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Storing carbon in biochar

1. Presentation of a biochar methodology by Marianne Tikkanen, Head of Carbon Crediting Program, Puro.earth

2. Comment

- Berta Moya, Carbon Removal Sourcing and Methodology Development, Carbonfuture
- Hamed Sanei, Professor & Director of the Lithospheric Organic Carbon Laboratory, Aarhus University

3. Q&A session

Brussels 26 Oct 2023
EU CRCF Expert Group

Puro.earth

The world's leading crediting platform for engineered carbon removal

Marianne Tikkanen, co-founder and
Head of Carbon Crediting Program

Puro.earth’s Impact

The world’s leading crediting platform for industrial carbon removal

485 012

CORCs issued, first CORC credits issued in 2019

123€

Price index for ton CO2 removed (net)

100

to 1000 years durability of carbon in the storage

5

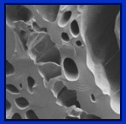
Puro Standard methodologies, first-mover for tech-based carbon removals

88

Projects registered

210 494

CORCs retired (B2B)



Biochar
Photosynthesis captures CO_2, pyrolysis stabilizes it, storage as a soil amendment

Carbonated Materials
Certain materials absorb CO_2 and mineralize it permanently

Geologically Stored Carbon BECCS DACCS
Atmospheric or biogenic CO_2 captured and injected to an authorized geologic cavity

Enhanced Rock Weathering
Minerals like basalt and olivine absorb CO_2 when crushed and spread on to fields

Terrestrial Storage of Biomass
Lignin containing biomass stored in either wet anoxic or very dry conditions

Puro Standard requirements

QUantification
Carbon removal activities are measured accurately and deliver unambiguous benefits for the climate

Long-term storage
Certificates clearly account for the duration of carbon storage and distinguish permanent storage from temporary storage

Sustainabil-ITY
Carbon removal activities must support sustainability objectives such as climate change mitigation and adaptation, biodiversity, circular economy, water and marine resources

Additionality
Carbon removal activities go beyond standard practices and what is legally required

Puro Standard requirements

Net-negative overall carbon footprint

Durable Storage for 100+ years

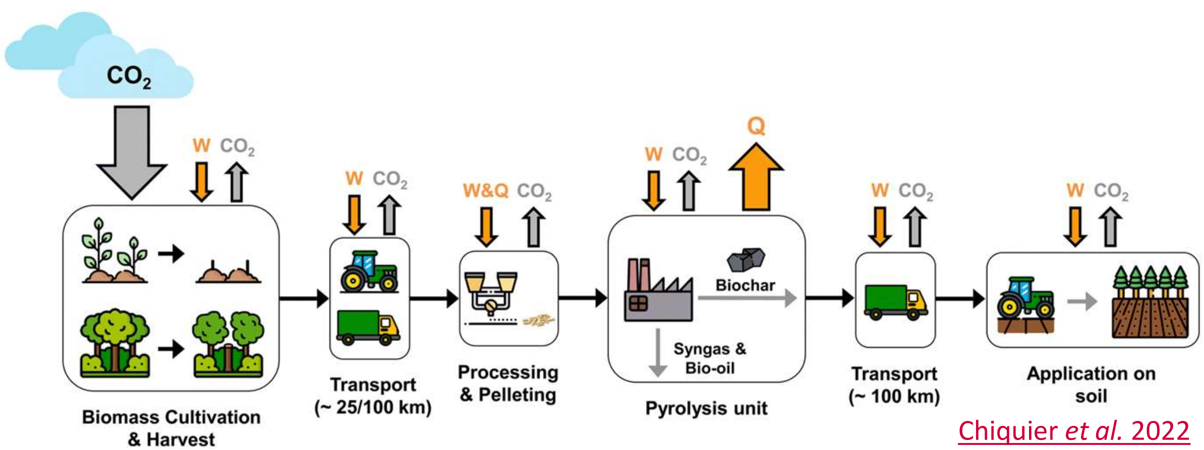
Environmental & Social **Safeguards**

Additionality result of carbon finance

Project specific* reporting and verification annually
*No blanket rules

Key requirements: Point of creation is the point of durable sequestration

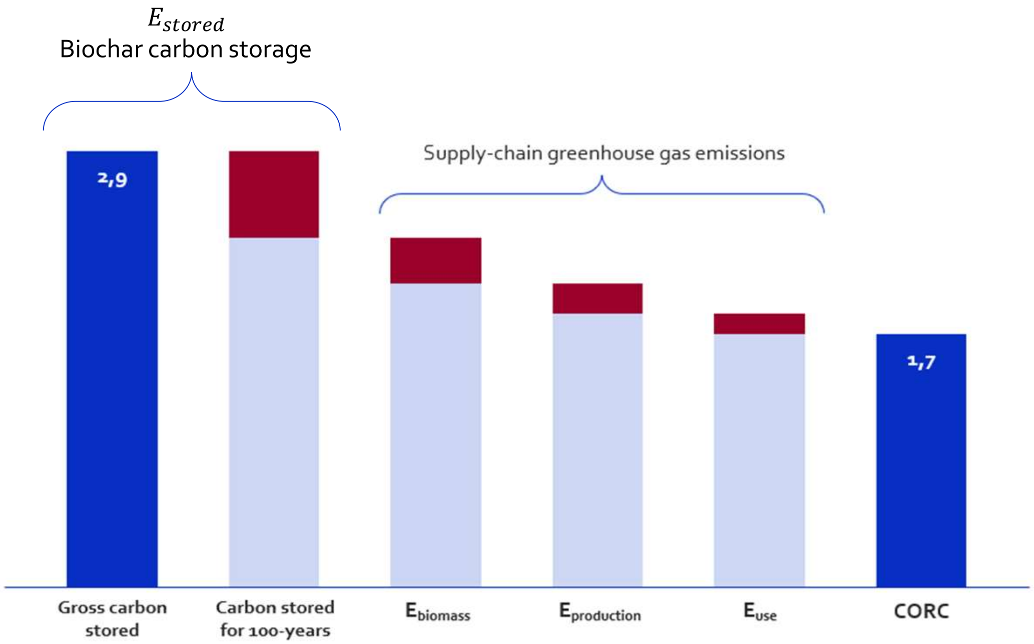
- CORCs are issued to the CO_2 *Removal Supplier.* They:
  - Must be authorized to represent the entire **end-to-end supply chain** of the storage activities.
  - Are responsible for following the rules of the methodology and making verification **data for all supply chain parties** available to the auditors.
- For CORCs to be issued:
  - Biochar must have been produced **and**
  - Biochar must have already been put to soil or mixed with a material where it can no longer be separated



Chiquier *et al.* 2022

CORC represents Net Carbon Removal – gross carbon stored minus emissions for the whole removal activity (tCO2-eq.)

$$CORCs = E_{stored} - E_{biomass} - E_{production} - E_{use}$$



For 1 tonne of biochar produced and used

Biochar carbon storage

$$E_{stored} = M \times DM \times C_{org} \times F_{perm}^{T_S, H/C} \times \frac{44}{12}$$

DM: Dry mass; C_{org}: Organic carbon %; $F_{perm}^{T_S, H/C}$: Permanence Factor %; $\frac{44}{12}$: Convert C to CO_2

$$F_{perm}^{T_S, H/C} = c_{T_S} - m_{T_S} \times H/C_{org}$$ (Woolf et al. 2021)

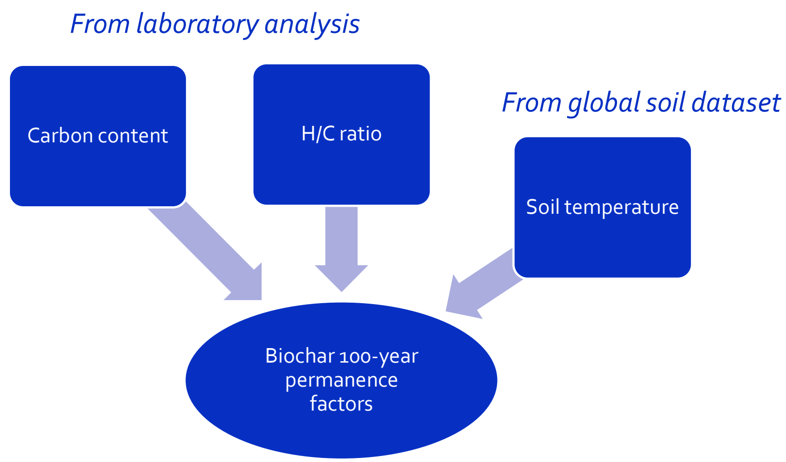
Supply-chain emissions derived from project specific LCA

- $E_{biomass}$ includes
  - All biomass production and transport emissions
  - If relevant, includes dLUC and/or energy leakage
- $E_{production}$ includes
  - All material, energy use, direct emissions
  - Factory infrastructure
- E_{use} includes
  - Material and energy use up to the point of biochar first mixing in eligible end-use matrix (soil, material, etc)

Biochar carbon storage – how much is stored for 100 years?

- Biochar carbon storage is closely monitored by frequently determining biochar carbon content and hydrogen-to-carbon ratio (H/C)
- H/C is a proxy indicator of the degree of carbonisation of the biochar, easy to measure and verify. It has been correlated to 100-year permanence fractions (Woolf *et al.* 2021)

- Woolf *et al.* 2021 research work was an update to IPCC's 2019 inventory guidelines for biochar, led by the same research group.
- Puro actively monitors developments in biochar durability science (e.g. Petersen *et al.* 2023, Rodrigues *et al.* 2023, Azzi *et al.* [in review]) for consideration in future methodology updates



Excerpt from laboratory analysis

Description	03006058
Date and time of sample taking	2019-10-25
Sample number	119151607

Parameter	Lab	Accr.	Method	LOQ	Unit		ar	db
Biochar properties								
Hydrogen	FR	JE02	DIN 51732: 2014-07	0.1	% (w/w)	-	0.7	1.0
Carbon	FR	JE02	DIN 51732: 2014-07	0.2	% (w/w)	-	69.9	93.6
Total nitrogen	FR	JE02	DIN 51732: 2014-07	0.05	% (w/w)	-	0.48	0.65
Oxygen	FR	JE02	DIN 51733: 2016-04		% (w/w)	-	2.0	2.6
Total inorganic carbon (TIC)	FR	JE02	DIN 51726: 2004-06	0.1	% (w/w)	-	0.2	0.3
carbonate-CO2	FR	JE02	DIN 51726: 2004-06	0.4	% (w/w)	-	0.8	1.1
carbon (organic)	FR	JE02	berechnet		% (w/w)	-	69.7	93.3
H/C ratio (molar)	FR	JE02	berechnet			-	0.13	0.13

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Risk of reversal/release and monitoring of re-emissions

Biochar is monitored closely during the project operation, and not post-closure because:

1. Expected re-emissions during 100-years are already deducted in the calculation of CORCs, using permanence factors from Woolf *et al.* 2021 and project-specific laboratory-determined biochar quality for the period.
2. Natural & human reversal risks are minimal once biochar is mixed into eligible application (e.g. soil, soil-product, material).
3. In-field monitoring of biochar decomposition would be incorrect (because of possible biochar vertical and lateral movements) and often not possible (because of technical challenges in distinguishing biochar carbon from soil carbon, outside of controlled scientific studies).

Environmental and Social safeguards

- To implement **environmental safeguards**, the CO_2 Removal Supplier must:
    - Assess environmental risks **in advance** of operations (via e.g. EIA, ERA) and implement measures to manage them.
    - Follow local environmental regulation for biochar end use. Measure and avoid contaminants in feedstock and biochar.
- To implement **social safeguards**, the CO_2 Removal Supplier must:
    - Demonstrate local stakeholder consultation and inform affected stakeholders. Can be part of building permit process
    - Ensure occupational health and safety. Avoid fire and dust risks for people handling biochar

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Sustainability

- Projects must comply with relevant environmental regulations, including air and water pollution limits
- Is biomass sustainably sourced?
  - Forest certifications accepted. Very often waste biomass, but not limited to waste biomass
  - Biomass eligibility is verified as part of annual audits. Record keeping of biomass used.
- What is the prior fate of biomass? Where is it away from? Electricity, biofuel, construction, biocoke?
  - If increase in fossil emissions is due to the project, such emissions will be accounted for and deducted
  - For purpose-grown biomass: all emissions of cultivation accounted (machinery use, fertilizer-related emissions, irrigation, soil disturbance)
- Biochar in soil has positive impact to soil health and biodiversity

Additionality – same requirements for all methods

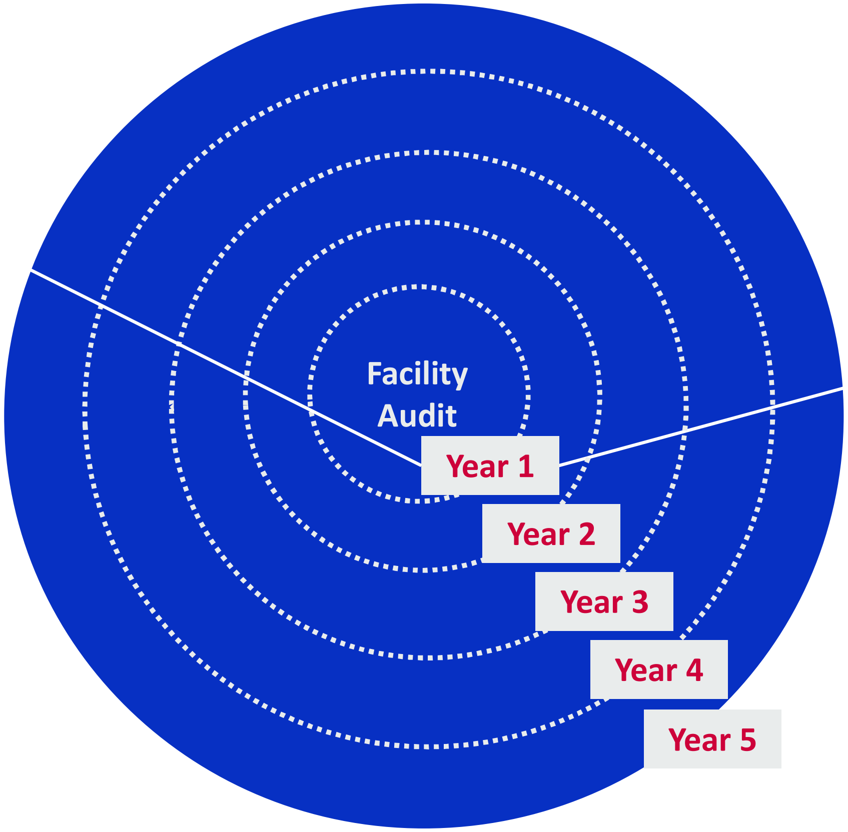
Re-assessed every 5 years

- **Natural**: Accounting only Carbon sequestrations on top of natural sequestration baseline
  - ➢ Biochar is not naturally formed, Engineering is always needed
- **Regulatory** additionality: not mandated by any laws
  - ➢ Biomass is not required to be made to biochar in any jurisdiction
- **Financial additionality**: The project must be dependent on carbon credit revenue to be viable
  - ➢ Every project will disclose to verification their revenues from different sources against the costs and investments and demonstrate that credit revenues for a significant part of the income and viability

Verification (MRV), Crediting period 5 years
All active suppliers are audited annually

Facility (site) audit
Every 5 years

- Carbon removing equipment and processes
- Full Life Cycle Assessment
- Baseline, Additionality
- Environmental permits
- Social impact
- Other Methodology requirements



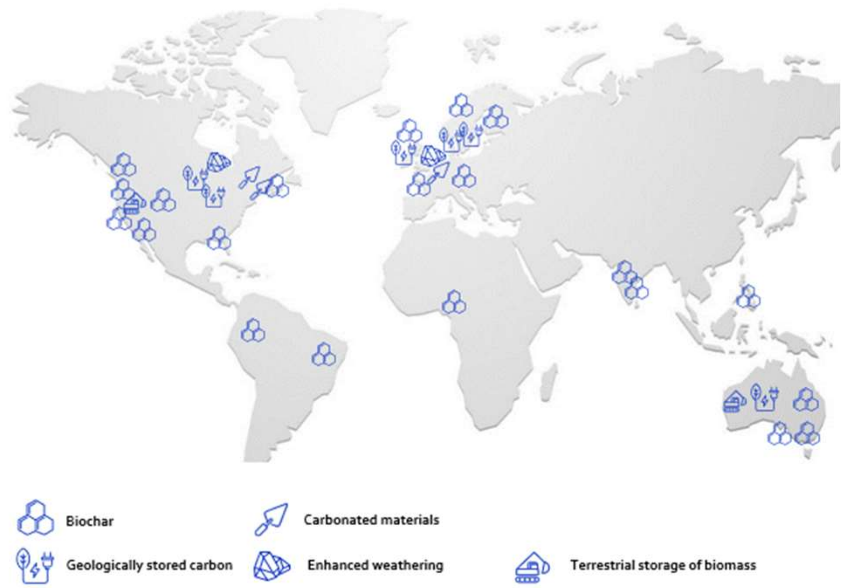
Output (production) audit
Every 1 year

- Volume of carbon removal
- Emissions
- Deliveries to application and final storage
- Lab results on material
- Calibration of metering devices

Practical examples of differences

Same rules have worked for a diversity of biochar projects on 5 continents

- **Feedstock**: forestry residues, straw, bagasse, husk, sewage,…
- **Scale**: 10 tn to 100 000 tonnes biochar per year
- **Carbon content**: 50% to 98%
- **H/C ratio**: 0.05 to 0.60 (eligibility limit 0.7)
- **Soil temperature**: 5°C to 35°C
- 100-year **permanence factor**: 56% to 99% remains at 100 years
- **Supply-chain emissions**: 50 to 700 kg CO_2-eq per tonne biochar
- **Net-negativity** (CORC factor): -3200 to -1700 kg CO_2-eq per tonne biochar(dry) (Theoretical maximum is -3600 kg/dry-tn)



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Thank you

puro.earth/methodologies

Appendix

Advisory Board

Experts who oversee Puro Standard's methodologies and crediting rules

Chairman: Professor Myles Allen

Myles Allen is Professor of Geosystem Science in the School of Geography and the Environment at the University of Oxford. He is Director of the Oxford Net Zero initiative, and credited with first demonstrating, 15 years ago, the need for 'Net Zero' carbon dioxide emissions to stop global warming. His research focuses on how human and natural influences on climate contribute to observed climate change and in quantifying their implications for long-range climate forecasts. Myles has served on the UN's Intergovernmental Panel on Climate Change (IPCC).

Secretary:
Grant McKelvey
Office of general Councel, Nasdaq

Nikki Batchelor
Director of the $100M XPRIZE for Carbon Removal

Todd Flach
Senior Advisor for carbon capture and storage (CCS) in The Bellona Foundation

Dr. Mai Bui
Over 10 years of research experience in carbon capture and storage technologies

Dr. Florian Kraxner
Principle Research Scholar at IIASA, with a focus on biodiversity and sustainability

Ali Mashayek
Associate professor of climate dynamics at the University of Cambridge

Quantification – how are CORCs calculated?

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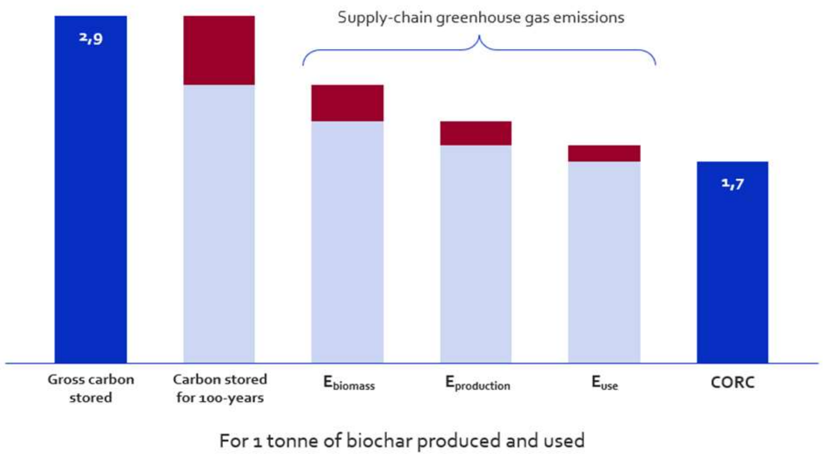
- Every project must perform a **project-specific LCA**, following the scope defined in the methodology and ISO 14064, 14044.
- LCA is both a **report** and a dynamic **calculation tool** that serves the project over its entire certification and issuance journey.
- Key factors for a high-quality LCA: **activity boundaries**, type of **emission factors**, completeness of **inventory**, **infrastructure** burdens, **verifiable input data.**
- Baseline & leakage: Emission avoidance relative to baseline is not included, leakage can be sanctioned
- Biochar permanence is a key part of quantification:
    - There's no way around **lab-determined carbon content**
    - **100-year permanence** based on Woolf et al. 2021, with soil temperature and biochar specific properties



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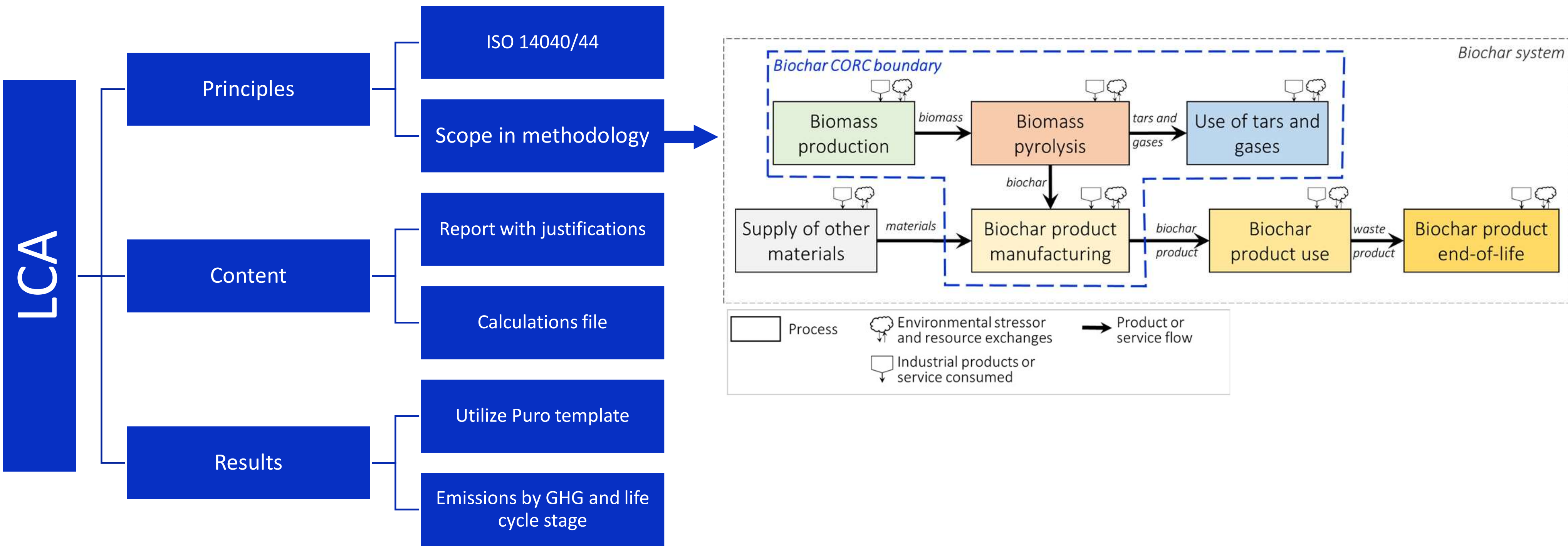
Key requirements: Life cycle assessment



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Biochar-specific topics to keep in view

- Multi-product and efficient processes: biochar AND syngas and oil (mostly converted to heat and power)
  - LCA: emissions are divided between multi-products according to energy content
  - Additionality: Carbon credits are not only income, but important income source
- Biochar – if done properly – has positive climate effects. The Puro methodology sets rules to achieve this:
  - Minimize methane emissions during production: requires sophisticated syngas control
  - Produce high-quality biochar: avoid contaminants in feedstock and biochar
  - Handle biochar safely: avoid fire and dust risks for people handling biochar
- Biochar is a CDR with multiple co-benefits and SDGs contributions, varying with diverse biochar end-uses:
  - Typical end use soil amendment, but also water filtration and construction materials coming
  - Batteries and biocoke (reductant) are good use on biochar, but not a long-term storage for carbon
  - Mixing biochar in concrete gives a long-term storage. We use same durability calculation as in soil.

Final verification step: third-party audit

Compliance to methodology requirements is assessed by an independent audit partner based on evidence (lab results, LCA, production volumes, etc.).

Auditor inspects the eligibility of the production and facility , verifies the quantification and issues an audit statement with reasonable assurance level.

The verified volume of carbon sequestered by the project is then issued as CO_2 Removal Certificates (CORCs) for every metric tonne of CO_2 removed and stored.

The principal is that the supplier pays for the cost of evidence to prove carbon net-negativity, and Puro.earth covers the cost of the audit.

Mineralisation - permanent storage in concrete

1. Presentation of a mineralisation methodology by Joana Vieira Duarte, Carbon Project Developer, Neustark

2. Comment

- Wijnand Stoefs, Policy Lead on Carbon Removals, Carbon Market Watch
- Xavier Guillot, Head of Product Certification and Standards, Holcim France and FastCarb

3. Q&A session

European Commission

neustark®

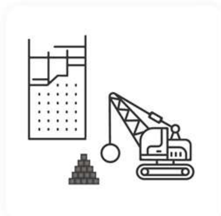
The neustark's CDR methodology

Expert Group - Industrial Removals EU-CRCF

Joana.vieiraduarte@neustark.com

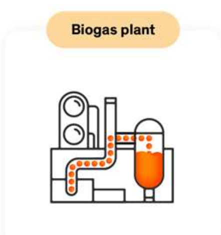
26 October 2023

How **neustark** removes CO_2



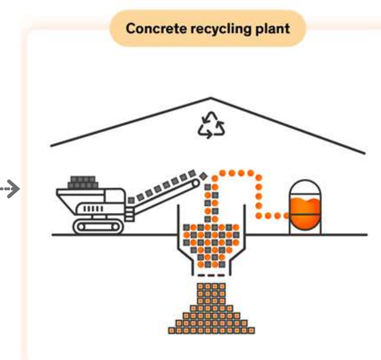
At the end of their life cycle, buildings are demolished…

…and the demolished concrete is transported, crushed and screened by a recycler



neustark captures CO_2, then liquefies…

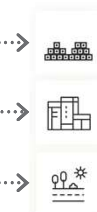
…and transports it to a concrete recycling plant



neustark's technology injects CO_2 into concrete granules, triggering a mineralization process that transforms the CO_2 into mineral

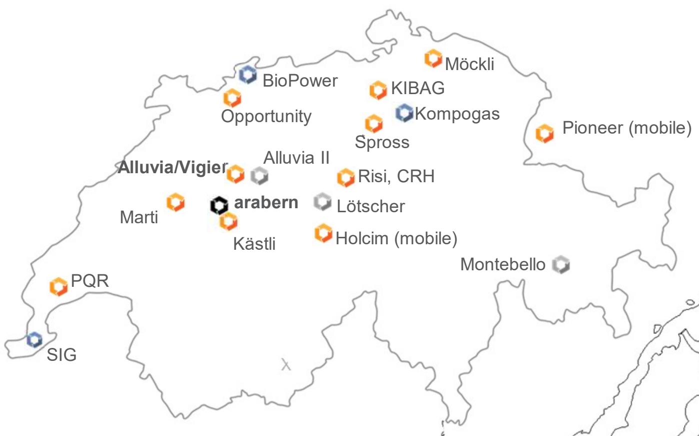
et voilà, the CO_2 is stored permanently

the recycler can use the CO_2 –enriched granules as per its usual process…



…to produce recycled concrete or other materials for building or roads

Status of **neustark** projects in Switzerland and EU



- CO_2 storage sites in operation
- CO_2 storage sites in construction
- CO_2 source sites in operation
- CO_2 source sites in construction

Applicability & Requirements

Follows the last version of the Gold Standard methodology: Carbon Sequestration Through Accelerated Carbonation of Concrete Aggregate

- **Accelerated mineralization by direct, indirect or slurry carbonation technologies**
- Mineral waste materials: <u>recycled concrete aggregate</u>, slags, ashes, mineral slurries
- CO_2 is collected from <u>existing biogenic sources or by DAC</u>: the sources and biogenic treatment processes shall be declared

- **Use cases:** To ensure permanency (> 10'000 years[2]) of stored CO_2, use cases that chemically or thermally compromise the stability of carbonate minerals are not allowed.

  e.g., carbonated material shall not be used to produce new clinker

  - End use declarations are signed by storage partners at each monitoring period

[2] Storage in minerals, *IPCC WG3 AR6 Chapter 12*

Baseline scenario

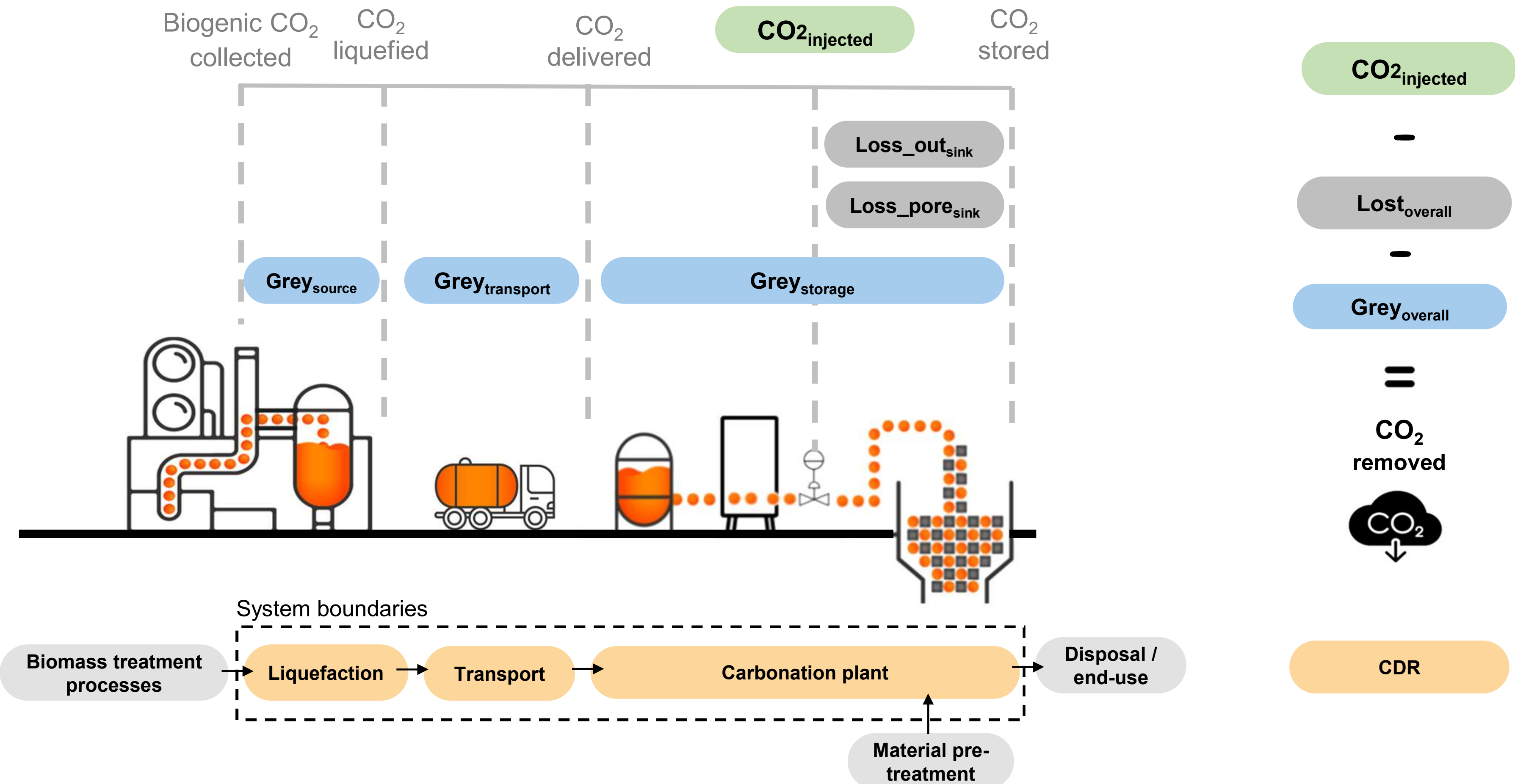
- Should consider the pre-existing activities along the CO_2 value chain: how biogenic CO_2 is produced and utilized & what happens to demolished concrete
- CDM Tool 02 “Combined tool to identify the baseline scenario and demonstrate additionality”

Biogenic CO_2 is produced from existing biomass treatment processes and released into the atmosphere as waste stream

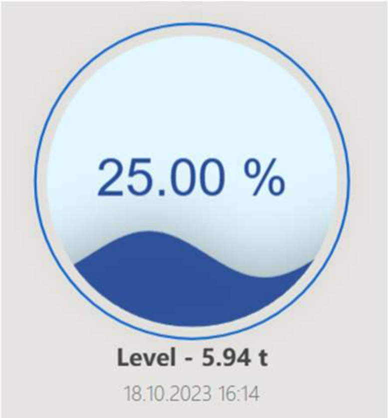
Mineral waste recyclers recover and process mineral waste for recycling and include it in secondary products (new concrete, filler material in road construction) or landfill

- Proportions vary at regional to country level

CO_2 value chain



MRV process



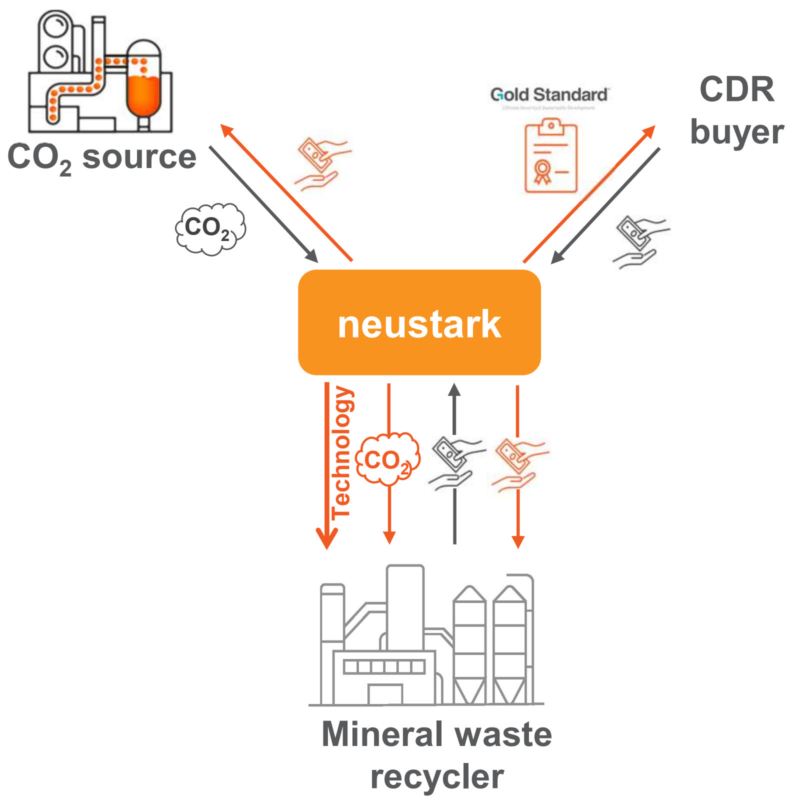
CO_2 level in the tank
Azure cloud system

- Responsibilities defined by contractual agreements with partners
- Real-time measurement of CO_2 flow, concentration and level in tank, and of power consumption (liquefaction and carbonation)
- Continuous or periodic reporting of material throughout
- Tracking transports and deliveries
- Other parameters to measure include density and bulk density, temperature, pressure.

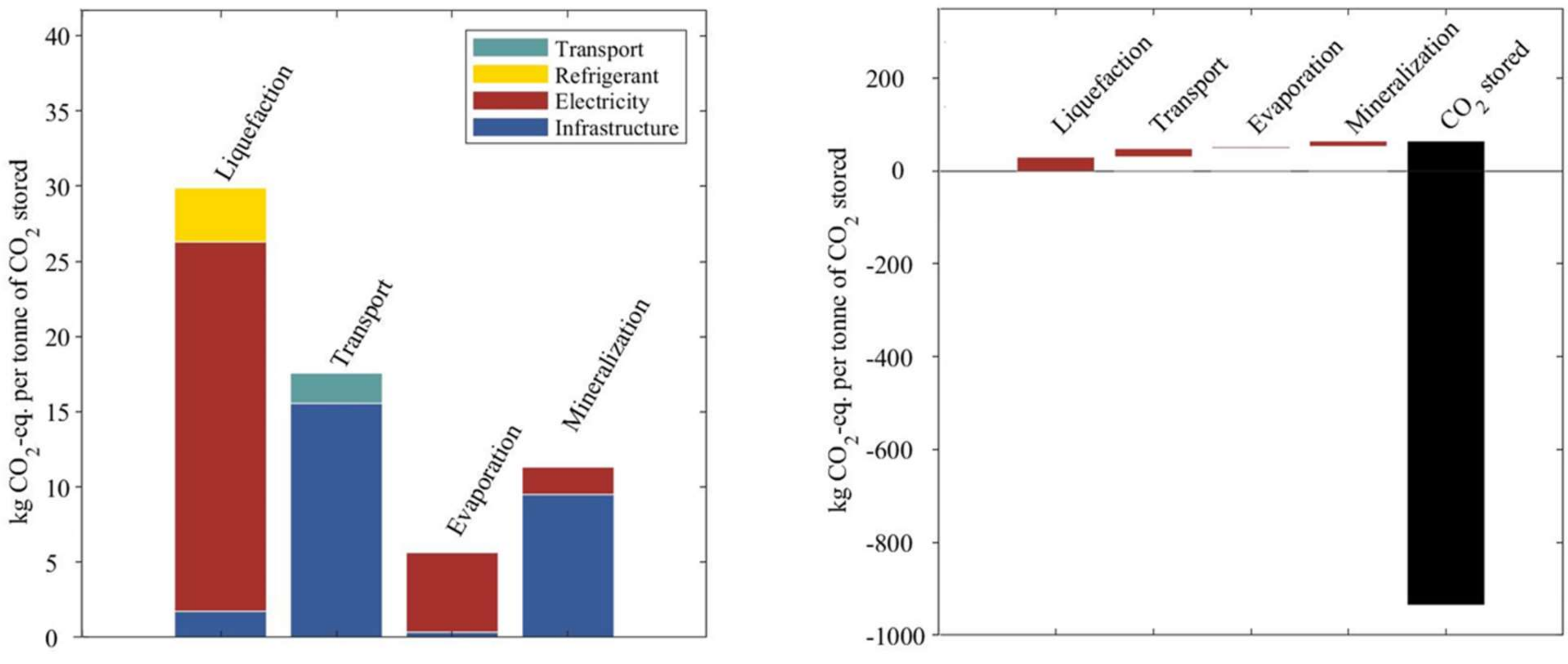
Our **goal** is to measure and record all monitoring data in real-time and store it in a cloud system, making it suitable for an automated MRV routine

Additionality criteria

- The project activity **is not required by any law or national/regional regulations**
- Perform an **additionality assessment for each project** individually at validation stage
- CDM Tool 02 *"Combined tool to identify the baseline scenario and demonstrate additionality", including:*
  - Barrier Analysis
  - **Simple cost analysis**: should consider the main cash-flows predicted/ incurred for the implementation of the project
  - Common Practice Analysis



neustark removal efficiency is ca. 80-94%



Source: Johannes Tiefenthaler et al. "Technological Demonstration and life cycle assessment of a negative emission value chain in the Swiss concrete sector". In: Frontiers in Climate 3 (2021). doi: 10.3389/fclim.2021.729259.

Thank you

Joana.vieiraduarte@neustark.com

Biogenic carbon storage in buildings

1. Presentation of the survey results on methodologies for long-lasting biogenic carbon storage in buildings by Jannes Nelissen, Partners for Innovation

2. Panel

- Bunthan Iea, Project manager for Building environmental performance, French Ministries of Ecology, Energy and Territory
- Sacha Brons, Head of Construction Stored Carbon, Climate Cleanup Foundation
- Frank Vasek, Head of Carbon Solutions, Timber Finance
- Kelsey Perlman, European Forest Campaigner, FERN

Moderated by Sevim Aktas, Policy Officer DG CLIMA

3. Q&A session

Long-term biogenic carbon storage in buildings

Findings from the analysis of calculation and certification methodologies

Jannes Nelissen | Partners for Innovation

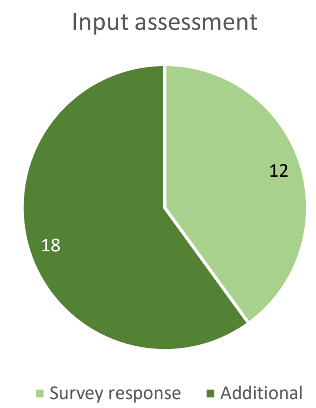
3rd Carbon Removal Expert Group meeting | Brussels 26-10-2023

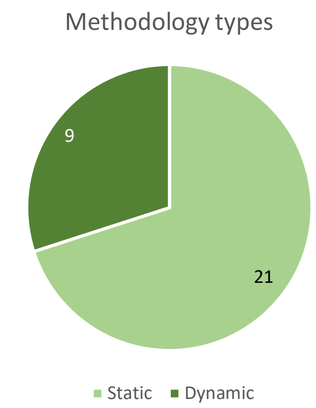
Content

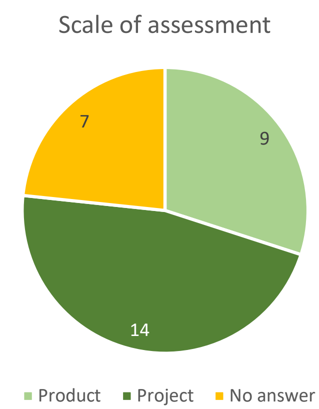
1. Survey results & analysis input
2. Quantification
3. Additionality
4. Long-term storage
5. Sustainability

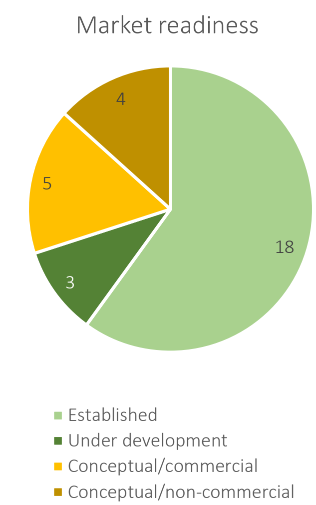
Survey results & analysis input

- 30 methodologies analysed
- 40% submitted through survey
  - Good examples or best practices according to methodology operators and economic operators
- 30% dynamic LCA
  - To assess how to include benefit of delayed emissions in quantification
- 60% established methodologies
  - Market-tested methodologies for practicality and adoption by industry
- 47% Project-level assessments
  - The aim is to create project-level certification









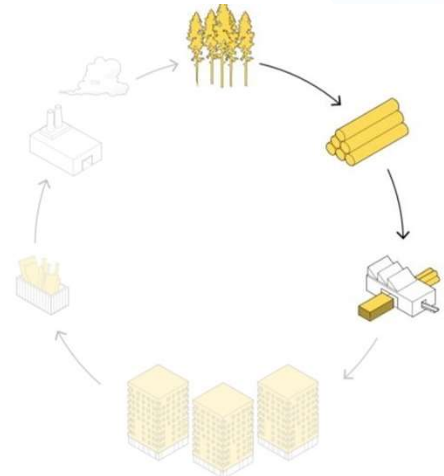
Quantification

Goals of the proposed regulation summarised:
- The quantification shall be relevant, accurate, complete, consistent, comparable, and transparent
- A standardised baseline shall be used to quantify additionality
- Uncertainties shall be accounted for in the quantification

- Complete & relevant: Scope commonly included sequestration of the CO_2 and emissions from production of construction elements
- When EoL is taken into account, immediate release as CO_2 is assumed
- Consistent, comparable, and transparent: Generally the same approach for amount of stored carbon:

$$Stored\ carbon = V * \rho * CC * \frac{44}{12}$$

- Dynamic methodologies include benefits of delayed emissions more complete and accurate but might be less transparent.



Quantification – Main findings

- Most methodologies **focus on stored carbon**, some report embodied carbon separately, few combine them.
- **Uncertainties** commonly not considered. Still some good examples are available.
- ~35% use a **baseline**. Two methodologies had a defined frequency for updates to the baseline.

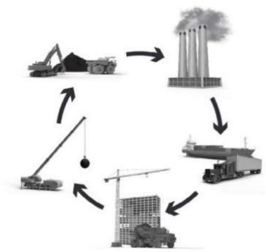


Image courtesy of ThinkWood

Quantification – open questions

- Which lifecycle stages should be included in the scope of the calculation?
- How can a standardised baseline on building level be established with minimal administrative complexity?
- When determining the baseline, is there a need to distinguish the types of buildings in a representative region?
- At what intervals should the baseline be updated?
- How can existing databases be used to determine $GHG_{increase}$ and $GHG_{baseline}$?

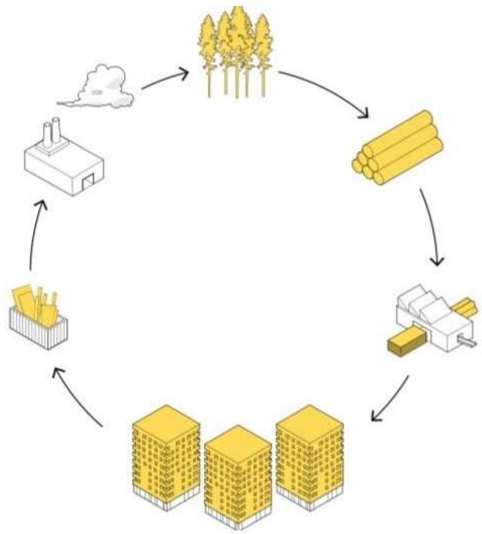


Image courtesy of Cleantech.com

Additionality

Goals of the proposed regulation summarised:

- The certified carbon storage shall be additional, going beyond statutory requirements and is incentivised or made possible by the certification.

Main findings

- Additionality is commonly taken into account in eligibility rules of the certification methodologies.
  - Both regulatory and financial additionality
  - Justification of the additionality is more common than its quantification
- Both new build and renovations can be eligible, as long as additionality is proven

Long-term storage

Goals of the proposed regulation summarised:

- The operator must proof that the carbon will be stored for the long-term
- The operator shall monitor and mitigate accidental early release of the carbon, and liability mechanisms are in place

Main findings

- Certification validity is commonly limited to a reporting period or (expected) lifespan of a building. Timely limited certificates are uncommon
- 50% of the analysed certification methodologies set requirements on monitoring
- Liability clauses are uncommon

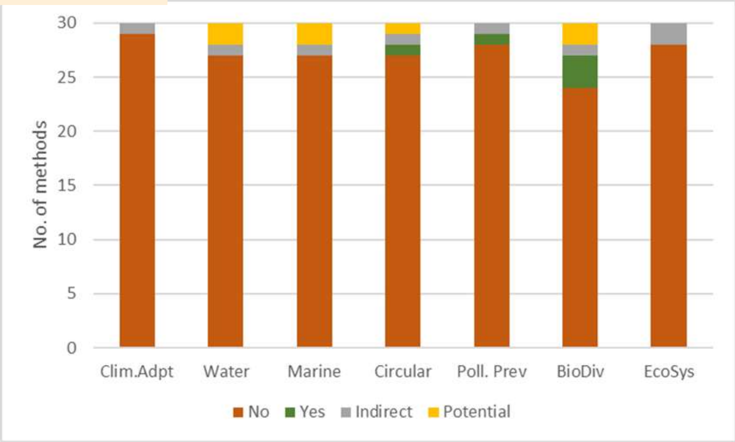
Open Questions

- What monitoring frequency should be required and could this be integrated with the existing building inspection routines?
- What is the likelihood of unforeseen carbon release and how can this risk be mitigated?

Sustainability

Goals of the proposed regulation summarised:

- The storage activity should ensure a neutral impact on or generate co-benefits for other (specified) sustainability objectives



Main findings

- For wood, certification of responsible sourcing (e.g. PEFC or FSC) is commonly used as an eligibility requirement
- Other sustainability objectives are commonly not incorporated
- Recycling and reuse of have been incorporated by two methodologies

Open questions

- Which sustainability requirements should be mandatory, and how should they be defined?
- Are current certifications for sustainably harvested wood adequate?
- How can the creation of co-benefits be stimulated?
    - Specifically, how can sufficiency, circularity, and cascading use be stimulated as co-benefits?

PANEL & Q&A:
IMPROVING MRV OF EMERGING METHODOLOGIES

Enhanced Weathering

1. Panel

- Freya Chay, Programme Lead, Carbon Plan
- Sophie Gill, Carbon Removal Scientist, Isometric
- Simon Manley, Head of Carbon, UNDO

Moderated by Andrea Klaric, Policy Officer DG CLIMA

2. Q&A session

European Commission