CFP or the partial CFP (see 6.3.4.1). Within the goal and scope definition phase, consistent criteria shall be defined: — for which unit processes a detailed assessment is needed due to an expected significant contribution to the CFP or the partial CFP; — for which unit processes the quantification of GHG emissions may be based on secondary data if the collection of primary data are not possible or practicable (see 6.3.5); — which unit processes may be merged, e.g. all transport processes within a plant.	Requirement Met				Closed
14067-8			**ISO 14067 6.3.4.3 Cut-off criteria** In general, all processes and flows that are attributable to the analyzed system shall be included. If individual material or energy flows are found to be insignificant for the carbon footprint of a particular unit process, these may be excluded for practical reasons and shall be reported as data exclusions. Consistent cut-off criteria that allow the exclusion of certain processes of minor importance shall be defined within the goal and scope definition phase. The effect of the selected cut-off criteria on the outcome of the study shall also be assessed and described in the CFP study report (see 6.4.5 and 6.6). NOTE For additional guidance on cut-off criteria, see ISO 14044:2006, 4.2.3.3.3.	Requirement Met				Closed
14067-9			**ISO 14067 6.3.5 Data and data quality** Site-specific data shall be collected for individual processes where the organization undertaking the CFP study has financial or operational control. The data shall be representative of the processes for which they are collected. Site-specific data should also be used for those unit processes that are most important and not under financial or operational control. NOTE 1 The most important processes are those which together contribute at least 80 % to the CFP, starting from the largest to the smallest contributions after cut-off. NOTE 2 Site-specific data refer to either direct GHG emissions (determined through direct monitoring, stoichiometry, mass balance or similar methods), activity data (inputs and outputs of processes that result in GHG emissions or removals) or emission factors. Site-specific data can be collected from a specific site, or can be averaged across all sites that contain the process within the system under study. They can be measured or modelled, as long as the result is specific to the process in the product's life cycle. Primary data that are not site-specific data, and which have undergone third-party review, should be used when the Secondary data shall only be used for inputs and outputs where the collection of primary data is not practicable, or for processes of minor importance. NOTE 3 In some cases, default emission factors as secondary data are not life cycle based emission factors and might require adaptation or modification. Secondary data shall be justified and documented with references in the CFP study report. A CFP study should use data that reduce bias and uncertainty as far as practical by using the best quality data available. Data quality shall be characterized by both quantitative and qualitative aspects. Characterization of data quality should address the following: a) time-related coverage: age of data and the minimum length of time over which data should be collected; b) geographical coverage: geographical area from which data for unit processes should be collected to satisfy the goal of the CFP study; c) technology coverage: specific technology or technology mix; d) precision: measure of the variability of each data value expressed (e.g. variance); e) completeness: percentage of total flow that is measured or estimated; f) representativeness: qualitative assessment of the degree to which the data set reflects the true population of interest (i.e. geographical coverage, time period and technology coverage); g) consistency: qualitative assessment of whether or not the study methodology is applied uniformly to the various components of the sensitivity analysis; h) reproducibility: qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the CFP study; i) sources of the data; j) uncertainty of the information. NOTE 4 The numbered list above is adapted from ISO 14044:2006, 4.2.3.6.2.	Requirement Met				Closed

			A two-step approach shall be taken for the data quality evaluation: — the data quality requirements according to items a) to d) above shall be characterized for the CFP study; — data shall be assessed with respect to the requirements for items a) to d) above. NOTE 5 Data quality requirements are a mandatory part of CFP–PCR (see 6.2). NOTE 6 Data quality requirements might differ for different types of data. Organizations undertaking a CFP study should have a system to manage and retain data. They should seek to continuously improve the consistency and quality of their data and control of documented information.					
14067-10			**ISO 14067 6.3.6 Time boundary for data** The time boundary for data is the time period for which the quantified figure for the CFP is representative. The time period for which the CFP is representative shall be specified and justified. The choice of the time period for data collection should consider intra- and inter-annual variability and, when possible, use values representing the trend over the selected period. Where the GHG emissions and removals associated with specific unit processes within the life cycle of a product vary over time, data shall be collected over a time period appropriate to establish the average GHG emissions and removals associated with the life cycle of the product. If a process within the system boundary is linked to a specific time period (e.g. seasonal products such as fruit and vegetables), the assessment of GHG emissions and removals shall cover that particular period in the life cycle of the product. Any activity (or activities) occurring outside that period shall also be included provided that it is within the product system (e.g. GHG emissions related to a tree nursery). These data on GHG emissions and removals shall be related to the functional or declared unit.	Requirement Met				Closed
14067-11			**ISO 14067 6.3.7 Use stage and use profile** When the use stage is included within the scope of the CFP study (see 6.3.2), GHG emissions and removals arising from the use stage of the product shall be included. The user of the product and the use profile of the product shall be specified in the CFP study. NOTE The use stage starts when the specified user takes possession of the finished product and ends when the product is ready for disposal, reuse for a different function, recycling or energy recovery. Service life information shall be verifiable. It shall refer to the intended use conditions and to the related functions of the product. The use profile should seek to represent the actual usage pattern in the selected market. Where not otherwise justified, the determination of the use profile (i.e. scenarios for service life and the selected market) shall be based on published technical information, such as: a) CFP–PCR (see 6.2); b) published International Standards that specify guidance and requirements for development of scenarios and service life for the use stage for the product being assessed; c) published national guidelines that specify guidance for development of scenarios and service life for the use stage for the product being assessed; d) published industry guidelines that specify guidance for development of scenarios and service life for the use stage for the product being assessed; e) use profiles based on documented usage patterns for the product in the selected market. Where no method for determining the use profile of products has been established in accordance with a) to e) above, the assumptions made in determining the use profile of products shall be established by the organization carrying out the CFP study. A sensitivity analysis shall be undertaken if the use stage assumption is shown to be significant for the conclusions of the CFP study. The manufacturer's recommendation for proper use (e.g. cooking in an oven at a specified temperature for a specified time) might provide a basis for determining the use profile of a product. The actual usage pattern might, however, differ from those recommended. Any difference should be explained. All relevant assumptions for the use stage shall be documented in the CFP study report.	Requirement Met				Closed
14067-12	3.21	Table 8	**ISO 14067 6.3.8 End-of-life stage** NOTE 1 The end-of-life stage begins when the used product under study is ready for disposal, recycling, reuse for different purposes or energy recovery. All the GHG emissions and removals arising from the end-of-life stage of a product shall be included in a CFP study, if this stage is included in the scope (see 6.3.2). End-of-life processes may include: a) collection, packaging and transport of end-of-life products; b) preparation for recycling and reuse; c) dismantling of components from end-of-life products; d) shredding and sorting; e) material recycling; f) organic recovery (e.g. composting and anaerobic digestion); g) energy recovery or other recovery processes; h) incineration and sorting of bottom ash; i) landfilling, landfill maintenance and promoting emissions from decomposition, such as methane. NOTE 2 For end-of-life processes, CFP–PCR can provide additional guidance. All relevant assumptions regarding end-of-life treatment, shall be: — based on best available information; — based on current technology; — documented in the CFP study report. End-of-life scenarios shall reflect the current market and be representative of one of the most likely alternatives, or more than one scenario (including future scenarios) may be assessed. The scenarios will allow users to scale the results to assess realistic options.	The reference for the percent of wood input for calculating wood ash to landfill in table 8 should be added. Is this number referred from Ecoinvent?	I don't have a specific reference... if you google you'Ll see percent as is between 6-10, 8 is the moddle and that I always use.			Closed
14067-13			**ISO 14067 6.4.1 General** LCI is the phase of LCA involving the compilation and quantification of inputs and outputs for a product throughout its life cycle. After the goal and scope definition phase, the LCI of a CFP study shall be conducted. This consists of the following steps, adapted from ISO 14044, which shall apply when relevant: a) data collection; b) validation of data; c) relating data to unit process and functional or declared unit; d) refining the system boundary; e) allocation. Special provisions in this document apply for: — CFP performance tracking; — the time period for the assessment of GHG emissions and removals; — the treatment of specific GHG emissions and removals. If CFP–PCR are adopted for the CFP study, the LCI shall be conducted according to the requirements in the CFP–PCR.	Requirement Met				Closed

14067-14	3.2.3	Table 10, 11	**ISO 14067 6.4.2 Data collection** The qualitative and quantitative data for inclusion in the life cycle inventory shall be collected for all unit processes that are included in the system under study. The collected data, whether measured, calculated or estimated, are used to quantify the inputs and outputs of a unit process. Significant unit processes shall be documented in the CFP study report. For those data that might be significant for the conclusions of the CFP study, details about the relevant data collection process, the time when data have been collected, and further information about data quality shall be referenced. If such data do not meet the data quality requirements, this shall be stated. Since data collection can span several locations and published references, a representative and consistent data set for the system under study should be used. NOTE 1 This subclause is adapted from ISO 14044:2006, 4.3.2. For further guidance, see ISO 14044:2006, 4.3.2.2. NOTE 2 For data and data quality, see 6.3.5.	Is the data about 7% water content of wood pellets mentioned in the table 10 and 11 an assumption or seconadry dataset used? If it is secondary data, the reference should be documented.	Primary data. Speciofied.			Closed
14067-15			**ISO 14067 6.4.3 Validation of data** A check on data validity shall be conducted during the process of data collection to confirm and provide evidence that the data quality requirements specified in 6.3.5 have been met. Validation should involve establishing mass balances, energy balances and/or comparative analyses of emission factors or other appropriate methods. As each unit process obeys the laws of conservation of mass and energy, mass and energy balances provide a useful check on the validity of the description of a unit process. NOTE This subclause is adapted from ISO 14044:2006, 4.3.3.2.	Requirement Met				Closed
14067-16			**ISO 14067 6.4.4 Relating data to unit process and functional or declared unit** An appropriate flow shall be determined for each unit process. The quantitative input and output data of the unit process shall be calculated in relation to this flow. Based on the flow chart and the flows between unit processes, the flows of all unit processes are related to the reference flow. The calculation shall relate system input and output data to the functional or declared unit. Care should be taken when aggregating the inputs and outputs in the product system. The level of aggregation shall be consistent with the goal of the CFP study. If more detailed aggregation rules are required, they should be explained in the goal and scope definition phase of the CFP study or should be left to a subsequent LCIA phase. NOTE This subclause is adapted from ISO 14044:2006, 4.3.3.3.	Requirement Met				Closed
14067-17	5.1.4		**ISO 14067 6.4.5 Refining the system boundary** Reflecting the iterative nature of the quantification of the CFP, if no CFP–PCR are used, decisions regarding the data to be included or excluded shall be based on a sensitivity analysis to determine the significance. The initial system boundary shall be revised, as appropriate, in accordance with the cut-off criteria established in the goal and scope definition phase. The results of this refining process and the sensitivity analysis shall be documented in the CFP study report. The refining of the system boundary based on a sensitivity analysis as described above may result in a) exclusion of life cycle stages or unit processes when lack of significance can be shown, b) exclusion of inputs and outputs that lack significance to the results of the CFP study, or c) inclusion of new unit processes, inputs and outputs that are shown to be significant. The refining of the system boundary serves to limit the subsequent data handling to those input and output data that are determined to be significant to the goal of the CFP study. NOTE This subclause is adapted from ISO 14044:2006, 4.3.3.4.	5.1.4 Various Sensitivity Analysis on the OSB Pathway You include an analysis of the impacts of using dynamic accounting and radiative forcing for gradually released biogenic CO2. The effect might be much larger on biogenic methane because of the delayed timing of its release, its much higher warming efficiency, and its decay in the atmosphere. Therefore, this sensitivity analysis should also include methane.	It does. Clarified.			Closed
14067-18			**ISO 14067 6.4.6 Allocation** **6.4.6.1 General** The inputs and outputs shall be allocated to the different products according to the clearly stated and justified allocation procedure. The sum of the allocated inputs and outputs of a unit process shall be equal to the inputs and outputs of the unit process before allocation. Whenever several alternative allocation procedures are applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach. When PCR or CFP–PCR are developed in accordance with ISO/TS 14027, no further sensitivity analysis shall be required. NOTE This subclause is partly adapted from ISO 14044:2006, 4.3.4.2.	Requirement Met				Closed
14067-19			**ISO 14067 6.4.6.2 Allocation procedure** The CFP study shall include the identification of the processes shared with other product systems and deal with them in accordance with the stepwise procedure presented below. NOTE Formally, step 1 is not part of the allocation procedure. a) Step 1: Wherever possible, allocation should be avoided by 1) dividing the unit process to be allocated into two or more sub-processes separately and collecting the input and output data related to these sub-processes, or 2) expanding the product system to include the additional functions related to the co-products. b) Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them. c) Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and the functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products. When outputs include both co-products and waste, the ratio between co-products and waste shall be identified and the inputs and outputs shall be allocated to the co-products only. Allocation procedures shall be uniformly applied to similar inputs and outputs of the product under study. For example, if allocation is made to usable products (e.g. intermediate or discarded products) leaving the system, then the allocation procedure shall be similar to the allocation procedure used for such products entering the system. The life cycle inventory is based on material balances between input and output. Allocation procedures should therefore approximate, as much as possible, such fundamental input/output relationships and NOTE 1 This subclause is adapted from ISO 14044:2006, 4.3.4.2.	Requirement Met				Closed
			ISO 14067 6.4.6.3 Allocation procedure for reuse and recycling The allocation principles and procedures in 6.4.6.1 and 6.4.6.2 also apply to reuse and recycling situations. Changes in the inherent properties of materials shall be taken into account. In addition, particularly for the recovery processes between the original and subsequent product system, the system boundary shall be identified and explained, ensuring that the allocation principles are observed as described in 6.4.6.2. However, in these situations, additional elaboration is needed for the following reasons: — reuse and recycling (as well as composting, energy recovery and other processes that can be assimilated to reuse/recycling) may imply that the inputs and outputs associated with unit processes for extraction and — reuse and recycling may change the inherent properties of materials in subsequent use. Specific care should be taken when defining the system boundary with regard to recovery processes.					

14067-20			Several allocation procedures are applicable for reuse and recycling. The application of some procedures is distinguished in the following to illustrate how the above constraints can be addressed. a) A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) material. However, the first use of virgin material in applicable open-loop product systems may follow an open-loop allocation procedure outlined in b). b) An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties. The allocation procedures for the shared unit processes should use, as the basis for allocation, the following order, if feasible: — physical properties (e.g. mass); — economic value (e.g. market value of the scrap material or recycled material in relation to market value of primary material); or — the number of subsequent uses of the recycled material. NOTE 1 An example how to treat recycling in LCA studies is given in Annex D. NOTE 2 This subclause is adapted from ISO 14044:2006, 4.3.4.3.	Requirement Met				Closed
14067-21			**ISO 14067 6.4.7 CFP performance tracking** When the CFP is intended to be used for CFP performance tracking, the following additional requirements for the quantification of the CFP shall be met: a) the assessments shall be carried out for different points in time; b) the change to the CFP over time shall be calculated for products with an identical functional or declared unit; c) the change to the CFP over time shall be calculated using the same method and, if used, the same PCR, for all subsequent assessments (e.g. systems for selecting and managing data, system boundaries, allocation, identical characterization factors). The time period between the points in time for which the CFP performance tracking is undertaken shall not be shorter than the time boundary for data as described in 6.3.6. It shall be described in the goal and scope of the CFP study.	Requirement Met				Closed
14067-22			**ISO 14067 6.4.8 Assessing the effect of the timing of GHG emissions and removals** All GHG emissions and removals shall be calculated as if released or removed at the beginning of the assessment period without taking into account an effect of delayed GHG emissions and removals. Where GHG emissions and removals arising from the use stage (see 6.3.7) and/or from the end-of-life stage (see 6.3.8) occur over more than 10 years (if not otherwise specified in the relevant PCR) after the product has been brought into use, the timing of GHG emissions and removals relative to the year of production of the product shall be specified in the life cycle inventory. The effect of timing of the GHG emissions and removals from the product system (as CO2e), if calculated, shall be documented separately in the CFP study report. The method used to calculate the effect of timing shall be stated and justified in the CFP study report. NOTE The time period of 10 years has been selected to avoid undue burden in data collection and additional reporting of GHG emissions and removals over shorter time periods and to achieve comparability in reporting. This value might be revised in future based on experience or improved scientific knowledge.	Requirement Met				Closed
14067-23			**ISO 14067 6.4.9 Treatment of specific GHG emissions and removals** **6.4.9.1 General** For the sake of consistency of quantification, specific requirements and guidelines are provided in the following subclauses for specific GHG emissions and removals where different approaches could lead to different results. Additional requirements, guidelines and data might be available in relevant CFP–PCR, other sector guidance documents or footprint programmes.	Requirement Met				Closed
14067-24			**ISO 14067 6.4.9.2 Fossil and biogenic carbon** Fossil GHG emissions and removals shall be included in the CFP or the partial CFP and documented separately as a net result. Biogenic GHG emissions and removals shall be included in the CFP or the partial CFP and should each be expressed separately (see Figure 3). NOTE 1 An example of fossil GHG removals is capture of fossil emissions from a power plant through a non-biological process followed by storage through geosequestration. All relevant unit processes of the life cycle of biomass-derived products shall be included in the system under study, including, but not limited to, cultivation, production and harvesting of biomass. NOTE 2 Treatment of GHG emissions and removals associated with land use change and land use are described in 6.4.9.5 and 6.4.9.6. NOTE 3 See Annex E for guidance related to agricultural and forestry products.	Requirement Met				Closed
14067-25			**ISO 14067 6.4.9.3 Biogenic carbon in products** NOTE 1 Biomass-derived carbon contained in a product is referred to as the biogenic carbon content of the product. When biogenic carbon is stored in a product for a specified time, this carbon shall be treated in accordance with the provisions in 6.4.8. If a product's biogenic carbon content is calculated, it shall be documented separately in the CFP study report but it shall not be included in the result of CFP or partial CFP. Information on biogenic carbon content shall be provided when performing cradle to gate studies, as this information may be relevant for the remaining value chain. For reporting requirements, see Clause 7. NOTE 2 In the case of products containing biomass, the biogenic carbon content is equal to the carbon removal during plant growth. This biogenic carbon can be released in the end-of-life stage.					Closed
14067-26	3.2.4	Figure 8	**ISO 14067 6.4.9.4 Electricity** **6.4.9.4.1 General** The GHG emissions associated with the use of electricity shall include: — GHG emissions arising from the life cycle of the electricity supply system, such as upstream emissions (e.g. the mining and transport of fuel to the electricity generator or the growing and processing of biomass for use as a fuel); — GHG emissions during generation of electricity, including losses during transmission and distribution; — downstream emissions (e.g. the treatment of waste arising from the operation of nuclear electricity generators or treatment of ashes from coal fired electricity plants). NOTE The same approach applies to purchased and sold heating and cooling energy and compressed air. This document includes the principle of avoidance of double-counting in 5.12 and guidance concerning electricity in 6.4.9.4.2 to 6.4.9.4.4. EXAMPLES No double-counting occurs: — where the process that used the electricity and no other process may claim the generator-specific emission factors for that electricity; — where the generator-specific electricity production does not influence the emission factors of any other process or organization.	As shown in the figure 8, abated electricity production in UK uses UK grid electriy. Is it UK average grid mix or UK residual grid electricity? Since table 12 shows only the quantity of unabated electricity from chip input but didn't include the details. Please clarify.	The electricity is used in pellet production hence specified in Table 11. However typo was corrected in table 12.			Closed
14067-27			**ISO 14067 6.4.9.4.2 Internally generated electricity** When electricity is internally generated (e.g. on-site generated electricity) and consumed for a product under study and no contractual instruments have been sold to a third party, then the life cycle data for that electricity shall be used for that product.	Requirement Met				Closed
			ISO 14067 6.4.9.4.3 Electricity from a directly connected supplier					

14067-28			A GHG emission factor obtained from the organization's supplier for the consumed electricity may be used if there is a dedicated transmission line between the organization and the generation plant from which the emission factor is derived, and no contractual instruments have been sold to a third party for that consumed electricity.	Requirement Met				Closed
14067-29			**ISO 14067 6.4.9.4.4 Electricity from the grid** Life cycle data from a supplier-specific electricity product shall be used when the supplier is able to guarantee through a contractual instrument that the electricity product: — conveys the information associated with the unit of electricity delivered together with the characteristics of the generator; — is assured with a unique claim (see 5.12); — is tracked and redeemed, retired or cancelled by or on behalf of the reporting entity— is as close as possible to the period to which the contractual instrument is applied and comprises a corresponding timespan; — is produced within the country, or within the market boundaries where consumption occurs if the grid is interconnected. If processes within the system under study are located in small island developing states (SIDS), the CFP or the partial CFP may additionally be quantified using contractual instruments for such processes, irrespective of grid inter-connectivity. NOTE 1 SIDS are defined by the United Nations[20]. When information on supplier specific electricity is not available, GHG emissions associated with the relevant electricity grid from which the electricity is obtained shall be used. The relevant grid shall reflect the electricity consumption of the related region, excluding any previously claimed attributed electricity. In case no electricity tracking system is in place, the selected grid shall reflect the electricity consumption of the region. NOTE 2 Contractual instruments are any type of contract between two parties for the sale and purchase of energy bundled with attributes about the energy generation, or for unbundled attribute claims. EXAMPLE Contractual instruments can include energy attribute certificates, renewable energy certificates (RECs), guarantee of origin (GOs) or green energy certificates. NOTE 3 Examples of the characteristics of a generator include the registered name of the facility, the owners and the nature of the energy generated, the generation capacity and the renewable energy supplied. NOTE 4 If specific life cycle data on a process within the electricity supply system are difficult to access, data from recognized databases (e.g. through the UNEP or UNFCCC) can be used. Some electricity attributes, such as green certificates are sold without direct coupling to the electricity itself. In some countries, parts of the electricity from renewable energy sources might be sold/exported as renewable electricity without being excluded from the supplied mix. For this reason, in such cases a sensitivity analysis applying the relevant consumption grid mix shall be conducted and reported in the CFP study report to demonstrate the difference in results of the electricity tracking instruments.	Requirement Met				Closed
14067-30			**ISO 14067 6.4.9.5 Land use change** The GHG emissions and removals occurring as a result of direct land use change (dLUC) within the last decades (see NOTE 1) shall be assessed in accordance with internationally recognized methods, such as the IPCC Guidelines for National Greenhouse Gas Inventories[17] and included in the CFP. The net dLUC GHG emissions and removals shall be documented separately in the CFP study report. If site-specific data are applied, they shall be transparently documented in the CFP study report. If a national approach is used, the data shall be based on a verified study, a peer reviewed study or similar scientific evidence and shall be documented in the CFP study report. NOTE 1 The IPCC tier 1 period of 20 years is frequently used. When the process under assessment causes changes in carbon stocks compared to the reference land use, the GHG emissions and removals associated with these changes shall be documented and assigned to the system under study. NOTE 2 "Changes in carbon stocks" refers to changes in soil carbon and changes in above- and below-ground biomass over time. NOTE 3 The choice of reference land use can have a significant impact on the CFP and the partial CFP. Annex E provides guidance on choosing the reference land use. The net changes shall be assigned to the system under study across the selected time period. The time period selected for analysis shall be documented and justified. At a minimum, it shall include at least one full rotation period for processes that involve growing crops or trees. NOTE 4 Wood from forest land that remains forest land has zero emissions in terms of LUC. For further guidance on LUC, see Annex E. NOTE 5 National approaches can include government-recognized and published methods and calculators. Indirect land use change (iLUC) should be included in CFP studies once an internationally agreed procedure exists. All choices and assumptions, including applied methodologies, shall be justified and documented in the CFP study report. NOTE 6 There is ongoing research to develop a methodology and data for the inclusion of iLUC in GHG reporting. NOTE 7 LUC emissions do not arise only from production of agricultural and forestry products, e.g. in the context of deforestation or conversion of grassland to energy crops, but also from LUC for other product systems, e.g. related to the conversion of land to quarries, infrastructure and production plants. NOTE 8 With respect to GHG emissions and removals connected to marine areas related to products, only very limited information is available.	N/A				Closed
14067-31			**ISO 14067 6.4.9.6 Land use** GHG emissions and removals occurring as a result of land use through changes in soil and biomass carbon stocks that are not the result of changes to management of land should be assessed and included in the CFP. If changes in soil and biomass carbon stocks are not assessed, this decision shall be justified in the CFP study report. Where included, these emissions and removals shall be assessed in accordance with internationally recognized methods, such as the IPCC Guidelines for National Greenhouse Gas Inventories[17] and shall be documented separately in the CFP study report. When changes in management of land cause changes in soil and biomass carbon stocks, compared with the reference land use, the GHG emissions and removals shall be documented and assigned to the system under study. NOTE 1 Changes in management of land within the same land-use category are not considered land use change. The net changes in soil and biomass carbon stocks shall be assigned to the system under study across the selected time period. The time period selected for analysis shall be documented and justified. At a minimum, it shall include at least one full rotation period for processes that involve growing crops or trees. If there is a net increase of soil or biomass carbon due to modified land use practices, the net increase shall be included in the CFP and the partial CFP only if measures are in place to address its permanence. If a national approach is used, the data shall be based on a verified study, a peer reviewed study or similar scientific evidence and shall be documented in the CFP study report. NOTE 2 National approaches can include government-recognized and published methods and calculators.	N/A				Closed

			NOTE 3 Ongoing land use can lead to a net increase or decrease of soil carbon, e.g. decrease during drought. NOTE 4 There is ongoing research to develop methodology and models, and provide data for the inclusion of soil carbon change in GHG reporting. NOTE 5 There are various ways to mitigate the risks of non-permanence of soil and biomass carbon, such as buffers and reserve accounts. NOTE 6 If detection of soil carbon change involves direct field measurement, results depend on variables, including the location of sampling sites, the number of replicate soil samples, the timing of sampling, the depth of the soil profile and the sampling techniques. The principles and rules for designing soil sampling strategies and techniques are provided in ISO 10381 (all parts). NOTE 7 For further guidance on land use, see Annex E.					
14067-32			**ISO 14067 6.4.9.7 Aircraft GHG emissions** Aircraft transportation GHG emissions shall be included in the CFP and documented separately in the CFP study report. Where an aviation multiplier is used, the effect of this multiplier shall not be included in the CFP and shall be reported separately together with the source. NOTE Aircraft GHG emissions under certain circumstances in high altitudes have additional climate impacts as a result of physical and chemical reactions with the atmosphere. For more information on GHG emissions from aircraft, see the IPCC Guidelines for National Greenhouse Gas Inventories[17] and the IPCC Special Report on Aviation[18].	Requirement Met				Closed
14067-33			**ISO 14067 6.4.9.8 Summary of requirements and guidance in 6.4.9** Table 1 provides an informative summary of the requirements and guidance given in 6.4.9. Figure 3 shows an informative illustration of the specific components of the CFP. Refer to 6.4.9.2 to 6.4.9.7 for the full requirements and guidance. Table 1 — Specific GHG emissions and removals treatment in the CFP or the partial CFP and documented separately in the CFP study report	Requirement Met				Closed

Sub-Clause	Specific GHG emissions and removals	Treatment in the CFP or the partial CFP			Documentation in the CFP study report	
		Shall be included	Should be included	Should be considered for inclusion	Shall be documented separately in the CFP study report	Shall be documented separately in the CFP study report, if calculated
6.4.9.5	GHG emissions and removals occurring as a result of dLUC a	X			X	
6.4.9.5	GHG emissions and removals occurring as a result of iLUCa	C		X		X
6.4.9.6	GHG emissions and removals from land use a		X			X
6.4.9.3	Biogenic carbon in Products a					X
6.4.9.7	Aircraft GHG emissions	X			X	

14067-34			—					Closed
14067-35			**6.5.1 General** In the LCIA phase of a CFP study, the potential climate change impact of each GHG emitted and removed by the product system shall be calculated by multiplying the mass of GHG released or removed by the 100-year GWP given by the IPCC in units of kg CO2e per kg emission (with carbon feedbacks, according to IPCC). NOTE 1 The CFP is the sum of these calculated impacts. Where GWP values are amended by the IPCC, the latest values shall be used in the CFP calculations if not otherwise stated and justified. GWP for other time horizons and GTP, as given by the IPCC, may be used in addition to GWP 100 but should be reported separately. NOTE 2 100-year global warming potential (GWP 100) is used to represent shorter-term impacts of climate change, reflecting the rate of warming. 100-year global temperature potential (GTP 100) is used as an indicator for the longer-term impacts of climate change, reflecting the long-term temperature rise. There is no scientific basis for choosing a 100-year time horizon compared to other time horizons. The time horizon is a value judgement of international convention that weighs the effects that are likely to occur over different time horizons. This text has been adapted from Reference [17].	Requirement Met				Closed
14067-36			**ISO 14067 6.5.2 Impact assessment of biogenic carbon** Removals of CO2 into biomass shall be characterized in the LCIA as −1 kg CO2e/kg CO2 in the calculation of the CFP when entering the product system. Emissions of biogenic CO2 shall be characterized as +1 kg CO2e/kg CO2 of biogenic carbon in the calculation of the CFP. NOTE The amount of CO2 taken up in biomass and the equivalent amount of CO2 emissions from the biomass at the point of complete oxidation results in zero net CO2 emissions integrated over time, except when biomass carbon is not converted into methane, non-methane volatile organic compounds (NMVOC) or other precursor gases.	Requirement Met				Closed

			For fossil and biogenic methane, the characterization factors in accordance with the most recent IPCC report shall be used.					
14067-37	Conclusion and Recommendations section and section 6. Conclusion and Limitations	p. 8 and 6.1 conclusions on p.52	**ISO 14067 6.6 Interpretation of CFP or partial CFP** The life cycle interpretation phase of a CFP study shall comprise the following steps: a) identification of the significant issues based on the results of the quantification of the CFP and partial CFP in accordance with LCI and LCIA phases; NOTE 1 Significant issues can be life cycle stages, unit processes or flows. b) an evaluation that considers completeness, consistency and sensitivity analysis; c) the formulation of conclusions, limitations and recommendations. The results of the quantification of the CFP and partial CFP according to the LCI or LCIA phases shall be interpreted according to the goal and scope of the CFP study. The interpretation shall: — include an assessment of uncertainty, including the application of rounding rules or ranges; — identify and document the selected allocation procedures in the CFP study report in detail; The interpretation should include: — a sensitivity analysis of the significant inputs, outputs and methodological choices, including allocation procedures, in order to understand the sensitivity and uncertainty of the results; — an assessment of the influence of alternative use profiles on the final result; — an assessment of the influence of different end-of-life scenarios on the final result; — an assessment of the consequences of recommendations [see 6.6 c)] on the final result. NOTE 2 For more information, see ISO 14044:2006, 4.5, and ISO 14044:2006, Annex B.	As mentioned in the conclusion and recommendations section, it states that "The use of wood feedstocks for producing electricity without BECCS produced lower carbon benefits, but these were still higher than carbon benefits of some other pathways." This statement needs to be revised if fossil GHGs, biogenic GHGs, and net GHG results from PE-coated paperboard plates might alter the ranking of the use pathways. My Suggestion is if the CFP results of use pathway changed, the conclusion might need to be revised. However, some numbers were changed after modification but didn't have an effect on the overall results. Thus, no revision was needed.	I am not sure what you are suggesting.			Closed
14067-38			**7.1 General** The purpose of the CFP study report is to describe the CFP study, including the CFP or the partial CFP, and to demonstrate that the provisions of this document have been met. Results reported in the CFP study report may be used in footprint communications (see ISO 14026). NOTE "CFP study report" is a specific term relating to the carbon footprint of products. Other standards use different terminology for the same type of document (e.g. "third-party report" used in ISO 14044:2006 and "footprint study report" used in ISO 14026). The results and conclusions of the CFP study shall be documented in the CFP study report without bias. The results, data, methods, assumptions and the life cycle interpretation (see 6.6) shall be transparent and presented in sufficient detail to allow the reader to comprehend the complexities and trade-offs inherent in the CFP study. The type and format of the CFP study report shall be defined in the goal and scope definition phase of the CFP study. The CFP study report shall also allow the results and life cycle interpretation to be used in a manner consistent with the goals of the CFP study.	Requirement Met				Closed
14067-39	section 4	Table 18, figure 14, and table 24	**ISO 14067 ISO 14067 7.2 GHG values in the CFP study report** Results of the quantification of the CFP or the partial CFP shall be documented in the CFP study report in mass of CO2e per functional or declared unit. The following GHG values shall be documented separately in the CFP study report: a) GHG emissions and removals linked to the main life cycle stages in which they occur, including the absolute and the relative contribution of each life cycle stage; b) net fossil GHG emissions and removals (see 6.4.9.2); c) biogenic GHG emissions and removals (see 6.4.9.2); d) GHG emissions and removals resulting from dLUC (see 6.4.9.5); e) GHG emissions resulting from aircraft transportation (see 6.4.9.7). The following GHG values shall be documented separately in the CFP study report, if calculated: — GHG emissions and removals occurring as a result of iLUC (see 6.4.9.5); — GHG emissions and removals occurring as a result of land use (see 6.4.9.6); — results of the sensitivity analysis applying the relevant consumption grid mix, when applicable; — biogenic carbon content of products; — CFP calculated using GTP 100. In cases of processes located in SIDS, an additional CFP or partial CFP, if calculated using contractual instruments for such processes, shall be reported as additional information (see 6.4.9.4.4).	The CFP results of PE-coated paperboard plates in table 2 and 18 are incorrect. Would the figure 14 and ranking results of use pathways in table 24 affect and need to be revised?	CFP results have been confirmed to be accurate.	No comment here but I assume it is still open because of comment below.		Closed
			ISO 14067 7.3 Required information for the CFP study report The following information on CFP quantification shall be included in the CFP study report: b) system boundary, including — the type of inputs and outputs of the system as elementary flows, and — decision criteria concerning treatment of unit processes, considering their importance for the conclusions of the CFP study; c) list of important unit processes; d) data collection information, including data sources (see 6.4.2);					
			e) the list of GHGs taken into account;	It would be very helpful to include a carbon balance for each scenario. The reasons for this are elaborated in more comments below.	Carbon balances were added for each scenario in the respective flow diagram. This helped identify errors that were corrected. In addition, in some cases we had used primary data that was more conservative than the carbon balance. Everything now has been changed to	The biogenic carbon balances are most helpful. Please check, however to make sure that all of biogenic C numbers in the Figures are in pink. In Figure 9, for instance, the 255 kg C from the production stage and the 23.5 kg C in the landfill should both be in pink.	Done	
			f) the selected characterization factors; g) the selected cut-off criteria and cut-offs (see 6.3.4.3); h) the selected allocation procedures (see 6.4.6); i) timing of GHG emission and removals (see 6.4.8 and 6.4.9.6), if applicable; j) description of data (see 6.3.5), including — decisions concerning data, and — assessment of data quality;					
14067-40	section 1.2	Figure 1	k) results of sensitivity analyses and uncertainty assessments;	As mention in section 5.1.3, it states "...we used US LCA to model the production of jet fuel (kerosene used as a proxy) which resulted in 12.4 g CO2e/MJ.". Which US LCA study or report used to model the production of jet fuel? Is the value of 12.4 g CO2e/MJ an average value for the US? Here are some reference for range of CI value of certified pathway - **Closed** https://rosap.ntl.bts.gov/view/dot/12295 https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities	Meant US LCI. Typo was corrected.			Closed

			l) treatment of electricity (see 6.4.9.4), which should include information on the grid emission factor calculation and relevant grid specific constraints;					
			m) results of the life cycle interpretation (see 6.6), including conclusions and limitations (see Annex A);	Another important limitation is that the study compares static and independent systems. The results do not, therefore, reveal the overall effects of, for instance, increasing the competition for woody biomass where bioenergy and wood product systems are relying on common sources of raw materials. Where changes in raw material availability and cost are imposed, bioenergy and forest product systems would likely respond differently, and in ways that would violate the assumption, applied in this study, that feedstock operations are not affected. Therefore, dynamic impacts on forest carbon would likely need to be considered.	Added to limitations in Section 6.4.			
			n) disclosure and justification of value choices that have been made in the context of decisions within the CFP study; o) scope, and modified scope, if applicable, along with justifications and exclusions (see 6.3.2);					
			p) description of the stages of the life cycle, including a description of the selected use profiles and end-of-life scenarios, when applicable;	As mentioned ISO 14040 in figure 1 and ISO 14067, the ISO 14040 and ISO 14067 sources should be added in the footnote on p.15 for the reference source. - **Closed**	References have been added and moved in the first instance where mentioned.			
			q) the assessment of influence of alternative use profiles and end-of-life scenarios on the final results; r) time period for which the CFP is representative (see 6.3.6); s) reference of the PCR applied or other supplementary requirements used in the study; t) description of performance tracking (see 6.4.7), when applicable.					
14067-41			**ISO 14067 7.4 Optional information for the CFP study report** In addition to the items above, the following items should be considered for inclusion in the CFP study report: a) conformity with Annex B; b) a graphical presentation of results of the CFP study.	Requirement Met				Closed
14067-42			**ISO 14067 8 Critical review** In compiling the CFP study, a critical review facilitates understanding and enhances the credibility of CFP. A critical review of CFP studies, if any, shall be performed in accordance with ISO/TS 14071.	Requirement Met				Closed
14067-43			The methodology for quantification can be applied for comparative studies. If a comparison is undertaken, the requirements in this annex shall be followed. An example for the use of comparative studies is internal decision making. While this document does not include any requirements for communication, the results of any CFP studies, including comparative studies, may be used for comparative footprint communication in accordance with ISO 14026. The calculation of CFPs of the products to be compared shall follow identical CFP quantification requirements. Comparative CFP studies shall include the full life cycle unless the function of the product is included in a partial CFP and the omitted processes of the product system are identical for all compared products. If CFP–PCR are adopted, the same CFP–PCR shall be used for all products assessed in the comparative CFP study. The CFP–PCR shall be in accordance with ISO/TS 14027. The following criteria shall be applied for the goal and scope definition phase: a) the product category definition and description (e.g. function, technical performance and use) are identical; b) the functional unit is identical; c) the system boundary is equivalent; d) the description of data is equivalent; e) the criteria for inclusion of inputs and outputs are equivalent; f) the data quality requirements (e.g. coverage, precision, completeness, representativeness, consistency and reproducibility) are the same; g) assumptions especially for the use stage and the end-of-life stage are the same; h) specific GHG emissions and removals (e.g. due to LUC or electricity use) are treated identically; i) the units are identical. The following criteria shall be applied for the life cycle inventory and LCIA phase: — the methods of data collection and data quality requirements are equivalent; — the calculation procedures are identical; — the allocation of the flows is equivalent; — the applied GWPs are identical.	Requirement Met				Closed
14067-44			**ISO 14067 Annex C(normative)The CFP systematic approach** **C.1 General** If an organization decides to develop a CFP systematic approach, it shall follow the requirements given in this annex. The CFP systematic approach is a series of activities developed by an organization through a set of procedures, in order to facilitate the development of CFPs for more products within the same organization. This is applicable when the same set of data and allocation procedures are applicable for all its products. The implementation of the CFP systematic approach should also simplify any verification activities, avoiding any redundancy in the verification of the data set.	Requirement Met				Closed
14067-45			**ISO 14067 C.2 General requirement** The organization shall describe its CFP systematic approach, including the sequence and interaction of activities that are part of this process, and establish procedures to ensure that the operation, control and monitoring of the CFP systematic approach are effective. Top management shall ensure that responsibilities and authorities related to the CFP systematic approach are defined and communicated within the organization. The organization shall determine and provide the resources and competences needed to implement and maintain the CFP systematic approach. The organization shall determine, provide and maintain the infrastructure needed to achieve conformity to the CFP systematic approach requirements. Infrastructure includes, where applicable: a) workspace and associated utilities; b) process equipment (both hardware and software); c) supporting services (i.e. information systems); d) LCA competence. The CFP systematic approach shall be able to develop the CFP of a single product in accordance with this document and with any further requirements contained in the PCR and in the rules established by the programme operator, where applicable. The CFP systematic approach shall contain measures able to identify changing conditions that increase the risk of making the CFPs out of date or not representative. Efficient control and applicable action shall be applied to such identified risks.	Requirement Met				Closed
			ISO 14067 C.3 Description of the CFP systematic approach **C.3.1 General** The description of the CFP systematic approach shall cover the following groups of activities:					

14067-46			a) data and information collection; b) data and information management; c) validation of the CFP systematic approach; d) use the systematic approach to perform the CFP for any product.	Requirement Met				Closed
14067-47			**ISO 14067 C.3.2 Data and information collection** The organization shall describe the data collection activity in order to have full data coverage and to minimize errors due to incorrect sampling (e.g. collection of double data, loss of data).	Requirement Met				Closed
14067-48	3.2.5	Table 13	**ISO 14067 C.3.3 Data and information management** The organization shall describe how to obtain a CFP from the starting data as, for example, allocation procedures, construction of models for the activities of the supply chain, procedures to overcome data gaps, use and end-of-life scenarios. Review of the CFP systematic approach shall be performed when significant changes apply to the models, assumptions or allocation procedures.	Is the Waste polyethylene treatment of waste polyethylene, municipal incineration data used from {GLO} or {RoW} for calculating the output of PE-coating to end-of-life? Please recheck the quantitty of this output. Is it still 1.84 g? The input data are correct. - Closed				Closed
14067-49			**ISO 14067 C.3.4 Validation of the CFP systematic approach** The CFP systematic approach shall be validated in terms of correctness and representativeness before being implemented in the development of a specific CFP. The validation should be performed through the development as a pilot test of a CFP for a specific product. The organization shall conduct internal CFP systematic approach assessments at planned intervals, to ensure its continuous suitability, adequacy and effectiveness.	Requirement Met				Closed
14067-50			**ISO 14067 C.3.5 Use the CFP systematic approach to perform the CFP for any eligible products** The obtained and validated procedures shall be implemented by the organization to achieve the CFP of its products that have the same set of data and allocation procedures.	Requirement Met				Closed
14067-51			**ISO 14067 C.4 Procedure** The procedure shall specify the following aspects: a) source and version of PCR adopted; b) any additional requirements of the programme operator, where applicable; c) specific activities within the CFP systematic approach, such as data collection, CFP quantification, critical review or external CFP verification (if any), maintenance of the CFP validity and representativeness.	Requirement Met				Closed
			Editorial Comments					
ED1	Acronyms	p.12		Please add "PE, MgO, ISO" in the Abbreviations and Acronym	Added MgO, others were already there.			Closed
TE	5.1.2	p.47		Missing the interpretation of the sensitivity analysis on location of SAF Pathway between the US and Europe in section 5.1.2 as shown in the table 21. Moreover, please clarify why producing SAF in Europe generated more benefits than producing SAF in the US.	I believe I had copied text and table from another section. This section, as mentioned by the title is only around plate making,			Closed
ED2	Quantification of the Carbon Footprint	p.6		It would be better to add "AR6" after mentioned "...2023 100-year GWP from IPCC." in the first sentence.	Added			Closed
ED3	Definition	Table		The definition of Low grade stemwood is "Wood from the stem of a tree (i.e., excludes branches, stumps and roots) that is not merchantable as sawtimber in local markets. This excludes salvage trees, end-of-life trees and trees removed for nature conservation." as mentioned in the glossary section in the website: https://sbp-cert.org/documents/interpretative-documents/normative-interpretations-v2/#glossary	Height of cells in table were hidding the te			Closed
ED4	Definition	Table		The definition of High grade stemwood is incomplete. It states"...that is merchantable as sawtimber in", it is "...in local markets"?				Closed
ED5	3.2.3	Figure 6		It's better understanding if adding a word like "...in the US" in a blue box after pallet production to explicit that it is produced in the US in this figure.	Thanks was not there when I last checked.			Closed
ED6	3.2.4	Figure8		See comment details above in ED5.	See above.			Closed
ED7	5.1.2	p.47		Typo: "that" to "than"	I found typos in this section, but not the one mentioned. I corrected the whole			Closed
ED8	5.4	table 25	Typo was in table 25 Data quality assessment in the report version 1.0. Regarding the version 1.2 that table 25 was chaged to table 26, the typo of "that" in the assessment of Time-related coverage and the typo of "BECSs" in the assessment of Geographical coverage are still in the table 26 of Data quality assessment. Please check	Typo: "that" to "than", and "BECSs" to "BECCS"	I don't find these typos in Table 25.			Closed
TE1	Results		The results:Typo identified.	Change "The use of wood feedstock for paper cups and SAF production leads to...." to "The use of wood feedstock for paper plates and SAF production leads to..." It is not revised yet in the section 4 on p. 47 and it was still mentioned "...for paper cups...".	Corrected.	1. Another typo in Secion 4., Carbon Footprint Results. Change "The use of **wood** dry ton..." to "The use of **one** dry ton..." - It still needs to be corrected, please check the 1st paragraph of section 4 on page 45.- 2. The word "cups" still needs to be changed to "plates" in the second paragraph of Section 4	Done.	Closed
ED9	Definitions		The definition of Harvest residues	pulp or paper. I assume that the analysis did not include a scenario where this is done.	Done.			Closed
ED10	1.3	Table 3	Objective of the study	Although the footnote indicates that some feedstock-pathway combinations were not studied because they are not appropriate, it would be more straightforward if paperboard plates were excluded from the list of use pathways for harvest residues.	Done.			Closed
TE2	2.5.1			Section 2.5.1 IPCC Methods and Category of Emissions Included Global warming potentials: Please show the specific GWPs used. Fossil and biogenic GHGs: Text is needed indicating that biogenic methane is included with fossil GHGs and is not included in biogenic GHGs.	Done. After checking biogenic CH4 is with	Thank you for adding the table of GWPs. However, if CH4 is reported with the biogenic gases, are the values for fossil emissions in the results and elsewhere still correct?	Yes.	Closed
TE3	2.5.1	Table 6		I assume that the "X" means that an item was included, but please add text or a footnote indicating this. Also, please provide explanation of why "not relevant" items	Added.			Closed

TE4	2.5.2		Section 2.5.2 Biogenic CO2	*Feedstock vs. non-feedstock biomass carbon* The use of the term "removal" in following text is confusing: "It has been assumed for [purchased wood-based fuels not part of the feedstock] that the carbon removed was equal to the carbon released… ". Are you talking about removals of wood from the forest or removals of carbon from the atmosphere? Based on material later in the report (e.g., see the last row of Table 10) it appears that this means that emissions from purchased biomass fuels are offset by removals. This effectively removes them from the calculations. This is confirmed in footnote to Table 18, where it states that "CO2 emissions and uptake from biofuels other than from the feedstock are excluded from the analysis." This raises another issue, however. You state that you consider biogenic C emissions only from the feedstock needed to produce each product (or function) because you want focus on the fate of carbon in the feedstock. It is not clear, however, how this facilitates valid comparisons of the different value chains. If a biomass C emission is associated with producing a product or function, shouldn't it be handled the same regardless of whether it came from the wood allocated to feedstock? Perhaps I misunderstand LCI conventions, but it seems to me that all biomass C entering the value chain should come with associated emissions equal to minus one unit of C. In any event, the rationale for the approach being used (i.e., offsetting only non-feedstock C) needs more support than is currently in the report. The discussion should explain how the approach being used facilitates valid comparisons of the systems being analyzed.	A footnote as added to the first instance of "removal" to clarify it refers to removal of carbon to the atmosphere (pp. 6 and 15). You are correct in your interpretation, but that would not have any incidence on the calculations because they would show as net zero in the calculations. It is normal convention in LCA to exclude what does not affect the conclusions. ANother reason, they were excluded is that a lot of the study relies on published data sources which would just not included these (cecause reporting only the non-biogenic CO2 GHG) and then we would also have to "reconcile" strage biogenic stuff from the eocinvent database.	Thank you for adding the footnotes. After further consideration, I am OK with the approach used for biogenic carbon emissions. Essentially what you have done is assume that all biogenic C is offset by removals from the atmosphere, but you have been explicit in showing this only for feedstock carbon. The biomass carbon balances help explain this. This means that the only biomass C impacts affecting the results would be (a) permanent storage of C in landfills, and (b) the impact of converting some of the emitted feedstock carbon to CH4.	Correct.	Closed
TE5	3.2.1	Table 8		The biogenic CO2 emissions are supposed to include only C in feedstock, yet the value shown (3,070,000 metric tons) is almost 10% higher than can be accounted for by one 1,530,000 metric tons of dry feedstock. One ton of dry feedstock equals 1.83 metric tons CO2. Multiply 1,530,000 by 1.83 yields 2,845,800 metric tons CO2. Please check the calculations and show in the report how they were done. I also suggest that in this, and all similar tables, a footnote	All carbon balances have now beeing corrected instead of using primary emission data. As discussed previously Biogenic CH4 is with biogenic.			Closed
TE6	3.2.2	Table 9		Please provide a source for the 1.2 factor to account for power needed for the CCS system. Added comments: 1. Error in table. Change 1.47 to	Primary data. Speciofied.	CO2 biogenic should be -1.74, not 1.47	Corrected and showed as an input (i.e. captured not released)	Closed
TE7	3.2.3	Table 10		Wood pellets are stated to contain 7% water by weight. Does 502,502 include water or not? If you assume that 502,502 is dry, then Figure 6 suggests that dry inputs equal 546,198 dry tonnes (=502,502 divided by 0.92). If you assume 502,502 includes 7% water, then you calculate that incoming dry wood requirements equal 507,964 dry tonnes (=502,502 times 0.93 divided by .92). The input used as feedstock (i.e., the reference flow) includes wood chips, roundwood, shavings and dust, which total 490,749 dry tonnes. Please indicate whether 502,502 tonnes of pellets include water and explain why the total of feedstock inputs (490,749) is less than the pellet output (502,502). If anything, the sum of the inputs should be greater than the pellet output because of the self-generation of fuels from some of the pellet feedstock.	Corrected.	1. The units for wood pellets is still unclear. Does the stated weight of 502502 include the 7% water or not? 2. The mass balance still does not seem to make sense. The wet weight of the pellets is 502502 tonnes. At 7% water, this is 467327 dry tonnes. Yet when you add the dry tonnes of feedstock (wood chips, low-grade roundwood, shavings and dust) you get only 418708 tons. The other biomass inputs are destined for use a fuel. How can you make more tonnes of pellets than you have incoming feedstock? Nore: If the 502502 figure is dry tonnes, the differences is evern larger.	The amount is dry weight as specified in the unit column. For some reason, changes were strange. Should work now.	Closed
TE8	3.2.3	Table 11		Add the word "unabated" to the title of Table 11. Again, does the weight of wood pellets (5,622,052) include water? This needs to be clarified in the table. Also, in this case, biogenic CO2 emissions have been "corrected to match carbon in wood assumed". Why was this not done in other examples of wood-to-energy? Again, carbon balances for all scenarios would be most helpful.	Done.	1. Again, the units for wood pellets is still unclear. Does the stated weight of 5662052 include the 7% water or not? I assume it does not because the units are presented as Dry tons, but this raises questions about the previous table where units were in tons (the word "Dry" has been removed from the description of the units). 2. The value for biogenic CO2 is correcy for the total system (including pellet production) but if the table is only for the electricity production process, the amount produced in pellet production should be subtractted from this.	Sorry about this. I don't know where my head was. I check in software and all numbers were right, buty not in the report. Should be corrected now.	Closed
TE9	3.2.4	Table 12		What is the source of the 1.17 factor used to account for power used in the CCS process?	Primary data. Speciofied.			Closed
TE10	3.2.5	Figure 9		29747 plates at 10.8 grams each (see table 13) produces a flow of 0.32 metric tons, not 0.29 metric tons.	Corrected.	The comment concerned the plastic plate numbers, which have not been corrected.	Done.	Closed
TE11	3.2.5	Table 13		Under "inputs" it would be helpful to note that the quantity of paperboard (0.54 dry tonnes) includes 0.49 dry tonnes of wood and 0.05 dry tonnes of other materials. In this, and all subsequent tables comparing wood products to non-wood products, please show separately the production emissions and EOL emissions of fossil and biogenic GHGs. In the EOL calculations, you assume that all degradable carbon is converted to gas. Please state this somewhere.	First clarification added. Then the the fraction degradable is mentioned in the assumptions.	The first two items were addressed. However, although the assumptions state the fraction of nondegradable C, they do not state that all degradable carbon is converted to gas.	Added.	Closed
TE12	3.2.6	Table 14		The value for biogenic CO2 emissions shoujld include the amounts released during use		The value for biogenic CO2 emissions shoujld include the amounts released during use	Done.	Closed

ED11	3.2.7		*Typo identified*	Citation should be to Siedt et al 2021, not 2020.	Corrected.	The date was corrected in the footnote but not in the text referring to the footnote. However, the date was not corrected in Table 16. Please correct.	Done.	Closed
TE13	3.2.7	Table 15		Biochar Pathway. Regarding the biogenic CO2 calculations: One tonne dry feedstock contains 500 kg C., The biochar from one tonne feedstock contains 222 kg C (from Table 15 and Figure 11) which is reasonable for 0.28 tonnes of biochar. The difference is 278 kg C, which converted to CO2 is 1019 kg CO2. This is much larger than 532 (the value in Table 15). Where did the rest of the carbon go? Again, a carbon balance would help. Clarify that the substituted product is farmyard manure compost. There are several types of compost examined in Siedt et al. 2021.	Corrected.	1.The first and last items have been corrected. 2. The table, however, still shows bio co2 emissions of 532 kg, while the figure (correctly) shows carbon emissions equal to 1408 kg CO2	Done.	Closed
TE14	3.2.8	Table 16		Please explain that the 16.2 m3 is the volume of the house being modeled and that this volume results from downscaling the house in Gorbunov to match the amount of OSB produced from 1 tonne feedstock. Does the 0.83 tons of OSB include non-wood components or only wood? Please specify. If it includes non-wood components. For fossil fuel emissions, it appears (based on results in Table 18) that you used the CORRIM value that includes A1, A2 and A3 stages, whereas I think you only wanted to include A3. I am having trouble coming close to the 354 kg estimate for biogenic CO2 emissions (feedstock only). 1000 kg of allocated feedstock equals 1830 kg CO2. 830 kg OSB (at 50% C) from allocated feedstock equals 1522 kg CO2. From this we need to subtract the permanently stored C in landfills. 72.5% of OSB (=1103 kg CO2) is landfilled and 80 percent of landfilled C is nondegradable (=883 kg CO2). The difference between the CO2 in the allocated feedstock and the stored CO2 is 1830-883=947 kg CO2. This is much different from 354. Co-product allocation is too small to account for the difference. Again, a carbon balance would help explain the values. I calculate different substitution ratios for fiber cement (1.48) and MgO board (1.15). Using the Gorbunov thesis (Table 3 and Appendix A, Table 12) I get ratios of 1.78 and 1.39, respectively. You may want to check these.	Correct for A3 vs. The rest. Carbon balance is now shown on the figure. Subsitution ratios were recalculated using the density of OSB in CORRIM to make sure that the wood data in consistent. All results were open.	1. A sentence has been added saying "Gorbunov assumes that all materials have sufficient lifetime to be used during the lifetime of the building". The word "during" should be changed to "throughout". 2.In the table, the following sentence has been added: "16.2 m3 is the volume of the house being modelled and that this volume results from downscaling the house in Gorbunov to match the amount of OSB produced from 1 tonne feedstock.". However, the value in the "quantity" box has been changed to 15.6 m3. 3. In addition, it would be good to use two sentences; "The house being modeled in this analysis has a volume of 15.6 m3. This volume results from downscaling the house modeled in Gorbunov so that the house modeled here requires an amount of OSB produced from 1 tonne feedstock." 4. Finally, it is confusing to say that the product is "sheeting" while showing a quantity of 15.6 m3. In the case of biochar, the "product was soil enrichment", shouldn't the product here be "shelter" or "housing"? 5. It is evident from the figured that the 0.83 tons of OSB shown in the table includes only the weight of the fiber (not the resins, etc.). The table should indicated that the 0.83 tonne value is the	1. Done. 2. Done. 3. Done. 4. I understand what you are sayong, but at the same time, it is not the full "housing" in contrast to the biochar. I revised to "Housing (sheeting part)". 5/6 After checking the 0.83 was including the resins. Carbon balance was redone and results adjusted.	Closed
TE15	3.2.9		Portal frames	such a small fraction of the sawtimber market. Is there a reason why you didn't focus on construction applications, such as a wood-stud wall compared to steel studs or concrete. There are many resources to draw upon focused on construction applications. The information in Table 19 (later in the report) from Leskinen et. al. is only one example	Easeness of use. We had all information needed. Important is substitution factor and we document this later in the report. In addition, sawtimber is presented just for reference and is not the main focus of the report.			Closed
TE16	3.2.9	Table 17		Based on the spreadsheet you used, it appears you used the CORRIM value for rough lumber, but it is more likely that dried finished lumber would be used. This is unlikely to have a significant effect on the results. I have the same question about the estimate of biogenic CO2 emissions here that I have for Table 16.	Switched to A3. I did include drying howev	Although I would note that the 125 kg C emitted from the saw mill equals 458 kg CO2, not 454 kg as shown in the table.		Closed
TE17	4	Table 18		and biogenic methane. In addition, I suggest a footnote clarifying that biogenic GHGs do not include biogenic methane. See correspondence re plates. For the case of PE-coated paperboard plates, there appears to be something wrong with the value for fossil GHGs. Production emissions from paper are 0.0326 kg CO2 per plate (table 13). I have been able to match this value so this is not the issue. Production emissions from plastic are 0.04726 kg CO2 per plate (table 13). I have also been able to match this value. EOL emissions from FAL (which I can match) are 0.008 kg CO2 per plate. To convert the net fossil emissions value in Table 18 (-1227 kg CO2 per tonne feedstock) to kg CO2 per plate, you divide by 29747, which equals -0.04125 kg CO2 per plate. This value should equal the total per plate emissions for paper minus the total per plate emissions for plastic. Knowing this, the EOL emissions	Biogenic CH4 is included in biogenic GHG	1.Thank you for showing methane separately. I assume that the "fossil GHGs" values now do not include biogenic methane, but this should be verified. 2. The row labeled "OSB-Fiberboard" and still needs to changed to "OSB-Fiber cement board". 3. The results show larger net benefits for displacing MgO board that displacing fiber cement board. My reading of Gorbonov (2022), however, suggests that fiber cement board is more GHG intensive. From our interactions, I assume that this is due to different assumptions about the amounts of material required.	1. Correct. 2. Done. 3. Correct.	Closed
TE18	5.1.4			You include an analysis of the impacts of using dynamic accounting and radiative forcing for gradually released biogenic CO2. The effect might be much larger on biogenic methane because of the delayed timing of its release, its much higher warming efficiency, and its decay in the atmosphere. Therefore, this sensitivity analysis should also include methane.	Methane was included.			Closed
ED12	6.1		Conclusions	The conclusions should be revisited after considering the comments and recalculations suggested above.	No revision was needed.		Not clear why still open	Closed
ED13	Table 19	p.47	Typo.	Does a double minus '--' have a meaning? If so, please explain in the note below a table but if no, please correct.				Closed
ED14	5.1.4	p.52	Typo.	Change "astly" to "Lastly"				Closed
ED15	Table 24	p.53	Typo.	Remove double minus for -727 and -2339 in table 24				Closed

ED16	Table 18	Table 18		The results in this CFP results table do not match those in the same table at the beginning of the report.	table copied from one place to the other.			Closed
TE19	CFP results	CFP results		The OSB Fiber Cement (NOT OSB Fiberboard) results show a net emission for biogenic co2 of -1313 but there is no explanation of how this was derived. An explanation is needed.	Added.			Closed
TE20	CFP results	CFP results		For systems involving CCS, the CFP results tables show fossil CO2 results of net removals from the system but this is not what should be in the table because it does not allow the sum at the right to be derived from the values in the columbns. The fossil CO2 eimssions should be those actually emitted (after CCS).	Move to removal.			Closed
ED17	General	General		[illegible] results in the individual inventory tables sometimes do not match the values in the carbon balance figures. Please check and correct. Specifically: 1. make sure the numbers are the same 2. make sure you include emissions from pellet manufacturing where this is relevant 3. in the inventory tables involving CCS, you now show only net removals. Actual emissions after CCs should also be shown.	Corrected. In some cases error where in the figures.			Closed