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Abstract. Wood and bio-based construction products are perceived as a way to use renewable resources, to save energy and to mitigate greenhouse gas (GHG)-emissions during production and to store carbon during the entire service life of the building. This article compares the carbon footprint per kilogram of wood products (softwood beams, plywood, oriented strand board panel, and fibre board) from the perspective of the life cycle assessment methodology for greenhouse gas (GHG) emissions of practitioners from 16 countries participating in the IEA Annex 72. These materials are used in PAL6 softwood structure multi-residential building. This article aims at comparing the carbon footprint accounting methods from 16 countries for PAL6 multi-residential building. Each national team applied the reference study period (RSP), life cycle modules covered, modelling rules, the geographical scope of inventory data as well as the LCA database according to its specific national method. The results show that there are three types of methodology to assess a building with biogenic content (0/0, -1/+1, -1/+1*). The results were more variable plywood, oriented strand board, and fibreboard than the softwood beams due to the variability in the wood transformation processes among the countries. A net negative carbon balance was obtained for the softwood beam for the countries using -1/+1* with a clear assumption of the fraction of the carbon permanently stored at the end-of-life (EoL). The carbon storage is only possible if it is secured at the EoL. Participating countries apply different definitions of permanence and EoL scenarios. Guideline on assessing, monitoring, and legally reporting carbon storage at the EoL are needed, based on concertation between standard, life cycle assessment, wood industry, and climate experts.

1. Introduction

Efficient design, construction, retrofit of buildings are part of the key adaptation and mitigation measures to achieve climate resilient urban systems [1]. Substitution of greenhouse gas (GHG) emission intensive material to material having less impact or offer the potential to permanently store carbon is part of the solution for the built environment. Wood construction is often proposed as a strategy to reduce to the embodied greenhouse gas emissions (GHG) of buildings [2, 3]. A systematic literature review of the life cycle assessment (LCA) of buildings using wood revealed that the embodied GHG is one third to half of the life-cycle-related GHG emissions of buildings in general [3]. The biogenic carbon content is often, however, not considered or declared.

The goal of this conference article is to do a comparative LCA-based carbon footprint of wood products in a multi-residential lightweight wood structure, and based on LCA-approaches of practitioners in 16 countries participating in the IEA EBC Annex 72. Three biogenic CO_2 accounting approaches were reported by the participants. The 0/0 method considers neither fixation nor releases of biogenic carbon. The –1/+1 method, prescribed by EN 15804+A2 [4], accounts for the fixation of biogenic carbon in the production stage and its release in the end-of-life (EoL) independent of the EoL treatment. Some countries apply a -1/0 or close to 0 in the case of recycling or landfill at the end of life: recycling and landfills are considered a permanent sink of biogenic carbon, and no or not all biogenic carbon is modelled as an emission at the end of life. Timber from certified forests has negative CO_2 emissions in the production stage (assuming that trees are replanted in certified forests), to distinguish it from non-certified forests. More details on the approaches and the results at the building level are found in the Annex 72 report [5] . This article presents the assumption on the permanence of carbon storage from the participants and the results of their assessments on four wood products.

2. Method

The object of assessment, the PAL6 multi-residential building was constructed in 2016 in Quebec City, Canada. Its lightweight softwood structure is made of (in mass) 52% concrete 25 MPa, 27% softwood beams, and other wood-based products, 7.6% fire-resistant gypsum panels and 4.6% regular gypsum panels. Laminated wood flooring is not included in the product comparison. In total, around 1500 metric tons of wood were used, with a volumetric breakdown into 1896 m^3 softwood beams, 116 m^3 plywood, 102 m^3 oriented strand board (OSB) panel, 32 m^3 fibreboard, and 0.1 m^3 laminated wood flooring. The laminated wood flooring was not included in the product comparison.

This study compared the carbon footprint accounting methods from 16 countries for the same building, according to the prevailing method between September 2020 and January 2021. Each national team applied the reference study period (RSP), life cycle modules covered, modelling rules, the geographical scope of inventory data as well as the LCA database according to its specific national method. The building specification and methodological choices from the participants are found in [2]. In this paper, the results are normalized in kg CO_2 equivalent per kg of wood products. The results are not adjusted for the service life, but presented in increasing order of service life. Each participant indicated the LCA phases considered and the LCA methodology (0/0, -1/+1, -1/+1*)

3. Results

3.1. Survey of national methods

Every country considered the initial embodied impacts of the product phase (A1-A3) (Table 1). Many countries also included the construction process (A4-A5), the replacement (B4), and the end-of-life (module C). The benefits and loads beyond the system boundary (module D) were considered by a few countries only. For France, D was reported separately in the Annex 72 spreadsheet but subtracted from C in the tool as it is used in France. Stages B6, B7, and D were not analyzed. The reference study period (RSP) at the time of this assessment is 50 years for Australia, Austria, Brazil, Czechia, Germany, Portugal, Spain, Sweden, and the United States, 60 years for Belgium, Canada, Norway, Switzerland. 90 years for New Zealand, and 100 years for France.

Table 1: Reference study period (RSP) and life cycle modules (according to CEN TC 350 standards) covered in the country's assessment

Country	Code	RSP	Life cycle modules covered														
			Product stage			Use stage							EoL stage				Bene-fits
			A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Australia	AU	50	x	x	x		x		x		x			x	x	x	
Austria	AT	50	x	x	x				x		x			x	x	x	
Belgium	BE	60	x	x	x				x		x		x	x	x	x	
Brazil	BR	50	x	x	x				x		x		x	x	x	x	
Canada	CA	60	x	x	x				x		x		x	x	x	x	
Czechia	CZ	50	x						x		x						
Denmark	DK	50	x						x		x				x	x	
France	FR	100	x	x	x				x		x	x		x	x	x	x
Germany	DE	50	x				x		x						x	x	x
New Zealand	NZ	90	x	x	x		x		x		x	x	x	x	x	x	x
Norway	NO	60	x						x		x						
Portugal	PT	50	x						x	x							
Spain	ES	50	x						x								
Sweden	SE	50	x	x	x		x		x		x						
Switzerland	CH	60	x						x		x		x	x	x	x	
USA	US	50	x	x	x		x		x				x	x	x	x	x

The LCA approach was attributional with a process based LCA database approach in all cases. Table 2 showed the methods used by the participating countries, with the software, database, carbon content source, and if the GWP of biogenic carbon is recorded separately. While some countries have national databases (e.g., Ökobau.dat) and EPDs in place, most countries use different versions of Ecoinvent adapted to the national tools and context. Spain for example chose to keep the continuity of environmental data over time, instead of a new version of the database and they found the version of the database does not affect significantly their results. The software SimaPro was the most often used software for the calculation and many countries had their own tool.

Table 2: Method for biogenic carbon, software and database used, as well as the possibility of showing GWP biogenic values (separately from GWP total values.

Country code	LCA method			Software	Database	Carbon content source	Is GWP biogenic separately given?
	0/0	-1/+1	-1/+1*				
AU			x*	SimaPro 9.0.0.41	AusLCI database (2016)	AusLCI database in SimaPro and EPDs Australasia	Yes
AT	x			SimaPro 9.1.0.8	Ecoinvent v3.5	n/a	No
BE	x			SimaPro 8.5.0	Ecoinvent v3.6	n/a	No
BR	x			SimaPro 9.0	Ecoinvent v3.4, 3.5, 3.6	n/a	No
CA			x*	Simapro 9.1.0.8	Ecoinvent v3.4	Ecoinvent	Yes
CZ	x			Excel-based tool/calculation	Ecoinvent v3.3	n/a	No
DK		x		LCAbyg 3.2	Ökobaudat v2016	EN 16449:2014	No
FR			x*,**	EQUER	Ecoinvent v3.4	Ecoinvent	No
DE		x		LEGEP 2018	Okobaudat v2018	EN 16449:2014	No
PT	x			SimaPro 8.4.0	LCIA database for Portuguese Building Elements and Materials	EN 16449:2014	No

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ES	x			Excel-based tool/calculation	Ecoinvent v2.0	n/a	No
SE	x			Byggsektorns Miljöberäkningsverktyg (BM), (Swedish Building Sector Environmental Calculation Tool)	Database embedded in Swedish Building Sector Environmental Calculation Tool (BM)	n/a	No
NZ			x*	LCAQuick 3.4.2	EPDs + Ecoinvent v3.1	EPDs Australasia	GWP total (biogenic carbon can be derived)
NO		x		ZEB tool	Norwegian EPDs + Ecoinvent 3.1	EN 16449:2014	Yes
CH	x			Excel-based tool/calculation	KBOB LCA data DQRv2:2016	n/a	No
USA	x			Athena IE v5.4	GaBi v9.2	n/a	No

* Wood sent to recycling and landfill gets a value ">0" but <<1".
** Differentiation between certified (-1) and non-certified (0) forests

3.2. Permanence in carbon storage

Table 3 shows end-of-life scenarios based on current national practice for the module C. The participating countries applied different definitions of permanence with respect to landfill (Table 1). The countries assuming a permanent sequestration in landfills are Australia, Canada, France and New Zealand. In Australasia, two values of degradable organic carbon fraction (DOCf) for softwood timber are allowed: NZ applied the lower value of 0.1% while AU applied the higher value of 10% [6, 7], which results in 99.9% and 90 % assumed permanent sequestration of biogenic carbon in NZ and AU, respectively. Canada assumes 11% release in landfills and France assumes 8 to 9%, according to the wood type. Wood landfilling is forbidden in most European countries due to its potentially reactive characteristics; it is often incinerated and a proportion is recycled. When wood is landfilled at the EoL, the assumptions taken when modelling landfilling wood and other biobased materials must be reported transparently, in particular whether biogenic carbon stored in landfills is considered permanently sequestered and if so under which conditions and for which time horizon.

Table 3. Shares of solid wood recycled, incinerated, landfilled in the countries' assessments for module C of EoL assessment (n/a means not available because EoL is not considered in the national methods)

	Wood recycled %	Wood incinerated %	Wood landfilled %	Permanent sequestration in landfill assumed Yes/No
AU	40	5	55	Yes
AT	75	25		No
BE	75	25		No
BR		100		No
CA	60		40	Yes
CZ	n/a	n/a	n/a	n/a
DK		100		No
FR		100		Yes
DE		100		No
ES	10	80	10	Yes
NO		100		No
PT	n/a	n/a	n/a	n/a
NZ	15	10	75	Yes
SE		100		No
CH	50	50		No
US	n/a	n/a	n/a	n/a

3.3 Wood products assessment

Figures 1 to 4 show the results, according to the three types of methodology to assess a building with biogenic content (Appendix table A1 to A4). The countries that applied a 0/0 method did not account biogenic carbon (Austria, Belgium, Brazil, Czech Republic, Portugal, Spain, and Sweden). All countries applying -1/+1 apply a GWP on biogenic CO_2 (Denmark, Germany, Norway). According to this approach, carbon dioxide capture (during biomass growth) is characterized by a factor of "-1 kg CO_2-eq/kg CO_2". When this carbon is released in the form of CO_2, the emission is characterized by a factor of "+1 kg CO_2 eq./kg CO_2 ". If the wood or fibre is recycled at the end of its life or reused by another system, a factor of "+1 kg CO_2 eq./kg CO_2 " is applied to the biogenic carbon content of the material. Australia, Canada, France and New Zealand applied a -1/+1* methods, which consider a fraction of carbon was permanently as just discussed in 3.1.

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For the softwood beams, the assessments from Canada and New Zealand show a net negative biogenic CO_2 balance considering phases A1-A3, A4-A5, and C1-C4. When considering plywood, OSB and fibreboard, only New Zealand shows a negative balance kg CO2-eq per kg of wood for plywood and OSB. The more wood is processed, the more variable were the wood products GHG emissions among the different countries, which is due to variations in the wood transformation processes. Plywood, oriented strand board (OSB), and fiberboard generally had a greater impact of kg CO2-eq/kg wood products, than the softwood beams.

The negative emission should be accounted only if permanent carbon storage is secured at the end of life. The carbon storage at the EoL can be secured by a legally binding commitment to not release the biogenic carbon in timber products to the atmosphere. However, in this assessment, the legal binding commitment was not checked. More concertation is needed about the procedure for monitoring and legally binding negative emission, before guideline. This could be achieved by incineration in wood heat and power plants equipped with carbon capture and storage (CCS), reuse/recycling (the legally binding commitment must be transferred to the new owner of the timber products). A legally binding commitment may be an entry in the land register. Module D is about potentially avoided emissions (based on counterfactual scenarios). While negative emissions were reported, there is no negative emission (withdrawal of CO_2 from the atmosphere) and shall not count on the negative side of zero net GHG emissions.

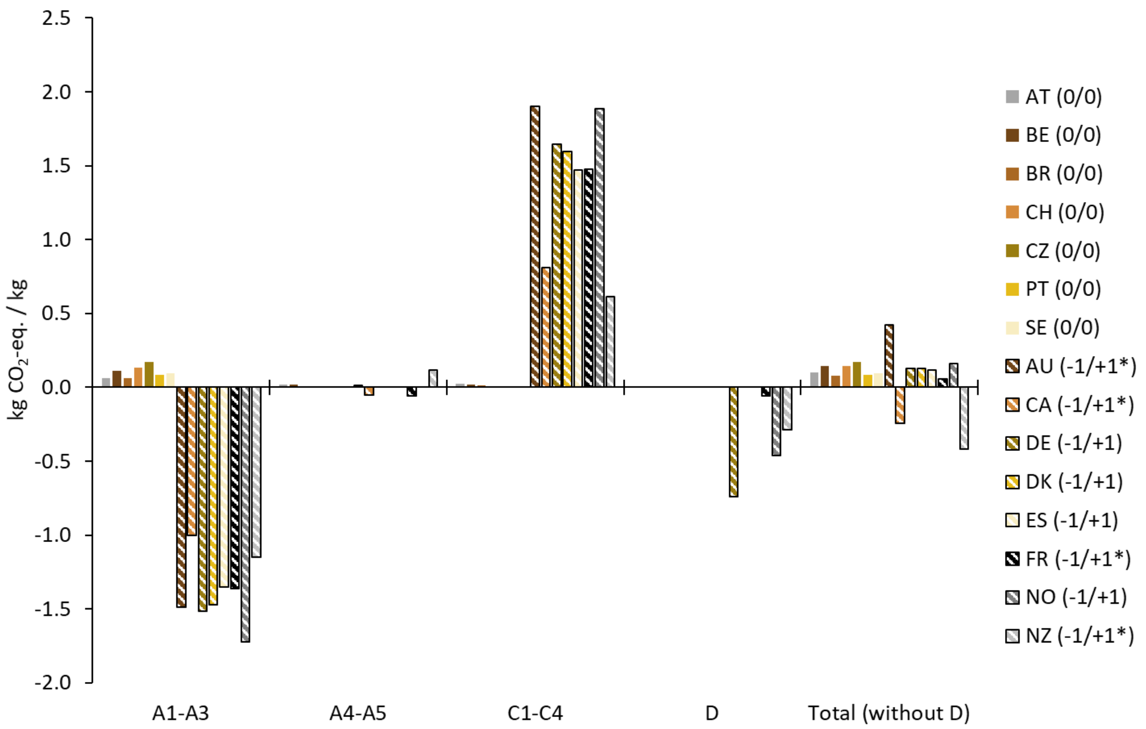

Figure 1. Greenhouse gas emissions in kg $CO_{2\text{-eq}}$ per kg softwood beams as assessed by the different countries and grouped according to the 0/0 and -1/+1 approaches

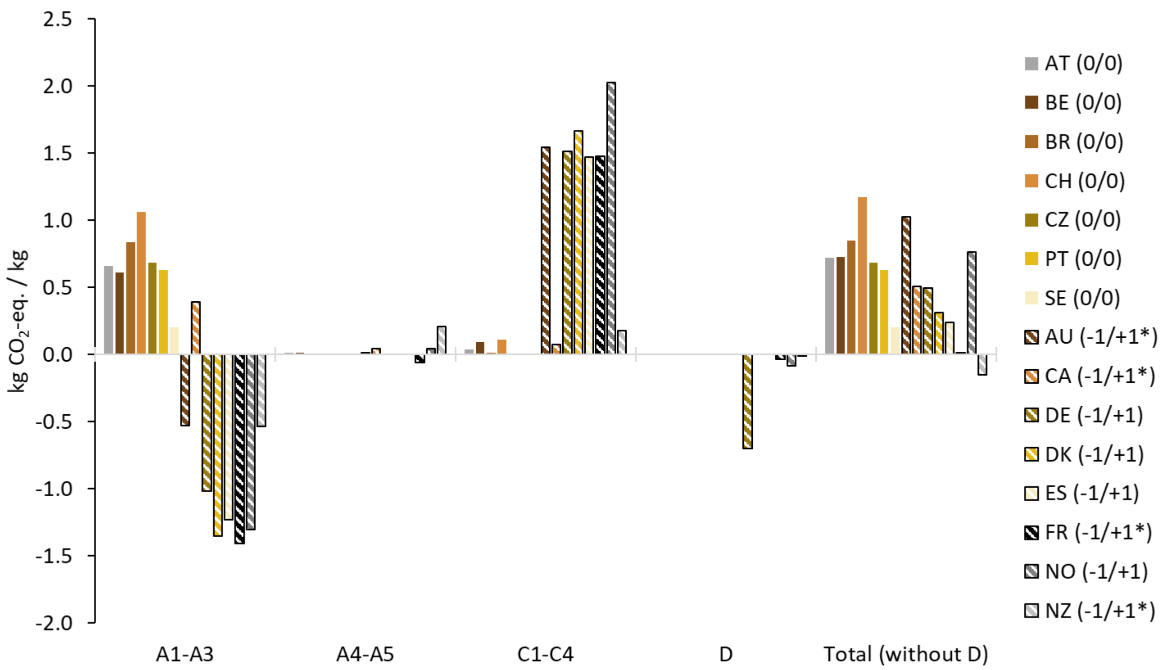

Figure 2. Greenhouse gas emissions in kg $CO_{2\text{-eq}}$ per kg plywood as assessed in the different countries and grouped according to the 0/0 and -1/+1 approaches

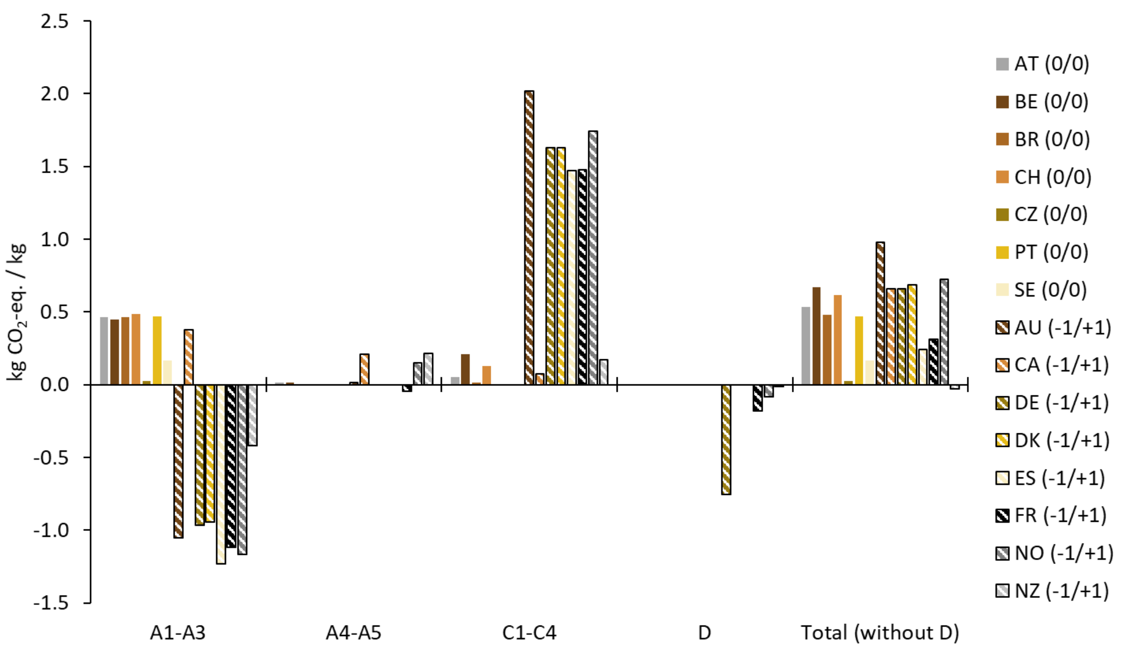

Figure 3. Greenhouse gas emissions in kg $CO_{2\text{-eq}}$ per kg of oriented strand board (OSB) as assessed in the different countries and grouped according to the 0/0 and -1/+1 approaches

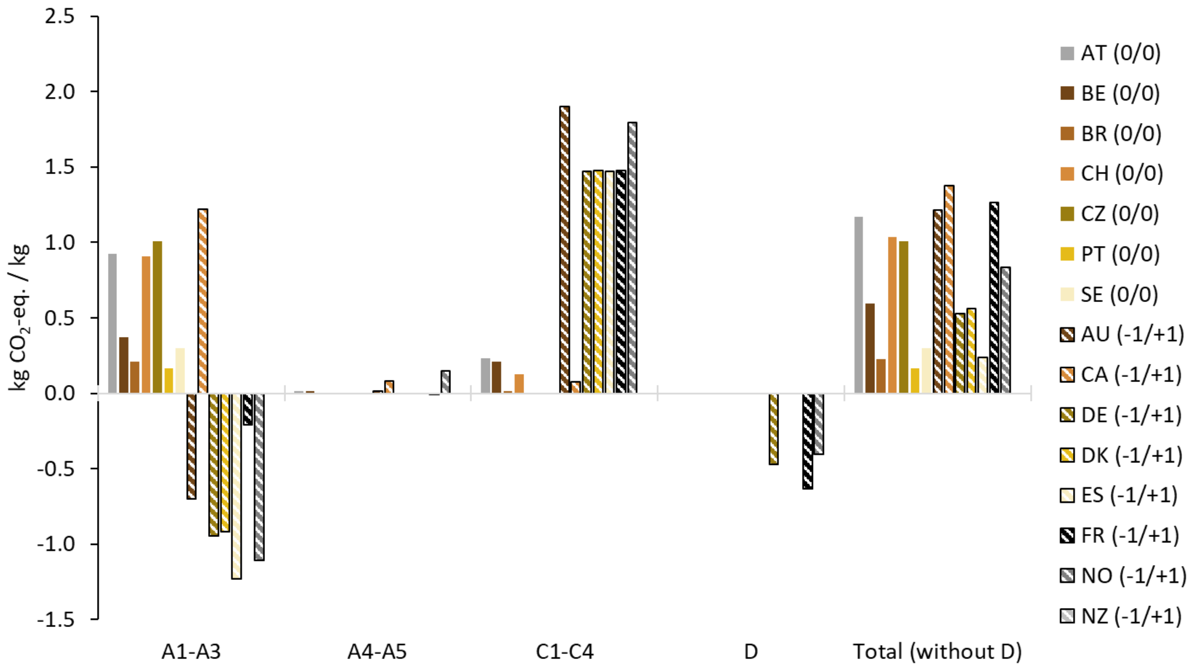

Figure 4. Greenhouse gas emissions in kg $CO_{2\text{-eq}}$ per kg fibreboard as assessed in the different countries and grouped according to the 0/0 and -1/+1 approaches.

A great potential for harmonization of the LCA methods is apparent from the comparative assessment of a multi-residential wooden building from the method applied in 16 countries. The full life cycle approach is needed to assess the impact of wood products if the -1/+1 and -1/+1* approaches are applied. The minimum stages to include are A1-A3, B4, and corresponding C1-C4. The mass balance of biogenic carbon must be checked: the amount of biogenic CO_2 fixed (withdrawn) in wood material manufacture must match with the amount of biogenic CO_2 released. The carbon content of 1 m^3 of wood products is calculated by multiply the kg carbon/kg wood and the molecular weight ratio of CO_2/C [8]. This calculation does not consider the service life. As different lengths of service life were used, the mass value can be further normalized. However, there is not a consensus yet on the use of the mass balance approach in the environmental product declaration [9]. The main difference between the -1/+1 and the -1/+1* assessments was due to different interpretations of the potential effect of landfilling and recycling wood at the end-of-life. The LCA must specify if landfilled biogenic carbon is considered permanently sequestered and the applied timeframe. Studies have been done extensively in Australia and there is one study in the USA[2]. The value reported by the countries should be supported by experimental data and there is a need for standardized testing procedure on carbon storage.

There are three stakeholders' groups what are willing to participate in guidance of LCA of biogenic carbon: (a) those developing or selecting/specifying "standards", (b) the consultants that provide building/project level GWP / embodied carbon emission figures on design-materials-specs- options to designers and/or owners, (c) the wood industry that want to promote the wood products in construction. Moreover, the methodology and results must connect to those performing the carbon balance at a larger scale to mitigate the anthropogenic carbon and its impact on the climate. The presented options for dealing with wood and/or bio-based products in LCAs make it clear that transparency and traceability are crucial to reducing uncertainty in decision-making. Thus, the influence of LCA outcomes on building design and material choices is growing. It is therefore urgent to consider the precision and accuracy of LCA outcomes. There is a great need for assessment results that are based on scientifically recognized and correctly used methods. In particular, with respect to a performance-based approach to the assessment of design options, the conception of funding programs or the development of legal requirements, the results must be reliable and credible. Discussions between LCA experts and those in charge of national greenhouse gas inventories of harvested wood would contribute to improving the harmonization of the LCA method to account for biogenic carbon. Approaches that are scientifically consensus-driven and have already been harmonized via standards are preferable.

4. Conclusion

The comparative life cycle assessment of a multi-residential wood lightweight structure revealed three approaches used by the practitioner of LCA in considering biogenic carbon (0/0, -1/+1, -1/+1*). The end-of-life scenarios (incineration, landfill, recycling) and different perceptions of the permanence of biogenic carbon landfilled cause variations in the assessment of the same building. New Zealand, using the -1/+1* methodology, reported a negative carbon balance for the softwood and the plywood, while Canada reported a negative balance of biogenic carbon for the softwood beams. There was more variability among countries for the plywood, OSB, and fibreboard, compared to the softwood beams. The input and output flows of biogenic carbon must be balanced to ensure a proper assessment of climate change impacts of biogenic CO_2. Future guidance on the LCA of biogenic carbon must consider the wood industry, LCA analyst doing an assessment at the building and project level, as well as the standard and climate experts.

References

[1] IPCC, "Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change," Cambridge, U.K., 2021.

[2] C. M. Ouellet-Plamondon *et al.*, "Carbon footprint assessment of a wood multi-residential building considering biogenic carbon," *Journal of Cleaner Production,* p. 136834, 2023/03/17/ 2023, doi: https://doi.org/10.1016/j.jclepro.2023.136834.

[3] C. E. Andersen, F. N. Rasmussen, G. Habert, and H. Birgisdóttir, "Embodied GHG Emissions of Wooden Buildings—Challenges of Biogenic Carbon Accounting in Current LCA Methods," (in English), *Frontiers in Built Environment,* Review vol. 7, no. 120, 2021-August-31 2021, doi: 10.3389/fbuil.2021.729096.

[4] *EN 15804:2012+A2:2019*, European Committee for Standardization (CEN), 2019.

[5] T. O. Alexander Passer, Nicolas Alaux, Thomas Lützkendorf, Martin Rock, Bernadette Soust-Verdaguer, Antonio Garcfa Martfnez, Marcella RM Saade, Rolf Frischknecht, Endrit Hoxha, Zsuzsa Szalay, Benedek Kiss, Lisa Wastiels, Alexander Hollberg, Aoife Houlihan Wiberg, Sebastien Lasvaux, Alina Galimshina, Guillaume Haberth, Rafael Horn, Roberta Di Bari, Katrin Lenz, Carmen Llatas, Juan Carlos Gomez de Cozar, Jakub Veselka, Harpa Birgisdottir, Maria Balouktsi, Daniel Plazza, Michael Ortmann, Deepshi Kaushal, Dave Dowdell, Jarred Butler, Claudiane Ouellet-Plamondon, Bruno Peuportier, Theres Reisinger, "EA EBC Annex 72: Assessing Life Cycle Related Environmental Impacts Caused by Buildings: Guidelines for design decision-makers: Energy in Buildings and Communities Technology Collaboration Programme," Uster, Switzerland 2023.

[6] Wood Solutions, "Environmental Product Declaration Softwood Timber " Forest and Wood Products Australia Limited, Australia, 2020.

[7] Australian Government, "National Greenhouse Accounts Factors – August 2016," Department of Environment, Canberra, ACT, Australia, 2016.

[8] Tallwood Design Institute, "Cross-Laminated Timber Info Sheets " University of Oregon Corvallis, Oregon, 2019 [Online]. Available: https://tallwoodinstitute.org/wp-content/uploads/2022/05/Info-Sheets_Final_200616.pdf

[9] H. Hauan and C. Donath. "ECO Platform Statement on Mass Balance Approach (MBA) from Dec 12, 2023." ECO Platform. https://www.eco-platform.org/position-statements.html (accessed 3 janvier 2024, 2024).

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Appendix

Table A1: Total greenhouse gas (GHG) emissions for the softwood (kg $CO_{2\text{-eq}}$ / kg)

Label	Method	Country	A1-A3	A4-A5	C1-C4	D	Total (without D)
AT (0/0)	0/0	AT	0.061	0.017	0.021	0.000	0.099
BE (0/0)	0/0	BE	0.111	0.016	0.018	0.000	0.146
BR (0/0)	0/0	BR	0.064	0.000	0.015	0.000	0.079
CH (0/0)	0/0	CH	0.133	0.000	0.010	0.000	0.143
CZ (0/0)	0/0	CZ	0.171	0.000	0.000	0.000	0.171
PT (0/0)	0/0	PT	0.085	0.000	0.000	0.000	0.085
SE (0/0)	0/0	SE	0.094	0.000	0.000	0.000	0.094
DE (-1/+1)	-1/+1	DE	-1.516	0.000	1.645	-0.739	0.129
DK (-1/+1)	-1/+1	DK	-1.469	0.000	1.596	0.000	0.127
ES (-1/+1)	-1/+1	ES	-1.354	0.000	1.472	0.000	0.118
NO (-1/+1)	-1/+1	NO	-1.723	0.000	1.884	-0.464	0.161
AU (-1/+1*)	-1/+1*	AU	-1.490	0.012	1.899	0.000	0.421
CA (-1/+1*)	-1/+1*	CA	-1.000	-0.055	0.813	0.000	-0.242
FR (-1/+1*)	-1/+1*	FR	-1.360	-0.059	1.478	-0.058	0.058
NZ (-1/+1*)	-1/+1*	NZ	-1.147	0.118	0.611	-0.287	-0.419

Table A2: Total GHG for plywood (kg $CO_{2\text{-eq}}$ / kg)

Label	Method	Country	A1-A3	A4-A5	C1-C4	D	Total without D
AT (0/0)	0/0	AT	0.662	0.016	0.041	0.000	0.718
BE (0/0)	0/0	BE	0.613	0.016	0.095	0.000	0.724
BR (0/0)	0/0	BR	0.834	0.000	0.015	0.000	0.849
CH (0/0)	0/0	CH	1.060	0.000	0.111	0.000	1.171
CZ (0/0)	0/0	CZ	0.685	0.000	0.000	0.000	0.685
PT (0/0)	0/0	PT	0.628	0.000	0.000	0.000	0.628
SE (0/0)	0/0	SE	0.204	0.000	0.000	0.000	0.204
DE (-1/+1)	-1/+1	DE	-1.016	0.000	1.512	-0.698	0.496
DK (-1/+1)	-1/+1	DK	-1.352	0.000	1.663	0.000	0.310
ES (-1/+1)	-1/+1	ES	-1.232	0.000	1.472	0.000	0.240
NO (-1/+1)	-1/+1	NO	-1.301	0.043	2.023	-0.085	0.766
AU (-1/+1*)	-1/+1*	AU	-0.530	0.012	1.540	0.000	1.022
CA (-1/+1*)	-1/+1*	CA	0.391	0.042	0.074	0.000	0.506
FR (-1/+1*)	-1/+1*	FR	-1.405	-0.062	1.478	-0.036	0.011
NZ (-1/+1*)	-1/+1*	NZ	-0.537	0.207	0.176	-0.013	-0.154

Table A3: Total GHG for oriented strand boards (OSB) (kg $CO_{2\text{-eq}}$ / kg)

Label	Method	Country	A1-A3	A4-A5	C1-C4	D	Total without D
AT (0/0)	0/0	AT	0.465	0.016	0.054	0.000	0.535
BE (0/0)	0/0	BE	0.445	0.016	0.210	0.000	0.671
BR (0/0)	0/0	BR	0.464	0.000	0.015	0.000	0.479
CH (0/0)	0/0	CH	0.487	0.000	0.127	0.000	0.614
CZ (0/0)	0/0	CZ	0.024	0.000	0.000	0.000	0.024
PT (0/0)	0/0	PT	0.472	0.000	0.000	0.000	0.472
SE (0/0)	0/0	SE	0.167	0.000	0.000	0.000	0.167
AU (-1/+1)	-1/+1	AU	-1.050	0.012	2.017	0.000	0.979
CA (-1/+1)	-1/+1	CA	0.378	0.209	0.074	0.000	0.661
DE (-1/+1)	-1/+1	DE	-0.968	0.000	1.629	-0.755	0.661
DK (-1/+1)	-1/+1	DK	-0.942	0.000	1.628	0.000	0.687
ES (-1/+1)	-1/+1	ES	-1.232	0.000	1.472	0.000	0.240
FR (-1/+1)	-1/+1	FR	-1.116	-0.047	1.478	-0.180	0.315
NO (-1/+1)	-1/+1	NO	-1.167	0.151	1.740	-0.081	0.724
NZ (-1/+1)	-1/+1	NZ	-0.419	0.216	0.173	-0.010	-0.030

Table A4: Total GHG for fibreboards (kg $CO_{2\text{-eq}}$ / kg)

Label	Method	Country	A1-A3	A4-A5	C1-C4	D	Total without D
AT (0/0)	0/0	AT	0.922	0.016	0.231	0.000	1.168
BE (0/0)	0/0	BE	0.371	0.016	0.210	0.000	0.597
BR (0/0)	0/0	BR	0.210	0.000	0.015	0.000	0.225
CH (0/0)	0/0	CH	0.910	0.000	0.126	0.000	1.036
CZ (0/0)	0/0	CZ	1.010	0.000	0.000	0.000	1.010
PT (0/0)	0/0	PT	0.167	0.000	0.000	0.000	0.167
SE (0/0)	0/0	SE	0.298	0.000	0.000	0.000	0.298
AU (-1/+1)	-1/+1	AU	-0.700	0.012	1.902	0.000	1.214
CA (-1/+1)	-1/+1	CA	1.219	0.083	0.074	0.000	1.375
DE (-1/+1)	-1/+1	DE	-0.946	0.000	1.473	-0.469	0.526
DK (-1/+1)	-1/+1	DK	-0.917	0.000	1.478	0.000	0.561
ES (-1/+1)	-1/+1	ES	-1.232	0.000	1.472	0.000	0.240
FR (-1/+1)	-1/+1	FR	-0.210	-0.002	1.478	-0.633	1.266
NO (-1/+1)	-1/+1	NO	-1.109	0.146	1.796	-0.405	0.834
NZ (-1/+1)	-1/+1	NZ	0.000	0.000	0.000	0.000	0.000