Sustainability Assessment of Tall Timber Buildings

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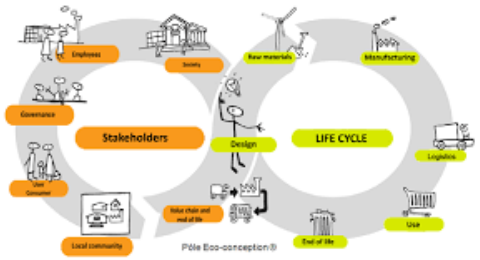
21 Floors - Residential

Acknowledgment

- School of Engineering, Liege University, Belgium
- The presentation visualisations are based on the slides of Dr. Alexander Hollberg Lecture on LCA (Chalmers) and Muheeb Al-Obaidy
- CEN/TC 350/SC 1 - Circular Economy in the Construction Sector Committee
- ISO/TC 323- Circular Economy in the Construction Sector Committee
- CA21103 - Implementation of Circular Economy in the Built Environment (CircularB)



European Cooperation in Science and Technology

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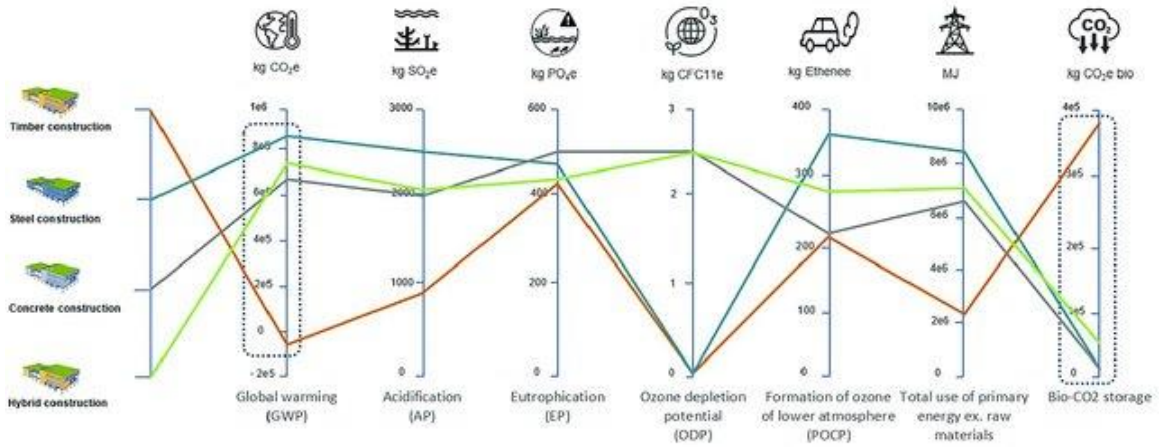
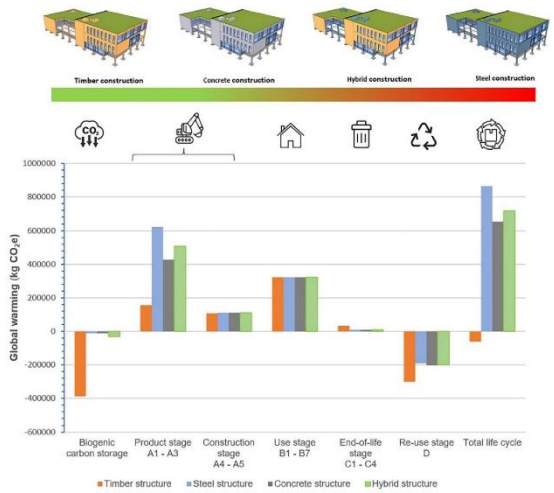
Motivation

t’ Centrum, Westerlo, Belgium
1st Circular Timber Building

Beneens Architecten: Het Centrum: Belgium, Westerlo





Al-Obaidy et al (2022) DOI: [10.3390/su14063370](https://doi.org/10.3390/su14063370)

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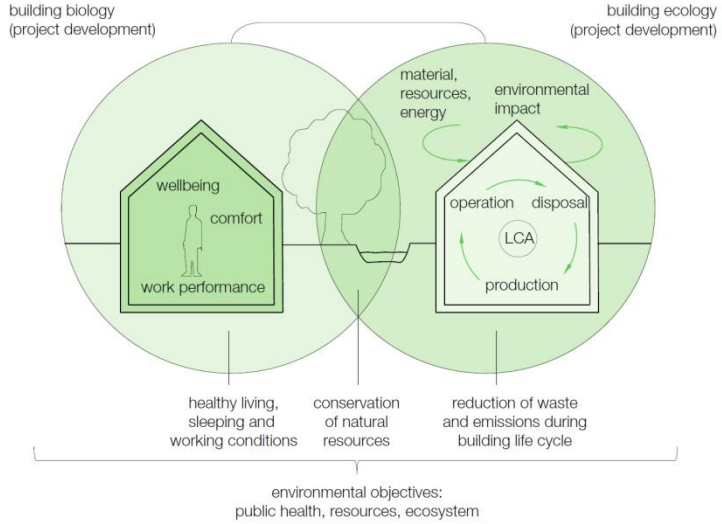
- Introduction
- Environmental Impact Assessment
- Timber and GWP
- EU Sustainability Assessment Policy
- COST Action 20139

Introduction

Sustainability Assessment



El Khouli, Zeumer. 2015.
Sustainable Construction Techniques

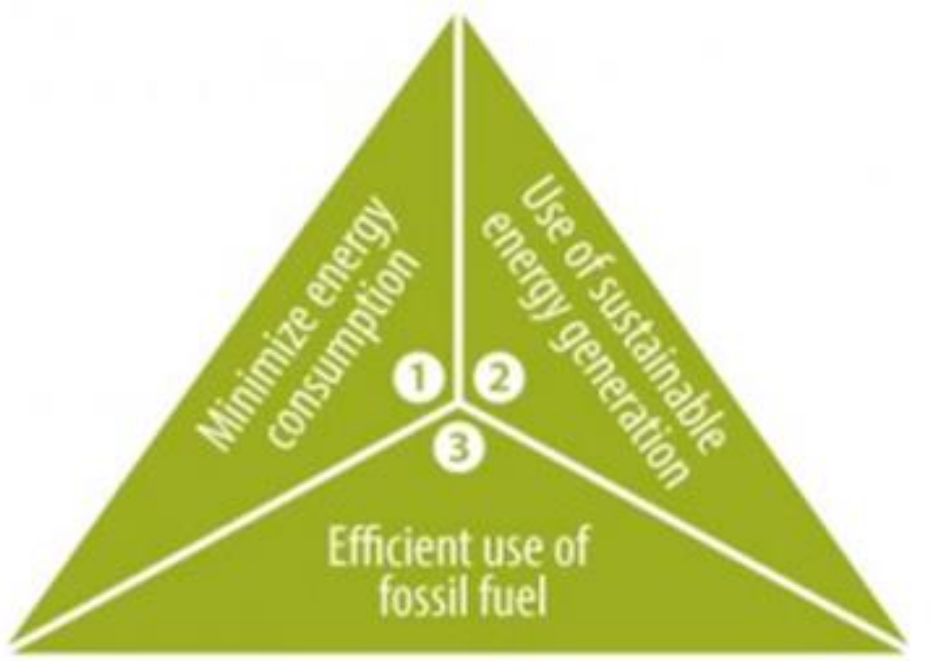


Figure 1a: Trias Energetica (Duijvestein, 2010)

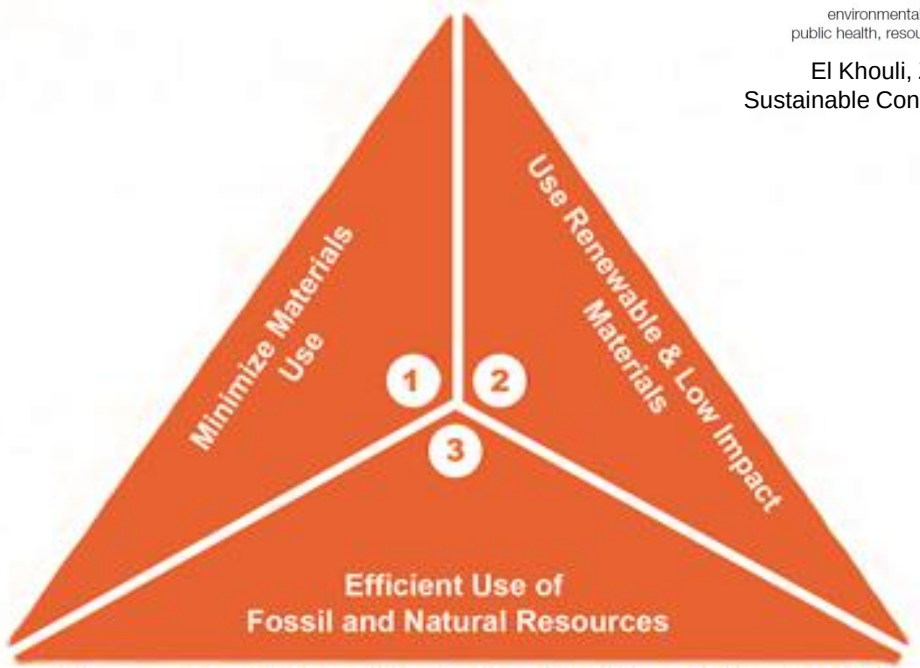


Figure 1a: Trias Materia (Duijvestein, 2010)

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Semantics: Terms and Definitions

Greenhouse gases A greenhouse gas (or GHG for short) is any gas in the atmosphere which absorbs and re-emits heat and thereby keeps the planet's atmosphere warmer than it otherwise would be. The main GHGs in the Earth's atmosphere are water vapor, **carbon dioxide** (CO_2), **methane** (CH4), **nitrous oxide** (N_2O), and **ozone**.

Global warming potential The GWP of a GHG indicates the amount of warming a gas causes over a given period of time (normally 100 years). GWP is an index, with CO_2 having the index value of 1, and the GWP for all other GHGs is the number of times more warming they cause compared to CO_2. E.g. 1kg of methane causes 25 times more warming over 100 years compared to 1kg of CO_2, and so methane has a GWP of 25.

Carbon dioxide CO_2 is the most common GHG emitted by human activities in terms of the quantity released and the total impact on global warming. As a result, the term "CO2" is sometimes used as a shorthand expression for all greenhouse gases. However, this can confuse, and a more accurate way of collectively referring to a number of GHGs is to use the term "carbon dioxide equivalent" or "CO_{2e}". Because CO_2 is considered the most important greenhouse gas, some GHG assessments or reports only include CO_2, and don't consider the other greenhouse gases, and this can lead to an understatement of the total global warming impact. Greenhouse gas inventories are more complete if they include all GHGs, not just CO_2.

Environmental Impact Assessment

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What is LCA ?

- Methodology to quantify and assess potential environmental impacts of a product system during its life cycle

- Holistic picture makes it possible to identify improvements without “burden shifting”

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Cradle to gate

EN 15978

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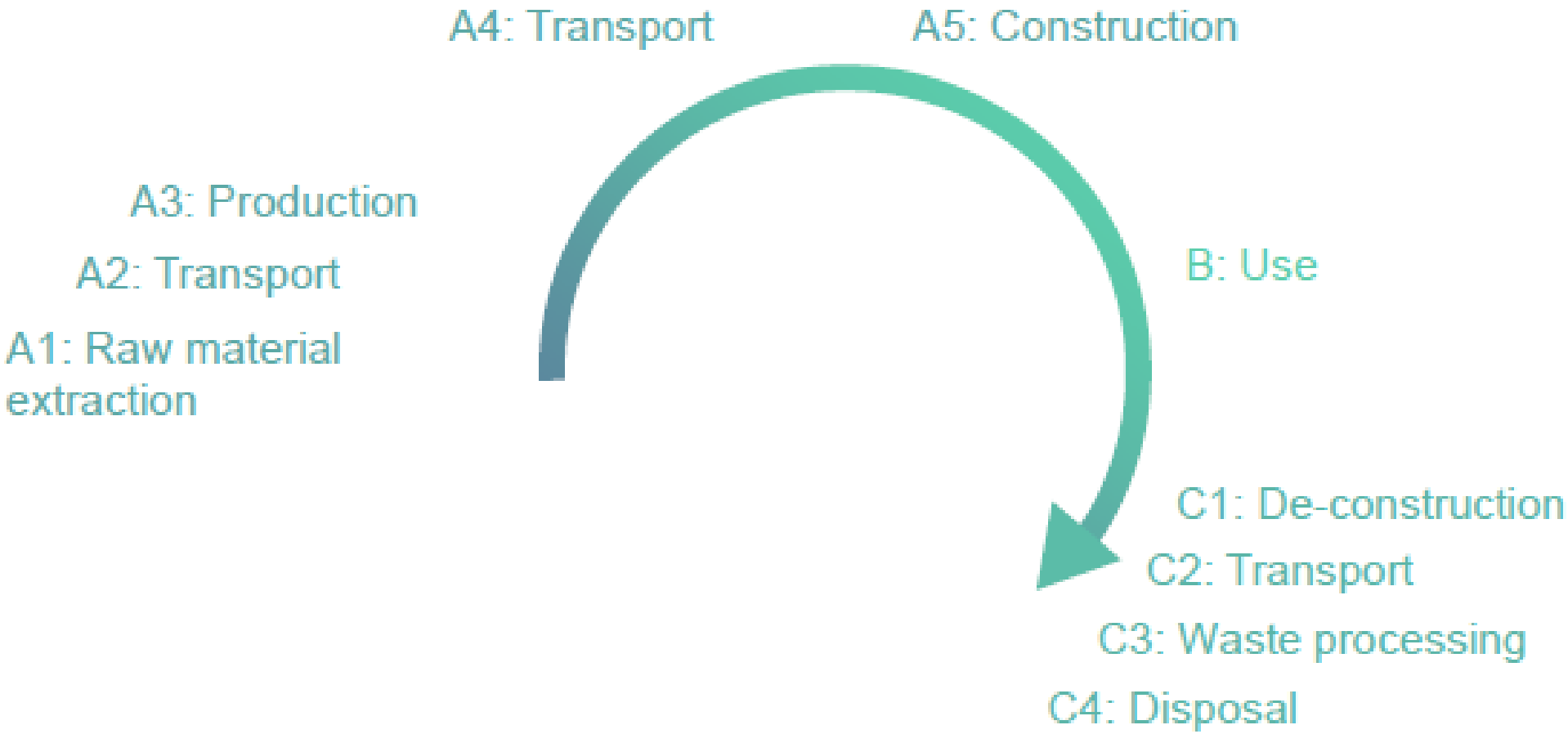
Cradle to grave

EN 15978



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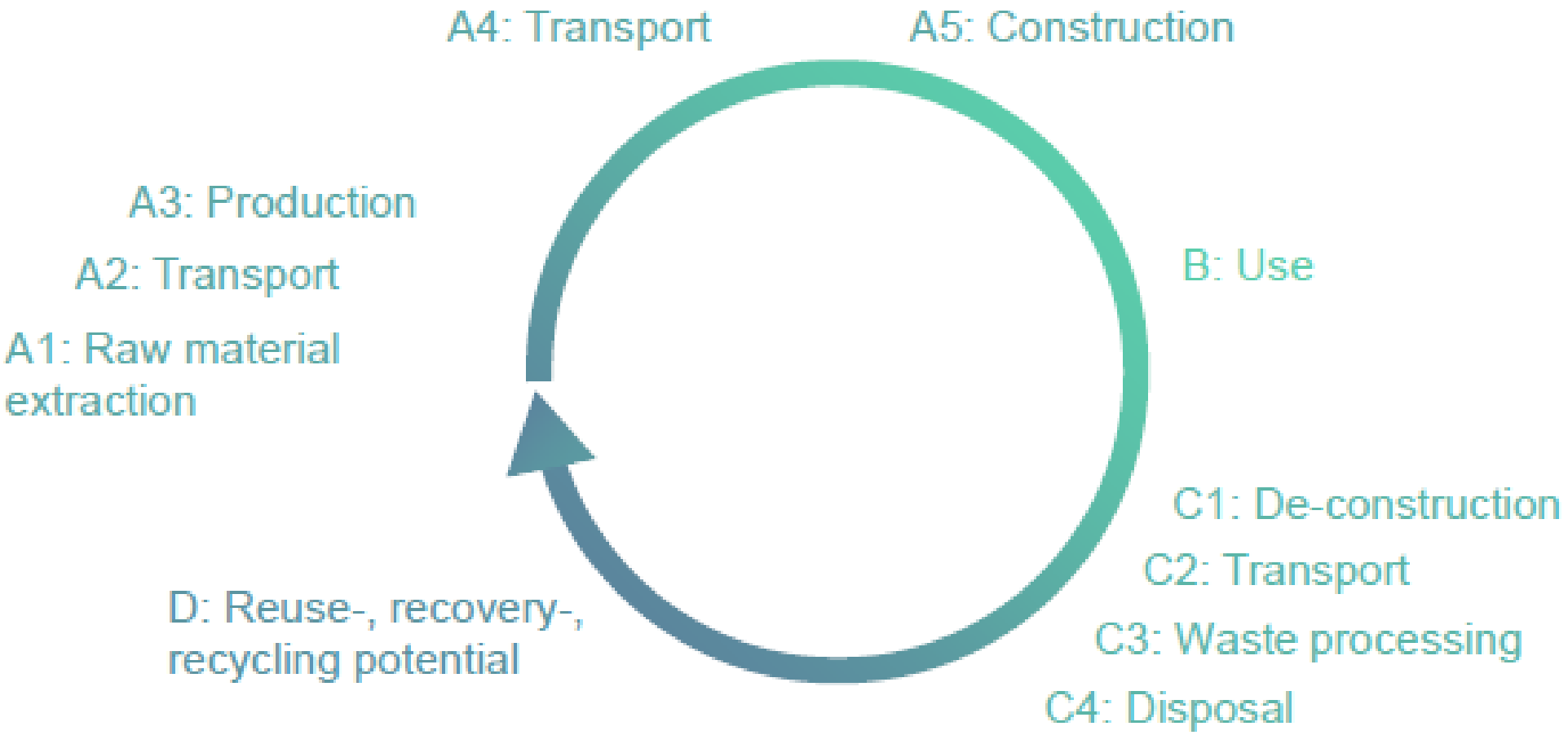
Cradle to cradle

EN 15978



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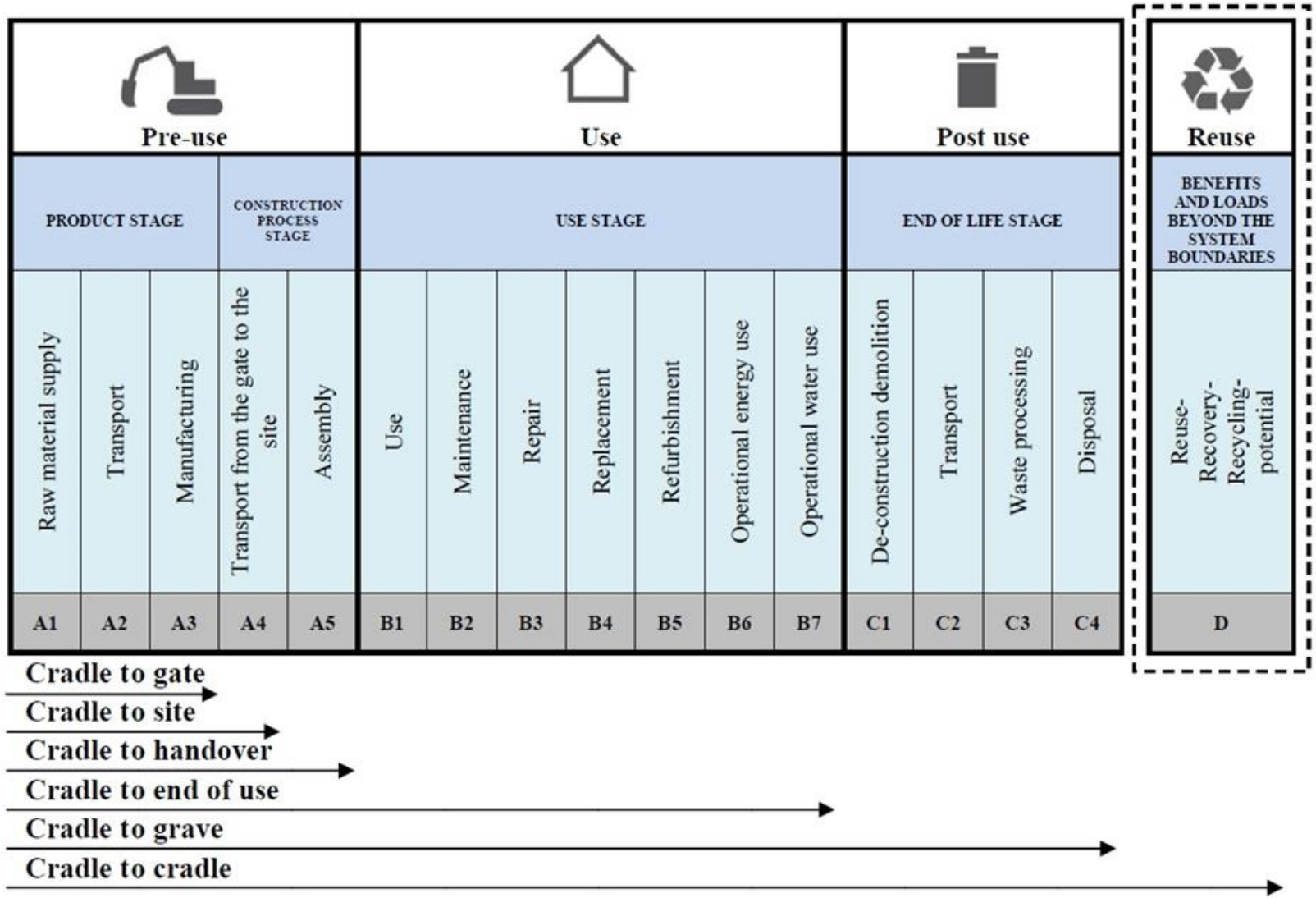
Building life stages

EN 15978



Description of the stages during the buildings' life, according to EN 15978.:2012, p.21

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Goal, Scope, Functional Unit & System Boundary

Goal: *Who wants to know about what and for what reason?*

Activities (ISO14040)

- Intended application of the study
- Reason for carrying out the study
- Communication of results (intended audience)

Scope: *Which model options?*

Activities

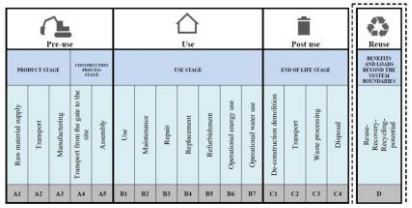
- Cradle to gate, grave, cradle
- Selection of impact categories and method
- Allocation method and LCA type

Functional Unit:

- Describes the function of the product system studied in the LCA
- Quantitative

- Used as a basis for calculation

System Boundary:



LCA inclusion and exclusion criteria

- System boundaries to consider
- Product system (assessed building elements)
- Life cycle modules
- Geography
- Time horizon/ Reference study period (e.g. 50 years)

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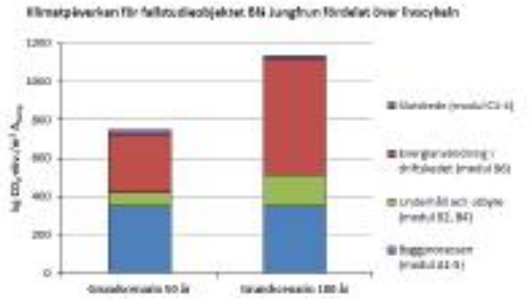
Levels of environmental impact assessment

Building

Element

Product/
Material

Building hot spot analysis



Choice of load bearing structure

EN 15804

Environmental product declaration

EPD®

THE INTERNATIONAL EPD® SYSTEM

Learning — Decision making — Communication

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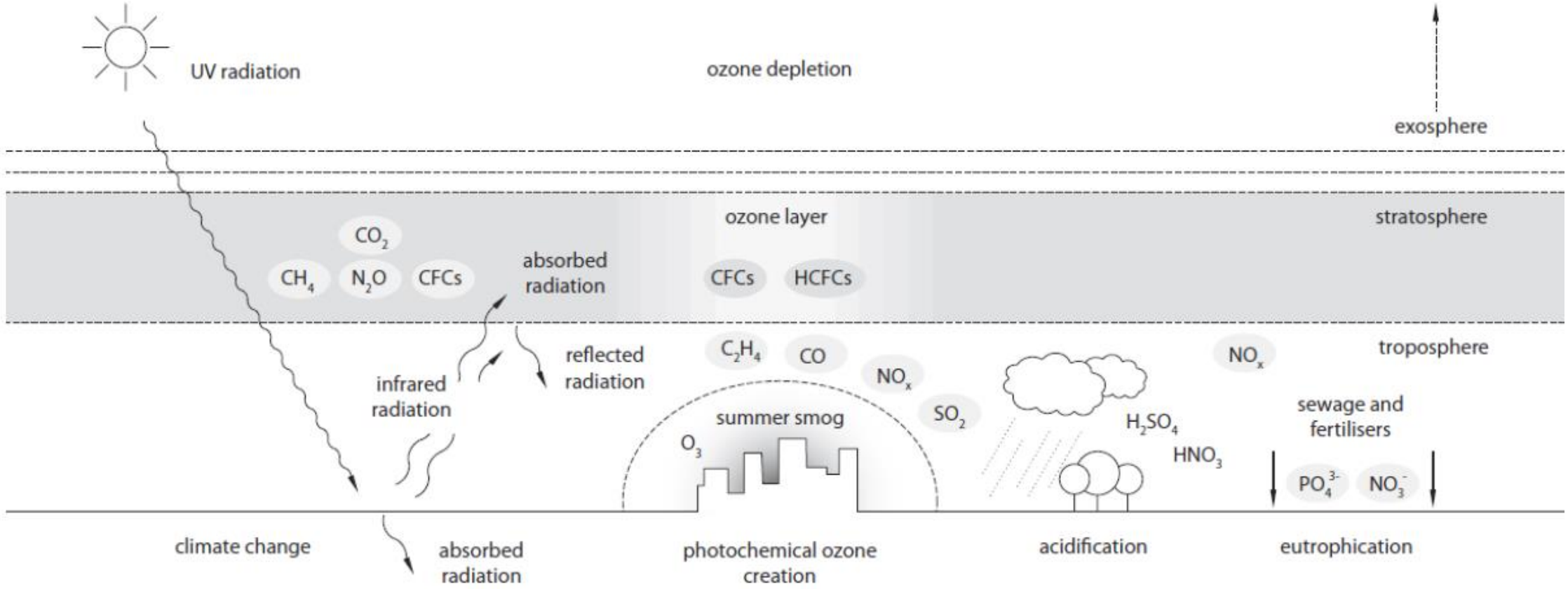
Environmental indicators in LCA

Climate change	Ozone Depletion	Eutrophication	Acidification of soil and water	Formation of photo oxidants	Abiotic depletion potential	Primary energy
Global Warming Potential (GWP)	Ozone Depletion Potential (ODP)	Eutrophication Potential (EP)	Acidification Potential (AP)	Photochemical Ozone Creation Potential (POCP)	Abiotic resource depletion - elements (ADPe) / Abiotic resource depletion - fossil fuels (ADPf)	Primary energy renewable total (PERT) / Primary energy non-renewable total (PENRT)
kg CO2-equivalent	kg R11-equivalent	kg PO43-equivalent	kg SO2-equivalent	kg C2H4-equivalent	kg Sb equivalent / MJ	MJ / kWh

Summary of LCA indicators found in EN 15804

Environmental indicators in LCA

overvue of some pollutants and their impact



V. John (2012), «Derivation of reliable simplification strategies for the comparative LCA of individual and «typical» newly built Swiss apartment buildings», DISS ETH No. 20608

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Sustainability Assessment

- Life Cycle Assessment (LCA)
- Life Cycle Costing (LCC)
- Social Life Cycle Assessment (SLCA)

Life Cycle Sustainability Assessment (LCSA)

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Timber and GWP

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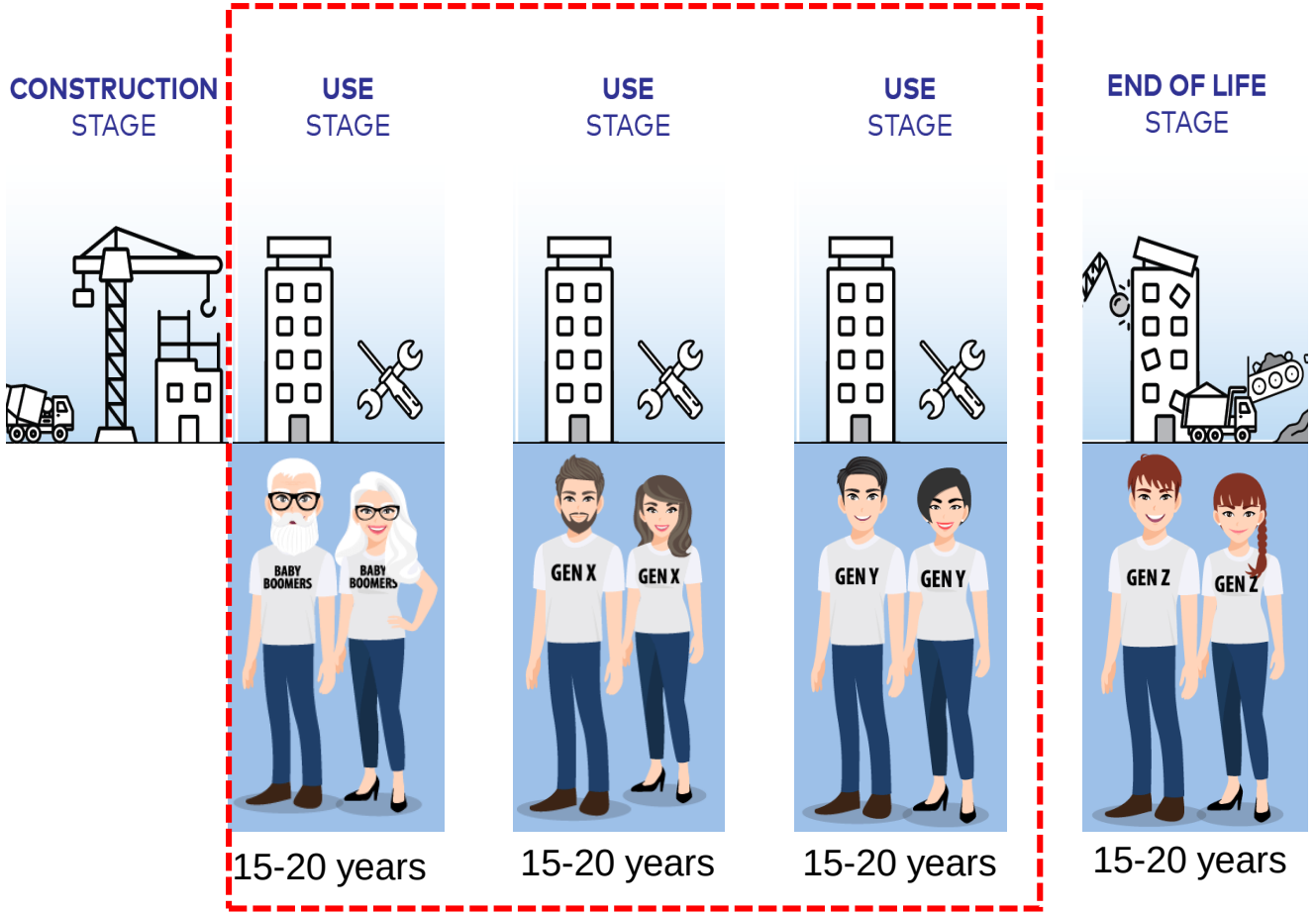
Timber



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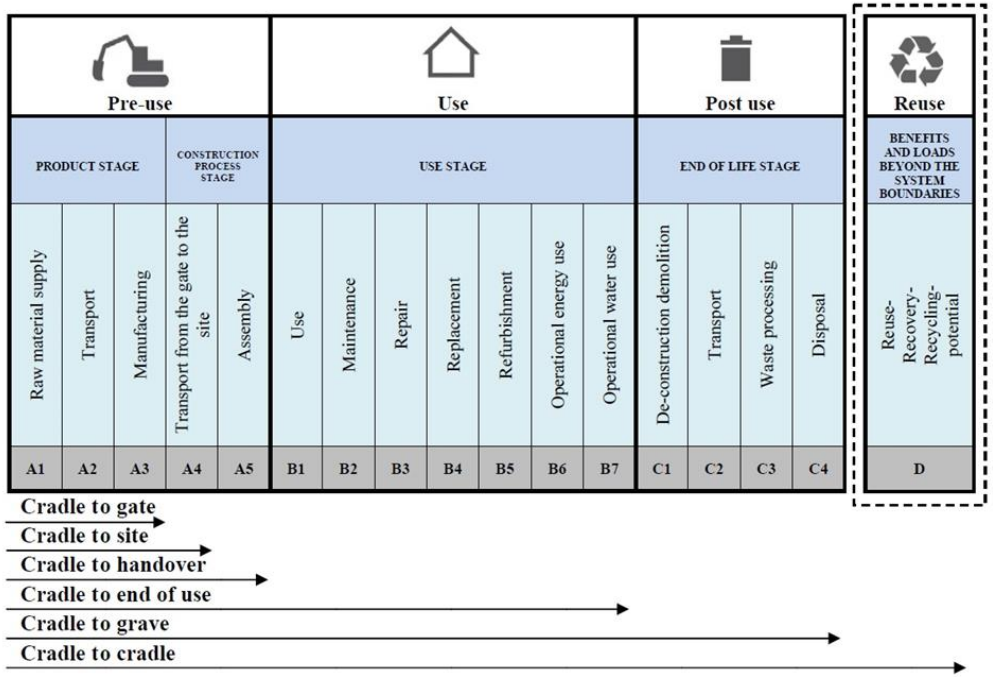
GHG emissions and Timber

Total GHG emissions can be calculated from the equation below.

$$E_{tot} = \sum_{m,=1}^{n} E_{m,GHG} \qquad (1)$$

E_{tot} is the total GHG emissions and $E_{m,GHG}$ is the GHG emissions from the m^{th} emission source.



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Biogenic Carbon (GHG emissions)

The **first approach**, the '0/0 approach' or 'carbon neutral approach', the release of CO_2 from a bio-based product at the end of its life is balanced by an equivalent uptake of CO2 during the biomass growth. As a consequence, there is no consideration of biogenic CO_2 uptake (0) and release (0).

The **second approach**, which is referred to as the '–1/+1' approach, consists of tracking all biogenic carbon flows over the building life-cycle. In this approach both biogenic CO2 uptake (–1) and release (+1) are considered, as well as the transfers of biogenic carbon between the different systems.

Hoxha, Eet al. (2020)

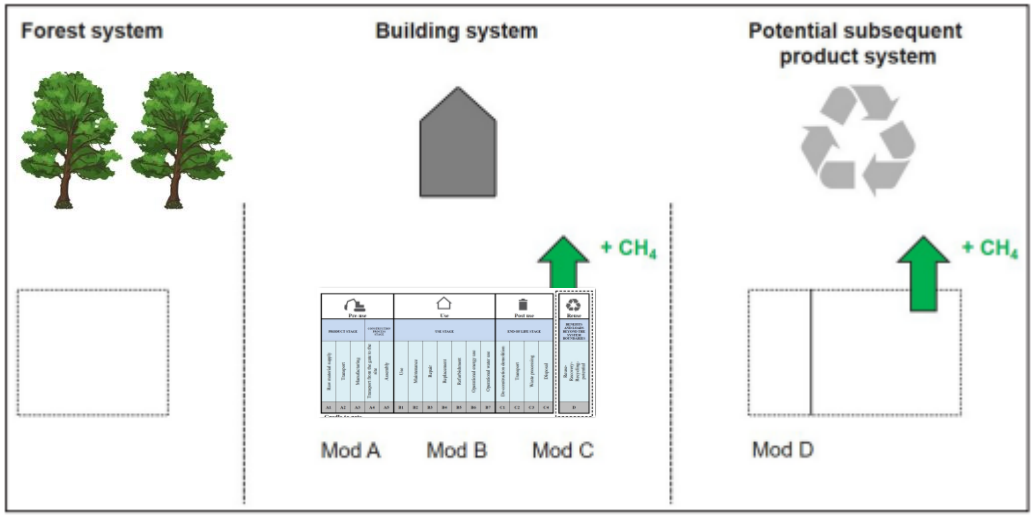

Figure 1: The 0/0 approach to model biogenic carbon uptake and release. Dotted lines indicate the product systems that fall outside the building system boundaries.

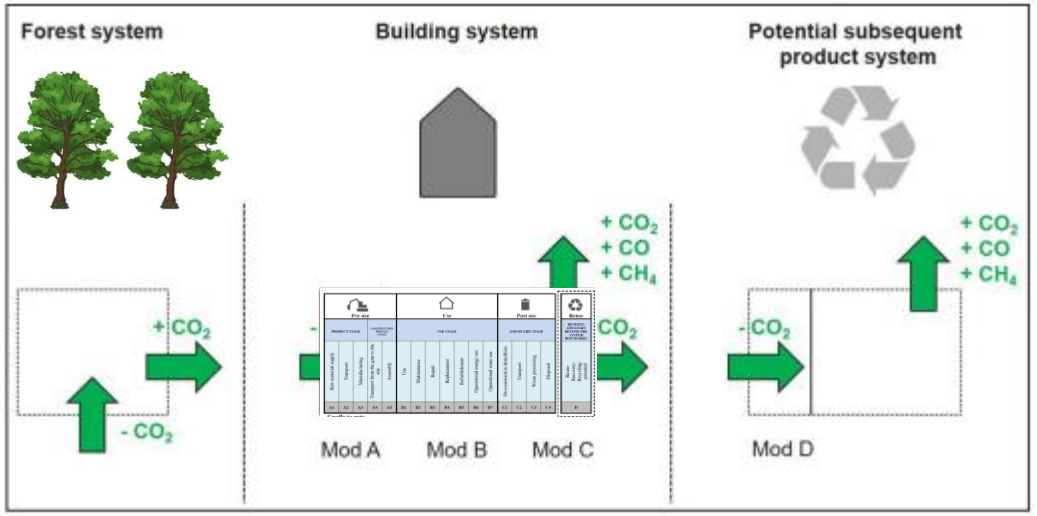

Figure 2: The –1/+1 approach to model biogenic carbon uptake and release. Dotted lines indicate the product systems that fall outside the building system boundaries

The European standards EN 15978, EN 15804, and EPDs often follow the cradle-to-gate options, mostly applying the –1/+1 approach. The impacts and carbon-storage credits are not included in most other existing methods. This means timber can not be considered carbon storage or sink. In other words, timber's sequestration ability is not considered.

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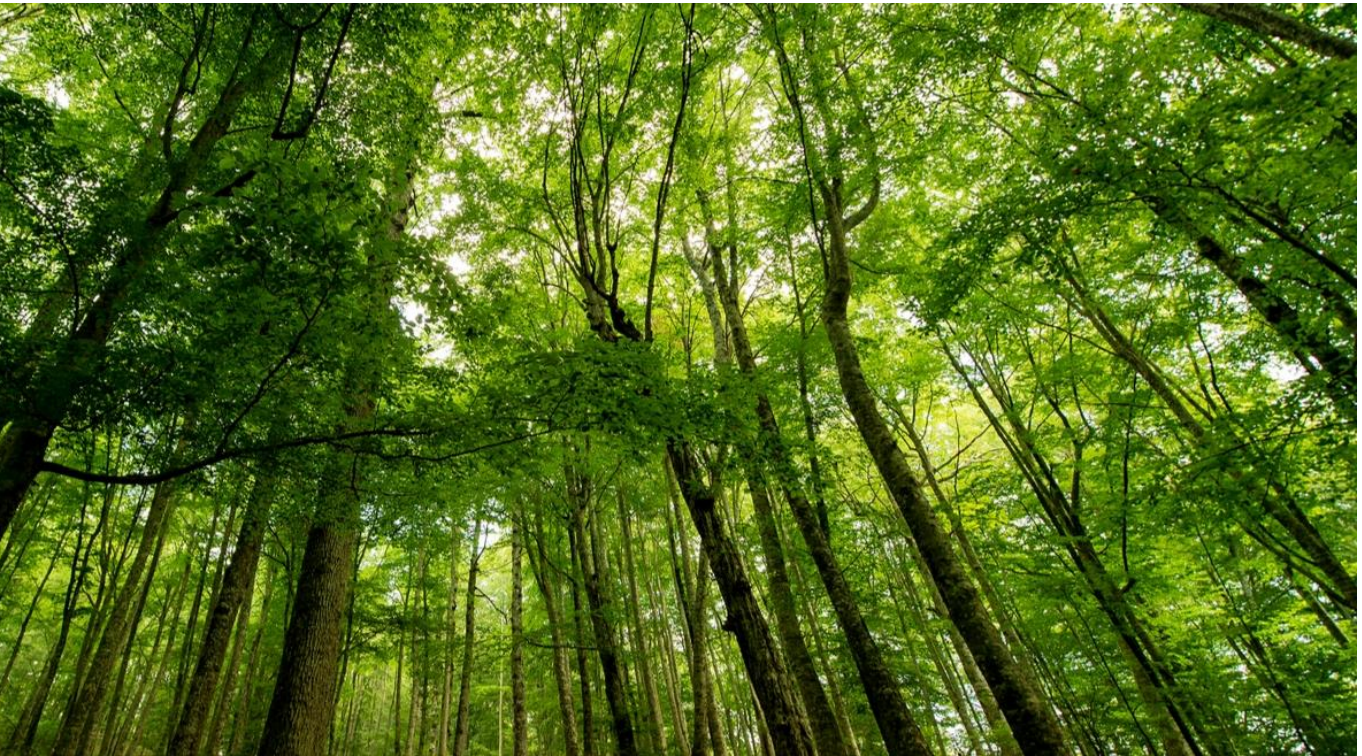
Sustainable Timber Sourcing

- Competition with food production
- Increase demand = increase forest areas
- Sustainable sourcing and tracing of chain of custody
- Influence of weak governance in non-standardized countries



- Forest Stewardship Council (FSC)
- Programme for the Endorsement of Forest Certification (PEFC)

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EU Sustainability Assessment Policy

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EU regulatory Framework

EN 15978 for LCA calculation methodology
EN 15804 for EPD

Ecodesign for Sustainable Products Regulation
Substantiating green claims from products placed on the European market

Construction Products Regulation
Delivery of environmental information from construction products and implementation of requirements

Based on EN15804+A2

Levels methodology
Sustainability assessment of buildings

Taxonomy
Sustainable activities

EPBD
Sustainable buildings

EED
Public procurement of buildings

CPR: Construction Product Regulation

REGULATION (EU) No 305/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 9 March 2011

laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC

(Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty on the Functioning of the European Union, and in particular Article 114 thereof,

(4) Member States have introduced provisions, including requirements, relating not only to safety of buildings and other construction works but also to health, durability, energy economy, protection of the environment, economic aspects, and other important aspects in the public interest. Laws, regulations, administrative measures or case-law, established either at Union or Member State level, concerning construction works may have an impact on the requirements of construction

CPR: Construction Product Regulation

EN 15978 for LCA calculation methodology
EN 15804 for EPD

CPR: (Essential) Basic Requirements

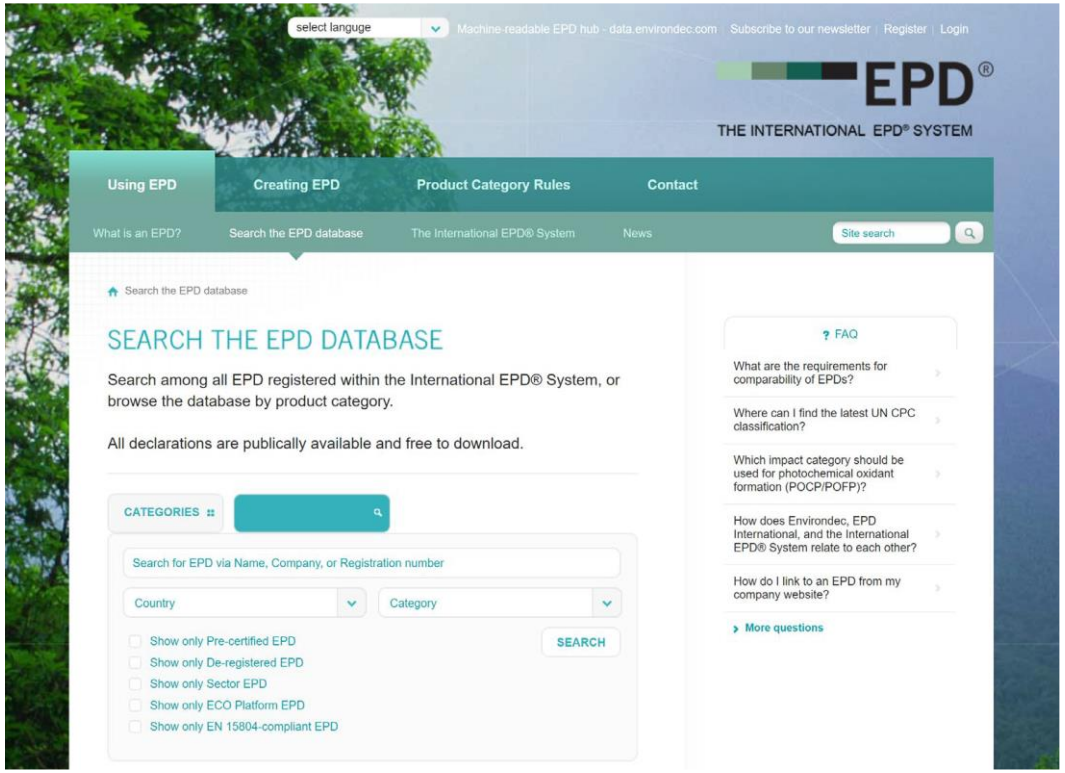
1. Mechanical resistance and stability
2. Safety in case of fire
3. Hygiene, health and environment
4. Safety in use and accessibility
5. Protection against noise
6. Energy economy and heat retention
7. Sustainable use of natural resources

EN 15978
EN 15804
EN 15804+A2

Environmental Product Declaration (EPD) as part of CPR: Construction Product Regulation

Four categories of indicators

- Environmental impact
- Resource use
- Output flows
- Waste categories



https://www.environdec.com/EPD-Search/

ISO 14040, ISO 14044, EN 15978, EN 15804

EPD Data

EN 15804

ENVIRONMENTAL IMPACTS															
Parameters	**Product stage**	**Construction process stage**		**Use stage**							**End-of-life stage**				**D Reuse, recovery, recycling**
	A1 / A2 / A3	A4 Transport	A5 Installation	B1 Use	B2 Maintenance	B3 Repair	B4 Replacement	B5 Refurbishment	B6 Operational energy use	B7 Operational water use	C1 Deconstruction / demolition	C2 Transport	C3 Waste processing	C4 Disposal	
Global Warming Potential (GWP 100) - *kg CO_2 equiv/FU*	2,14E+00	1,24E-01	1,52E-01	0	0	0	0	0	0	0	4,10E-02	1,34E-02	1,54E-03	1,24E-01	-2,18E-02
The global warming potential of a gas refers to the total contribution to global warming resulting from the emission of one unit of that gas relative to one unit of the reference gas, carbon dioxide, which is assigned a value of 1.															
Ozone Depletion (ODP) *kg CFC 11 equiv/FU*	5,52E-08	1,90E-17	2,76E-09	0	0	0	0	0	0	0	5,59E-18	7,03E-15	2,47E-12	6,94E-16	9,80E-05
Destruction of the stratospheric ozone layer which shields the earth from ultraviolet radiation harmful to life. This destruction of ozone is caused by the breakdown of certain chlorine and/or bromine containing compounds (chlorofluorocarbons or halons), which break down when they reach the stratosphere and then catalytically destroy ozone molecules.															
Acidification potential (AP) *kg SO_2 equiv/FU*	8,24E-03	4,95E-04	5,54E-04	0	0	0	0	0	0	0	1,44E-04	5,48E-05	1,74E-05	7,08E-04	1,82E-05
Acid depositions have negative impacts on natural ecosystems and the man-made environment incl, buildings. The main sources for emissions of acidifying substances are agriculture and fossil fuel combustion used for electricity production, heating and transport.															
Eutrophication potential (EP) *kg $(PO_4)^{3-}$ equiv/FU*	1,51E-03	1,21E-04	9,33E-05	0	0	0	0	0	0	0	8,38E-06	1,38E-05	3,2E-06	8,03E-05	-3,45E-01
Excessive enrichment of waters and continental surfaces with nutrients, and the associated adverse biological effects.															
Photochemical ozone creation (POPC) *kg Ethylene equiv/FU*	3,03E-04	1,81E-05	5,11E-05	0	0	0	0	0	0	0	9,68E-06	2,25E-06	2,14E-06	5,84E-05	0
Chemical reactions brought about by the light energy of the sun. The reaction of nitrogen oxides with hydrocarbons in the presence of sunlight to form ozone is an example of a photochemical reaction.															
Abiotic depletion potential for non-fossil ressources (ADP-elements) - *kg Sb equiv/FU*	1,96E-06	1,65E-09	1,99E-06	0	0	0	0	0	0	0	1,02E-09	1,15E-09	8,46E-10	4,22E-08	0
Abiotic depletion potential for fossil ressources (ADP-fossil fuels) - *MJ/FU*	3,66E+01	1,73E+00	2,29E+00	0	0	0	0	0	0	0	5,11E-01	1,81E-01	1,64E-02	1,65E+00	0
Consumption of non-renewable resources, thereby lowering their availability for future generations.															

COST Action 20139

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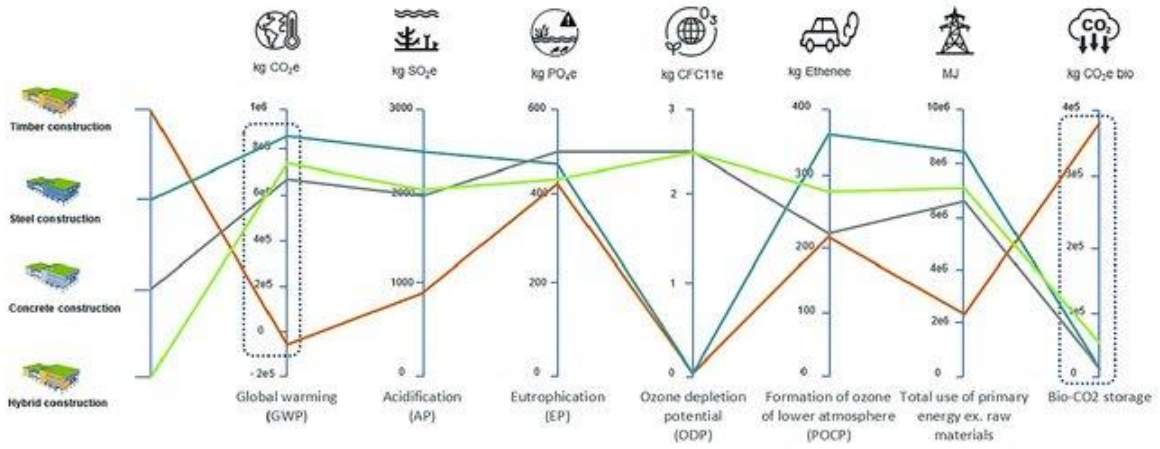
Discussion I: Sustainability

1. We should avoid using the term **~~'carbon emissions/footprint'~~** and replace it with **'GHG emissions'** or use the term **'GWP indicators'**
2. We can't claim the ~~'carbon storage'~~ or ~~'sequestration~~' or '~~carbon sinks'~~ features associated with timber
3. **We should follow the EN 15804 boundary condtions** (GWP, ODP, POCP, AP, EP, ADPe, ADPf), reference study period 50 years, A-B-C-D.
4. The circularity concept must be strongly support to benefit from the end D stage.
5. **We should follow the EN 15804 calculation and reporting approach (EPD) and try to extend our EIA beyond its limitations**
6. **EPD It is not only about the GWP indicator but other EPD indicators.**
7. **EN 15804 +A2 was approved and has been mandatory since July 2022.** One of the biggest changes in EN 15804+A2 concerns biogenic carbon in all forms. In EN 15804+A1, it was possible to deduce biogenic carbon stored in a product from cradle-to-gate impacts and add them back to represent their release in the end-of-life phase; but only if the product came from sustainably managed forestry. This created some contention within the industry, and EN 15804+A2 resolves these problems.

In EN 15804+A2, the climate impact category is split into four different reported categories. The new categories are:
1. Climate change – total (sum of subcategories), 2.Climate change – fossil, 3.Climate change – biogenic, 4. Climate change – LULUC (land use and land use changes)
The new standard makes the minimum scope for all products to cover modules A1-A3, C1-C4, and D. This means that products must declare both the cradle-to-gate as well as end-of-life phases and the external impacts outside the system boundary. The calculation rules are provided in Annex D of EN 15804+A2.

Discussion II: Sustainability

8. **Sustainable Timber Sourcing is crucial to avoid unintended negative Consequences**
9. **It is time to perform some EIA parametric studies for some case studies.**



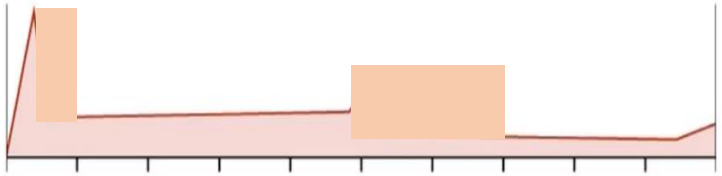
Al-Obaidy et al (2022) DOI: 10.3390/su14063370

Beneens Architecten: Het Centrum: Belgium, Westerlo

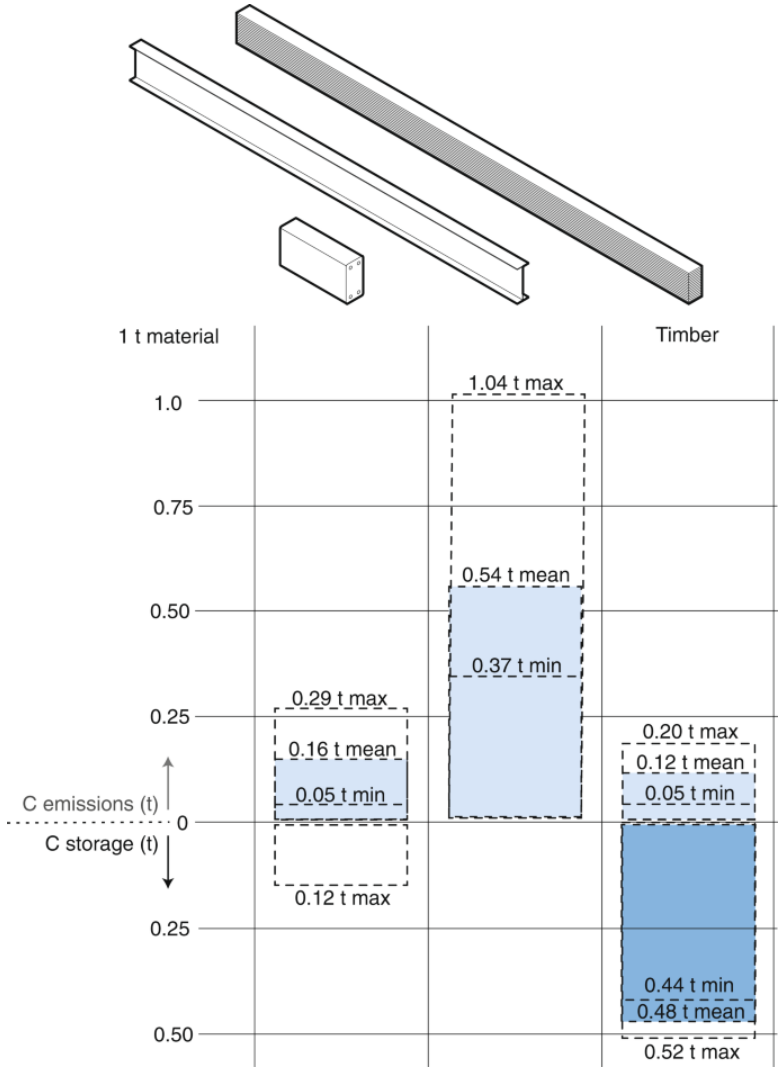
Example: GWP profiles of Building Elements

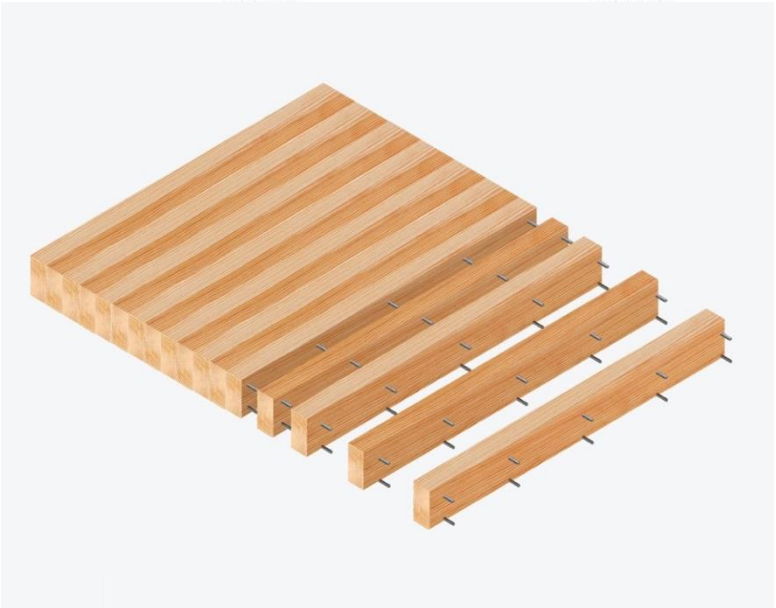
Criteria

- GWP: GHG emissions
- Building elements
- Hot Spot Analysis
- EPD + SA + UA



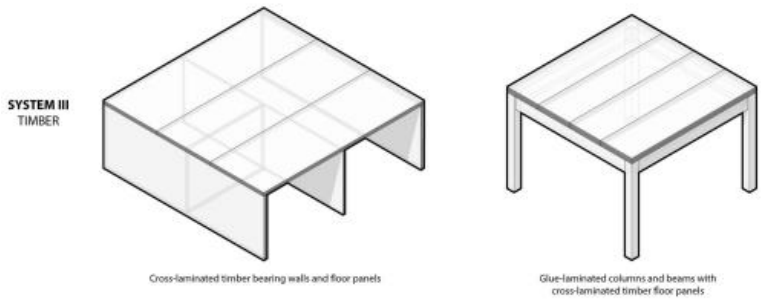
Product			Construc-tion		Use Stage							End of Life				Benefits and loads beyond the system boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Demolition	Transport	Waste processing	Disposal	Re-use, recovery and recycling potential





Nail-laminated Timber

Cross-laminated Timber



Churkina, et al (2020)

Thank you

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