ALIGNED framework for Carbon accounting

- Insights for the ALIGNED/CALIMERO Science-for-Policy Joint Event

ALIGNED

CONSTRUCTION - PULP AND PAPER - WOODWORKING - TEXTILE - BIO-CHEMICALS

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Towards GHG neutrality, the issues that are voiced

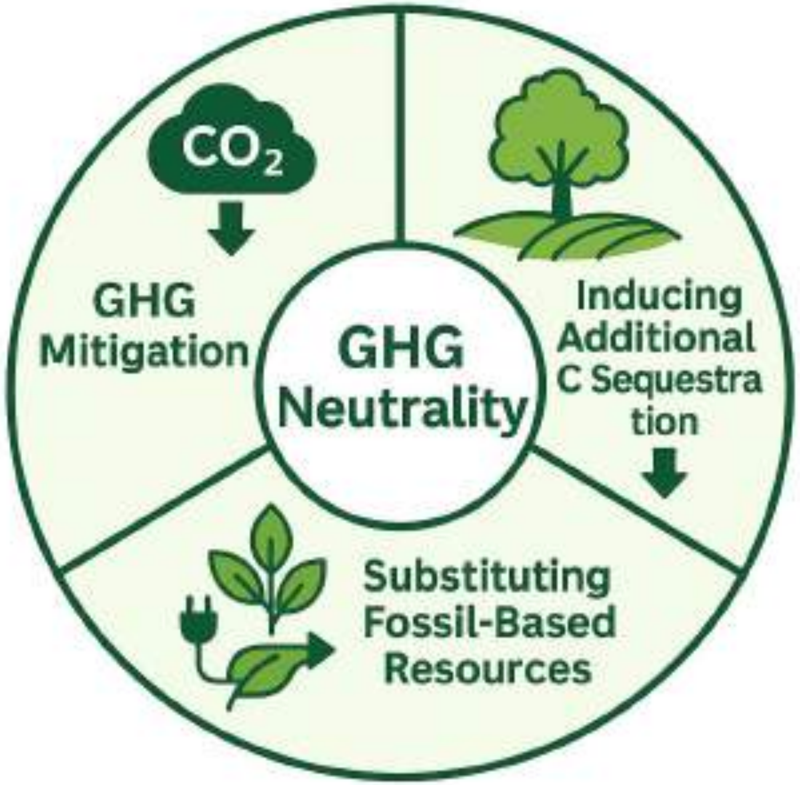
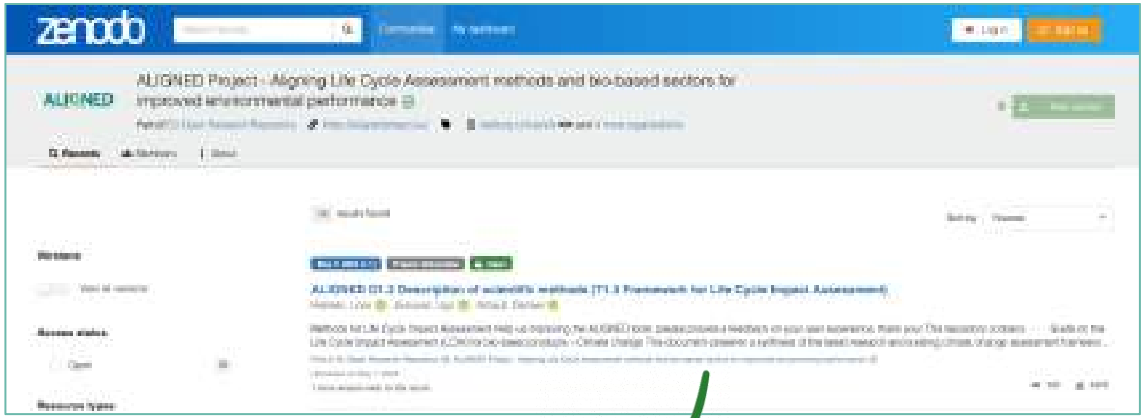


Image Credit: ChatGPT

ALIGNED recommendations – climate change midpoint scores estimation



The baseline principles:

- System boundaries: implement **<u>cradle-to-grave</u>**
- Inventory phase: document and **<u>report separately all biogenic and non-biogenic carbon flows</u>**
- Climate impacts scores:
  - Compute <u>at least two indicators</u>: **short-term** and **long-term** effects
  - Implement **<u>the -1/+1 approach</u>** - biogenic C flows always accounted!
  - Analyse at least **<u>the total indicators</u>** – including contribution of both biogenic and non-biogenic carbon
  - At least include **<u>time effects</u>** with provided Tiered approach

Hamelin, L., Javourez, U., & Arbault, D. (2024). ALIGNED D1.2 Description of scientific methods (T1.3 Framework for Life Cycle Impact Assessment) (1.1). Zenodo. https://doi.org/10.5281/zenodo.11126481

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Tiered approach

Current practice	ALIGNED		
	Tier 1	Tier 2	Tier 3
GWP100	GWP100 (t) GWP500 (t)		GWP100 GWP500 GTP50 GTP100 GWP100_Ventura
Static Time-invariant	4 temporal stages	Time-distributed	

Credit: Damien Arbault

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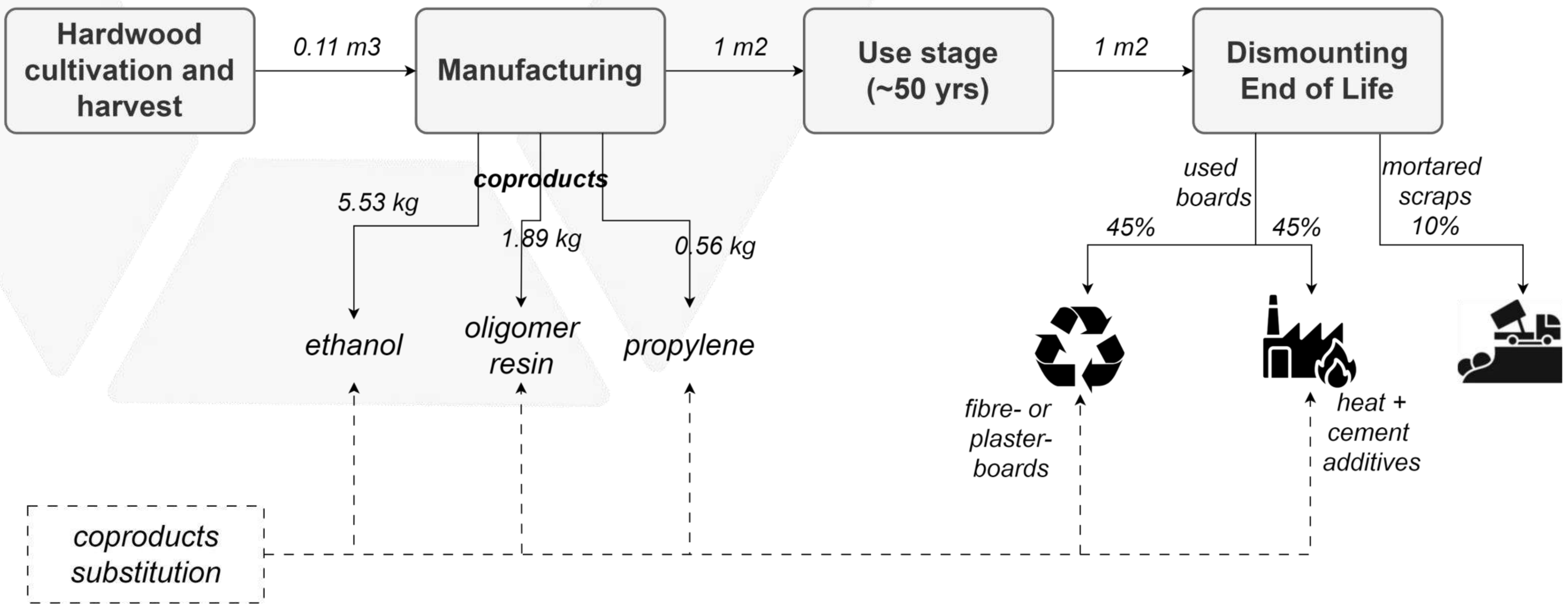
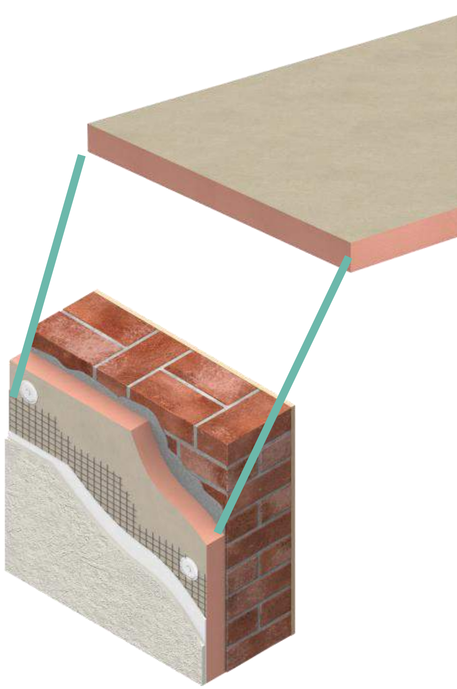
Case study: bio-based phenolic foam as thermal insulating board





Kingspan's Kooltherm K5

Kingspan

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Tier 1: 3 steps

1. Define Life Cycle phases

Calendar period	Equivalent year	Year count from reference year	Life cycle phase
2025-2065	2045	20	Hardwood cultivation
2026	2026	1	Manufacturing + coproducts substitution
2077	2077	52	End of Life

2. GHG emissions inventory (per functional unit)

Year count	Life cycle phase	kg CO2f	kg CO2b	kg CH4f	kg CH4b	kg N2O
20	Hardwood cultivation	1.01	-111	0.0045	3.73E-05	7.37E-05
1	Manufacturing + coproducts substitution	16.90	88.80	0.023	-0.0059	-0.0051
52	End of Life	0.041	4.58	-0.0088	-3.18E-04	-4.47E-05

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Tier 1: 3 steps

3. Time-dependent Characterization Factors

kg CO2e / kg	GWP100			GWP500		
Year count	**CO2**	**CH4**	**N2O**	**CO2**	**CH4**	**N2O**
1	0.99	26.50	261.55	1.00	7.56	123.67
20	0.84	26.47	227.90	0.97	7.56	123.42
52	0.56	26.05	156.11	0.92	7.56	122.90
Static (IPCC)	*1.00*	*27.00*	*273*	*1.00*	*7.20*	*130.00*

CO2_CF	CH4_CF	N2O_CF	
Period-specific GWP100 CF in kgCO2-eq/kgGHG			
1.00	26.50	263.16	*year 0*
0.99	26.50	261.55	*year 1*
0.98	26.50	259.92	*year 2*
0.98	26.50	258.28	*year 3*
0.97	26.49	256.62	*year 4*
0.96	26.49	254.94	*year 5*
0.95	26.49	253.25	*year 6*
0.94	26.49	251.55	*year 7*
0.94	26.49	249.83	*year 8*
0.93	26.49	248.09	*year 9*
0.92	26.49	246.34	*year 10*
0.91	26.49	244.57	*year 11*
0.90	26.49	242.78	*year 12*
0.90	26.49	240.98	*year 13*
0.89	26.48	239.16	*year 14*
0.88	26.48	237.33	*year 15*
0.87	26.48	235.48	*year 16*
0.86	26.48	233.61	*year 17*
0.86	26.48	231.72	*year 18*

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Results – Tier1 vs static

Significant differences between static and Tier1 results, for GWP100 (shorter term effects)

→ **Temporality of GHG flows matters**

Major difference found in Forestry phase

→ **Next step with Tier 2: refining temporalized GHG inventory**

kgCO2e / FU	GWP100		GWP500	
	static	Tier1	static	Tier1
Hardwood cultivation	-109.53	-91.94	-109.63	-106.26
Manufacturing + coproducts substitution	104.71	103.93	105.11	104.98
End of Life	4.37	2.32	4.55	4.17
Total	-0.45	+14.32	+0.02	+2.89

Credit: Damien Arbault

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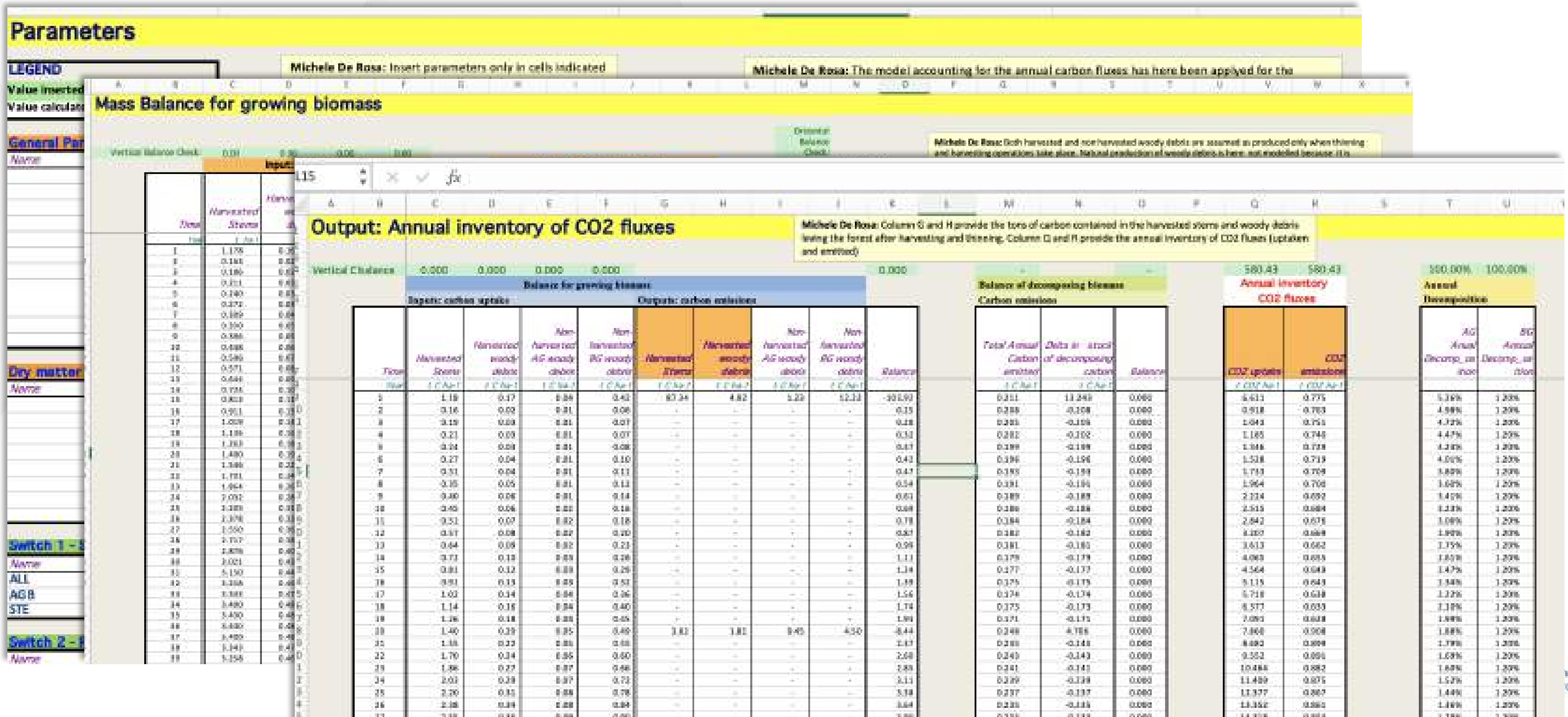
Tier2: temporal distribution of GHG flows

Forest management model: ALIGNED T1.2 “Dynamic foreground flows” (10.5281/zenodo.10843342)



Credit: Massimo Pizzol

Results – Tier1 vs Tier2

Tier 2 = 'fine-tuning' of Tier 1

Long-lasting activities: noticeable differences between Tier 1 vs Tier 2

'Pulse' processes, near present time: no significant difference

Activities in far future: significant differences between Static vs Tiers

kgCO2e / FU	GWP100			GWP500		
	static	**Tier1**	Tier2	static	**Tier1**	Tier2
Hardwood cultivation	-109.53	**-91.94**	-98.85	-109.63	**-106.26**	-107.31
Manufacturing + coproducts substitution	104.71	**103.93**	103.93	105.11	**104.98**	104.98
End of Life	4.37	**2.32**	2.34	4.55	**4.17**	4.17
Total	**-0.45**	**+14.32**	+7.42	**+0.02**	**+2.89**	+1.84

Credit: Damien Arbault

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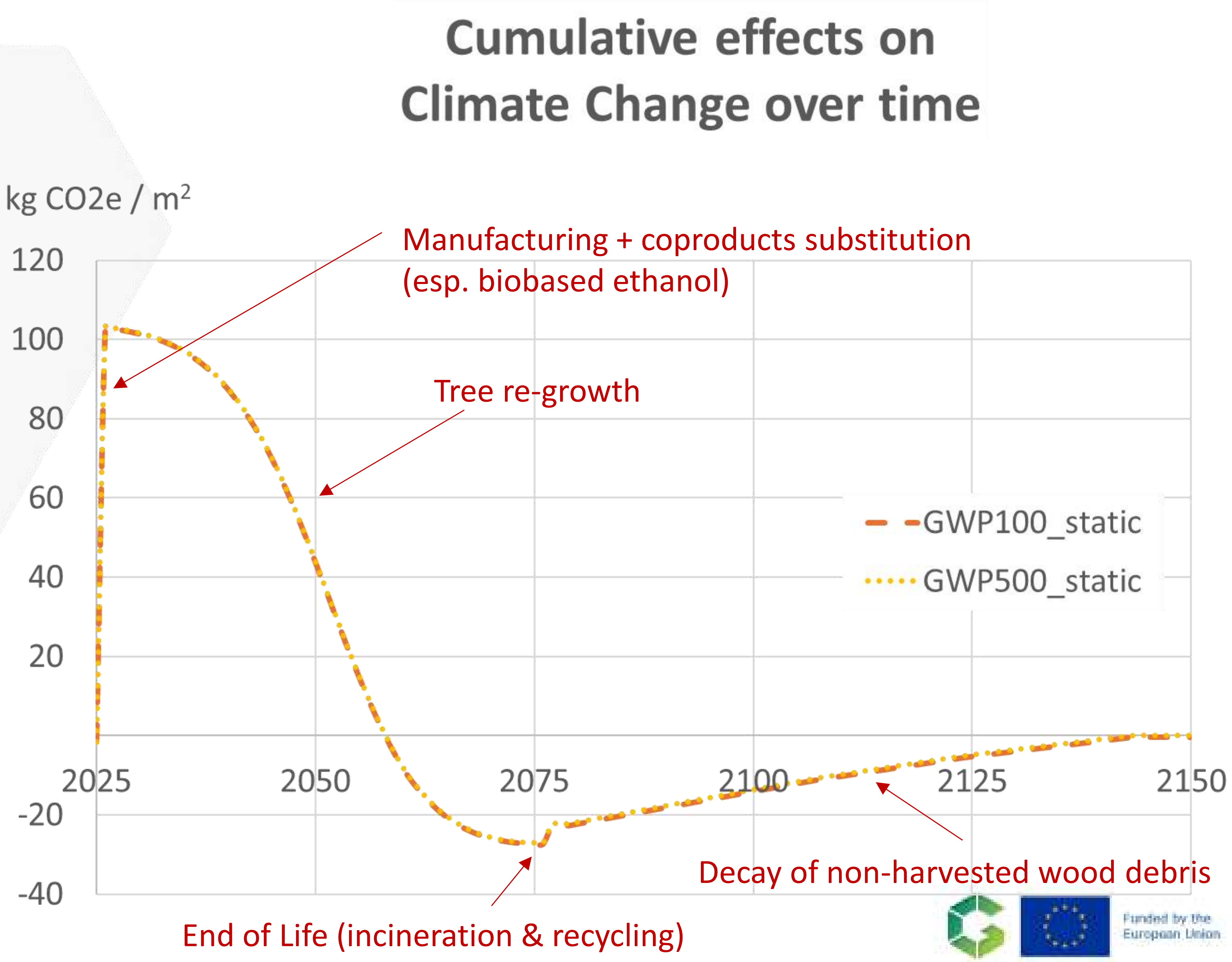
Results – Tier2

1/2: analysis of LC stages

Year 1 peak: substitution of sugarcane ethanol
→ *Displaces CO2 uptake in other production systems!*

Production in 2025
= GHG flows for 100+ years!

GWP100 ≈ GWP500
→ *CO2 responsible for almost all effects (CH4 and N2O contributions are negligible)*



Credit: Damien Arbault

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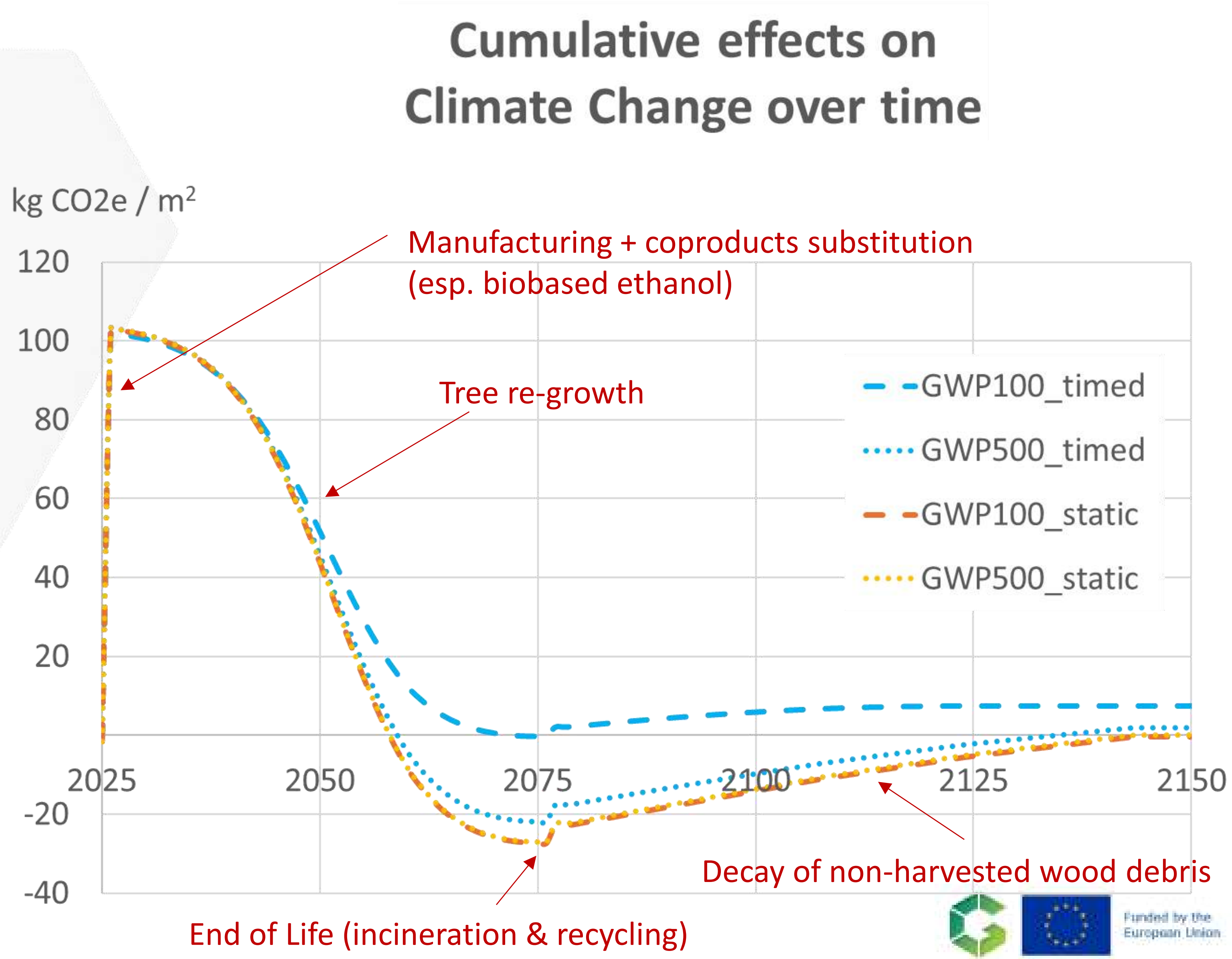
Results – Tier2

2/2: comparison of indicators

Net CC effects remain 'positive' for 30+ yrs



Credit: Damien Arbault

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Conclusions & perspectives

Stepwise learning on temporalized LCA:

- Tier1: slicing system into LC phases
  - Basic application
  - Learn data organization
  - Quick answer to: ‘is temporalization useful?’
- Tier2: fine-tuning temporal distribution
  - Enables visual analysis
  - Short-term vs long-term consequences of a decision

Overall learning:

- Effects of temporal C storage in products are rather small in comparison to those of the biomass cultivation. High sequestration at early years matters!

Next steps:

- Feedbacks most welcome!
- Update guidelines and tools

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THANK YOU

ALIGNED consortium in Lisbon, October 2024.

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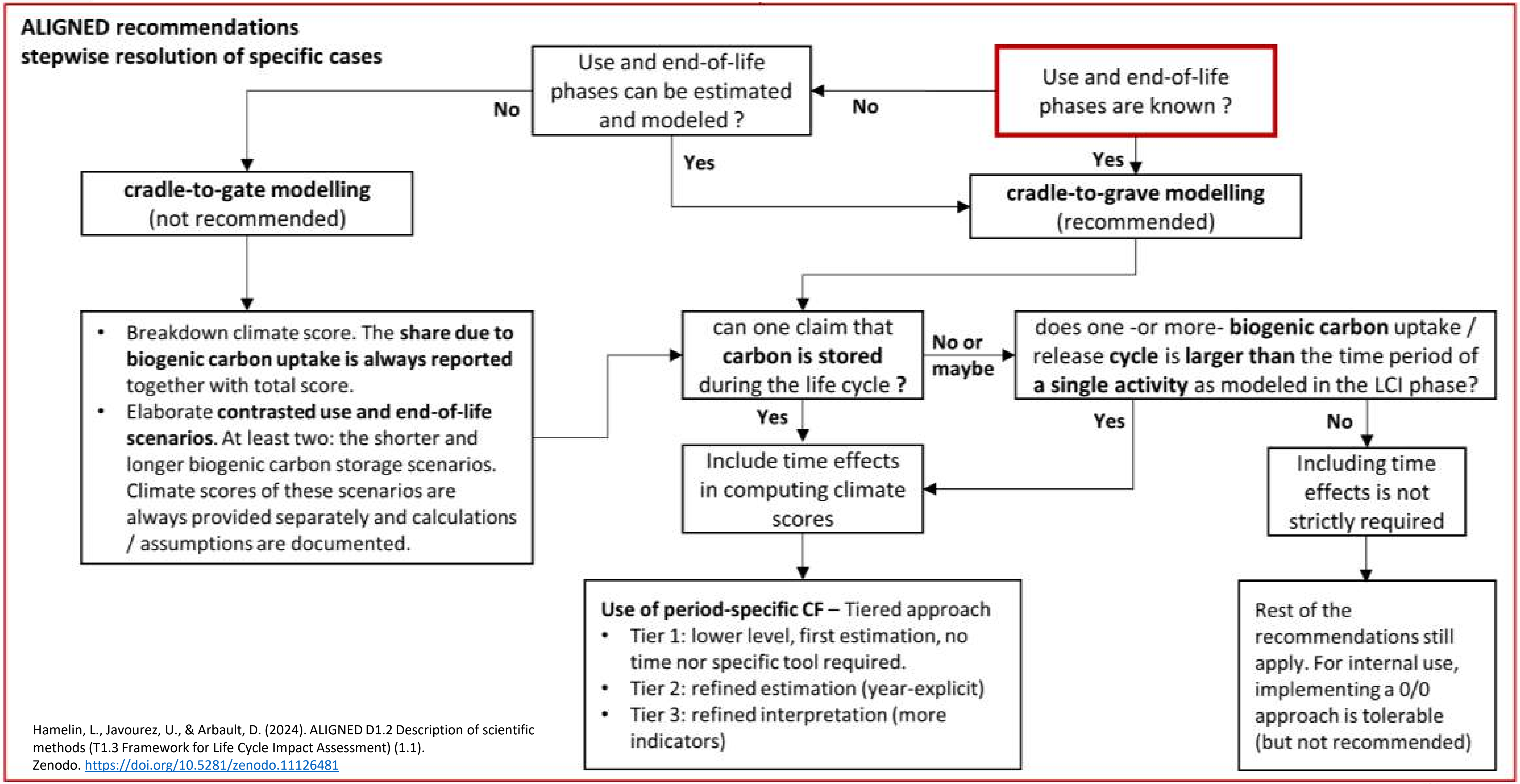
Background material

Funded by the European Union

Time-dependent characterization factors for the climate impact



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	A	B	C	D	E	F	G	H	I	J	K	L	M
1				GWP100					GWP500				
2		Calendar year	Year count	CO2f	CO2b	CH4f	CH4b	N2O	CO2f	CO2b	CH4f	CH4b	N2O
3	year 0	2025	0	1,0000	1,0000	26,4972	26,4972	263,1619	1,0000	1,0000	7,5560	7,5560	123,6794
4	year 1	2026	1	0,9922	0,9922	26,4967	26,4967	261,5480	0,9985	0,9985	7,5560	7,5560	123,6677
5	year 2	2027	2	0,9843	0,9843	26,4962	26,4962	259,9193	0,9969	0,9969	7,5560	7,5560	123,6558
6	year 3	2028	3	0,9765	0,9765	26,4956	26,4956	258,2755	0,9954	0,9954	7,5560	7,5560	123,6439
7	year 4	2029	4	0,9686	0,9686	26,4950	26,4950	256,6166	0,9939	0,9939	7,5560	7,5560	123,6318
8	year 5	2030	5	0,9607	0,9607	26,4943	26,4943	254,9423	0,9924	0,9924	7,5560	7,5560	123,6197
9	year 6	2031	6	0,9527	0,9527	26,4935	26,4935	253,2527	0,9908	0,9908	7,5560	7,5560	123,6074
10	year 7	2032	7	0,9448	0,9448	26,4927	26,4927	251,5475	0,9893	0,9893	7,5560	7,5560	123,5950
11	year 8	2033	8	0,9368	0,9368	26,4918	26,4918	249,8265	0,9878	0,9878	7,5560	7,5560	123,5825
12	year 9	2034	9	0,9289	0,9289	26,4909	26,4909	248,0897	0,9862	0,9862	7,5560	7,5560	123,5699
13	year 10	2035	10	0,9208	0,9208	26,4898	26,4898	246,3369	0,9847	0,9847	7,5560	7,5560	123,5571
14	year 11	2036	11	0,9128	0,9128	26,4887	26,4887	244,5680	0,9832	0,9832	7,5560	7,5560	123,5443
15	year 12	2037	12	0,9048	0,9048	26,4875	26,4875	242,7827	0,9816	0,9816	7,5560	7,5560	123,5313
16	year 13	2038	13	0,8967	0,8967	26,4861	26,4861	240,9810	0,9801	0,9801	7,5560	7,5560	123,5182
17	year 14	2039	14	0,8886	0,8886	26,4846	26,4846	239,1627	0,9785	0,9785	7,5560	7,5560	123,5050
18	year 15	2040	15	0,8805	0,8805	26,4830	26,4830	237,3276	0,9770	0,9770	7,5560	7,5560	123,4917
19	year 16	2041	16	0,8724	0,8724	26,4813	26,4813	235,4756	0,9755	0,9755	7,5560	7,5560	123,4782
20	year 17	2042	17	0,8642	0,8642	26,4794	26,4794	233,6066	0,9739	0,9739	7,5560	7,5560	123,4647
21	year 18	2043	18	0,8560	0,8560	26,4773	26,4773	231,7203	0,9724	0,9724	7,5560	7,5560	123,4509
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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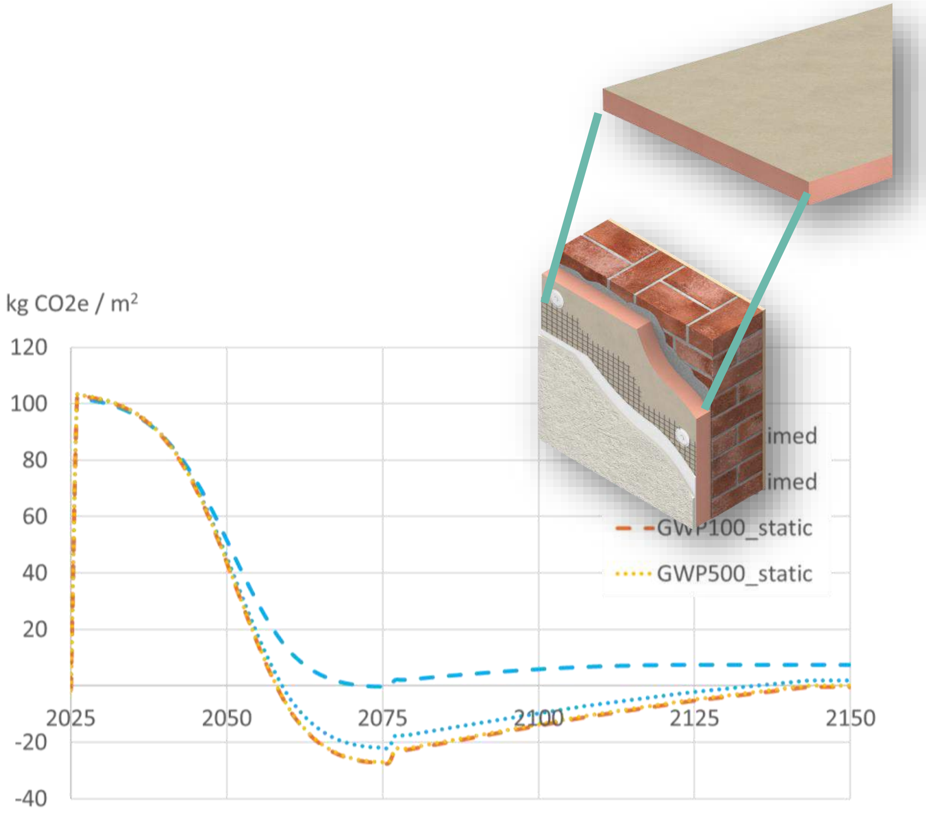
Case study takeaways

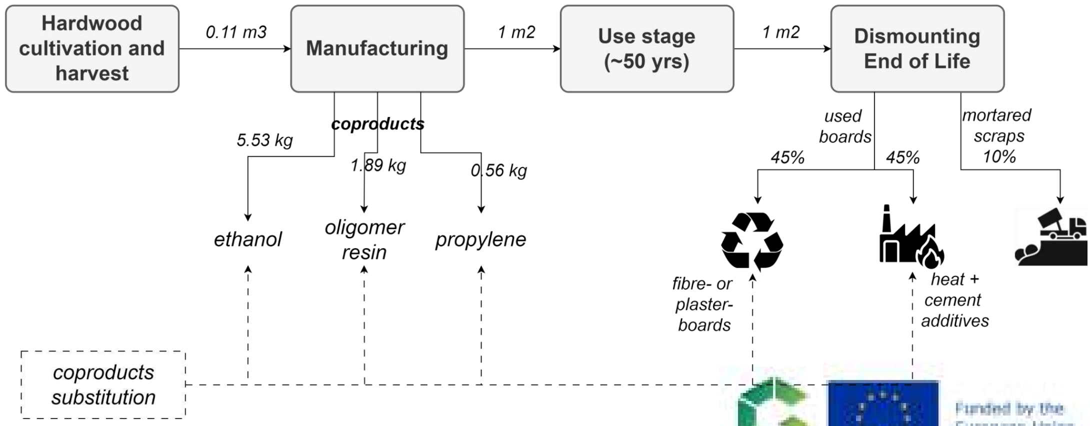
- Relying on long-term rotation biomass to reach climate neutrality requires **secured sustainable forestry planning**

Time-dependent vs Time-invariant Characterization Factors:

- GHG flows close to Time Horizon have smaller GWPs with time-dependent CFs

→ Time-dependent CFs are consistent with using a fixed Time Horizon

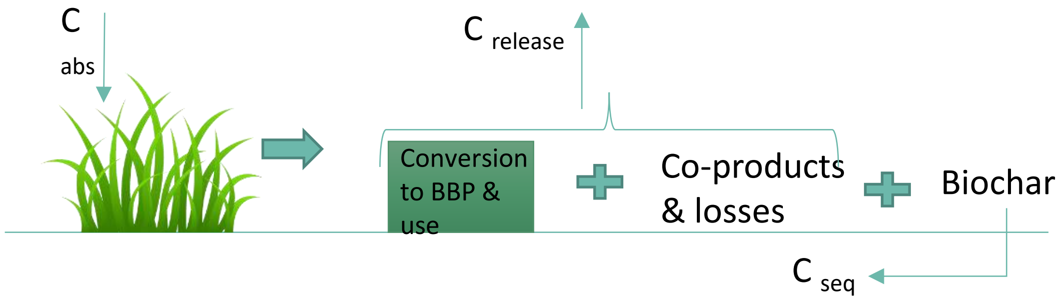




Credit: Damien Arbault

Issue 1: How to account for biogenic CO2?

<u>Approach 1: 0/0</u> : Absorbed and released CO2 with a CF of 0 (kg CO2e/kg CO2; GWP metric). Induced sequestration with a CF of +1 (while flux accounted as minus).



- Issues:
  - Induce the idea that there are no climate effects from the use of biomass
  - Important CO2 flows invisible in results (thus also for decision-making)
  - Mass balance distorted when C emitted back as CH4, CO, etc. (not necessarily re-absorbed by plants)
  - Temporary storage when biomass is harvested but not ‘emitted’ immediately is not reflected
  - Land use changes: if our process induce that some biomass, somewhere, is not permitted to grow back, there is a permanent addition of biogenic CO2 to the atmosphere, and this is then not reflected!

- Uses:
  - Used in PEF/PEFCR; but most industrial guidelines seem to NOT recommend this approach

Table 2
Standard methods to account biogenic carbon.

Standardized guidance for product-level data	Approach
PEFCR (European Commission, 2017)[a], SIA 2032 (SIA, 2020)	0/0
PAS 2050 (BSI, 2011), EN 15804+A2; 2019 (CEN, 2019), ISO 14067 (ISO, 2018) and ISO 21930 (ISO, 2017a)	−1/+1

[a] For cradle to grave assessments of final products with a life time of less than 100 years.

Ouellet-Plamondon et al. (2023).

Relevant litterature: Cucurachi et al. (2022). https://publications.jrc.ec.europa.eu/repository/handle/JRC129632; Ouellet-Plamondon et al. (2023). https://doi.org/10.1016/j.jclepro.2023.136834 ; TfS (2022). https://www.tfs-initiative.com/how-we-do-it/scope-3-ghg-emissions; EC (2018). https://eplca.jrc.ec.europa.eu/permalink/PEFCR_guidance_v6.3-2.pdf

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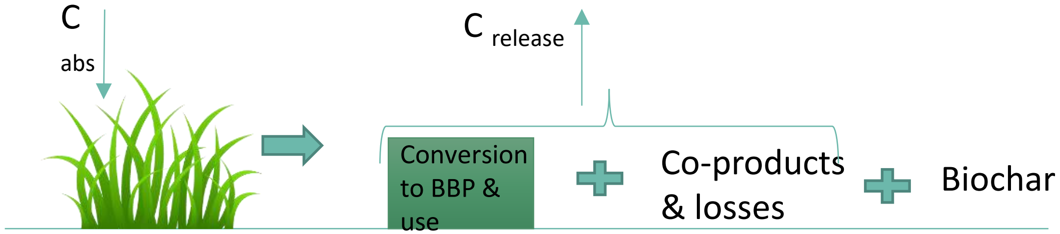
Issue 1: How to account for biogenic CO2?

Approach 2: -1/+1 : Uptake from the atmosphere accounted with a CF of -1, releases to atmosphere with a CF of +1. Only net flows are accounted (so sequestration not assigned a flow).



- Issues:
  – Calculation potentially more difficult
  – Eventual misinterpretation of results (C-negative products) because of system boundary inconsistencies in cradle-to-gate
  – How to account for the absorption ?
    - Industries often advocate to take it equal to C in the product. This implies neglecting the C flows absorbed by the biomass but not converted to the product (because part of crop residues or below-ground, because of conversion losses, etc.). This error can be problematic especially if these losses do not occur as CO2, or if they occur later in time.
    - Based on NPP / crop yield. To adopt this more rigourous approach, guidelines and suggestions of generic values are necessary.

Relevant litterature: Cucurachi et al. (2022). https://publications.jrc.ec.europa.eu/repository/handle/JRC129632; Ouellet-Plamondon et al. (2023). https://doi.org/10.1016/j.jclepro.2023.136834 ; TfS (2022). https://www.tfs-initiative.com/how-we-do-it/scope-3-ghg-emissions; EC (2018). https://eplca.jrc.ec.europa.eu/permalink/PEFCR_guidance_v6.3-2.pdf

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