Negative Emission Transition Adviesbureau NET

BIOCHAR IN GEOPOLYMER

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Consultancy - **Adviesbureau NET**

3D concrete printing - **Silklines BV**

Biochar - **CarStorCon GmbH**

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Disclaimer

- Geopolymers are not alkali activated materials (AAM).
- Literature studies mostly discuss alkali-activated/biochar composites, not ‘pure’ geopolymer/biochar materials. Yet, most articles we found refer to their research as ‘biochar in geopolymers’.
- This inconsistency in the academic community is apparent in the literature study we’ve preformed.
- In the summary we will address this topic further for future research.

Overview

- What is Biochar
- How is it made
- Life Cycle of Biochar
- Biochar in concrete: CO_2 footprint reduction
- Literature study for biochar in geopolymer
- Summary: future research & cooperation

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What is Biochar?

- Small carbon particles < 8mm
- Higher purity than charcoal
- Residue from pyrolysis of biomass
- 75% CO_2 biomass stored in biochar
- Highly efficient Carbon-sink

How is Biochar made

- **Biomass** from wood production residues.
  No trees are cut for biochar!
- **Pyrolysis** – Deoxygenated thermal decomposition at high temperature >800°C.
- Resulting Biochar is 85-95% **pure carbon**.
  No cellulose hydrocarbons remaining.
- By EU-regulation pure Biochar is considered a **Carbon-sink**, generating *Carbon credits*.

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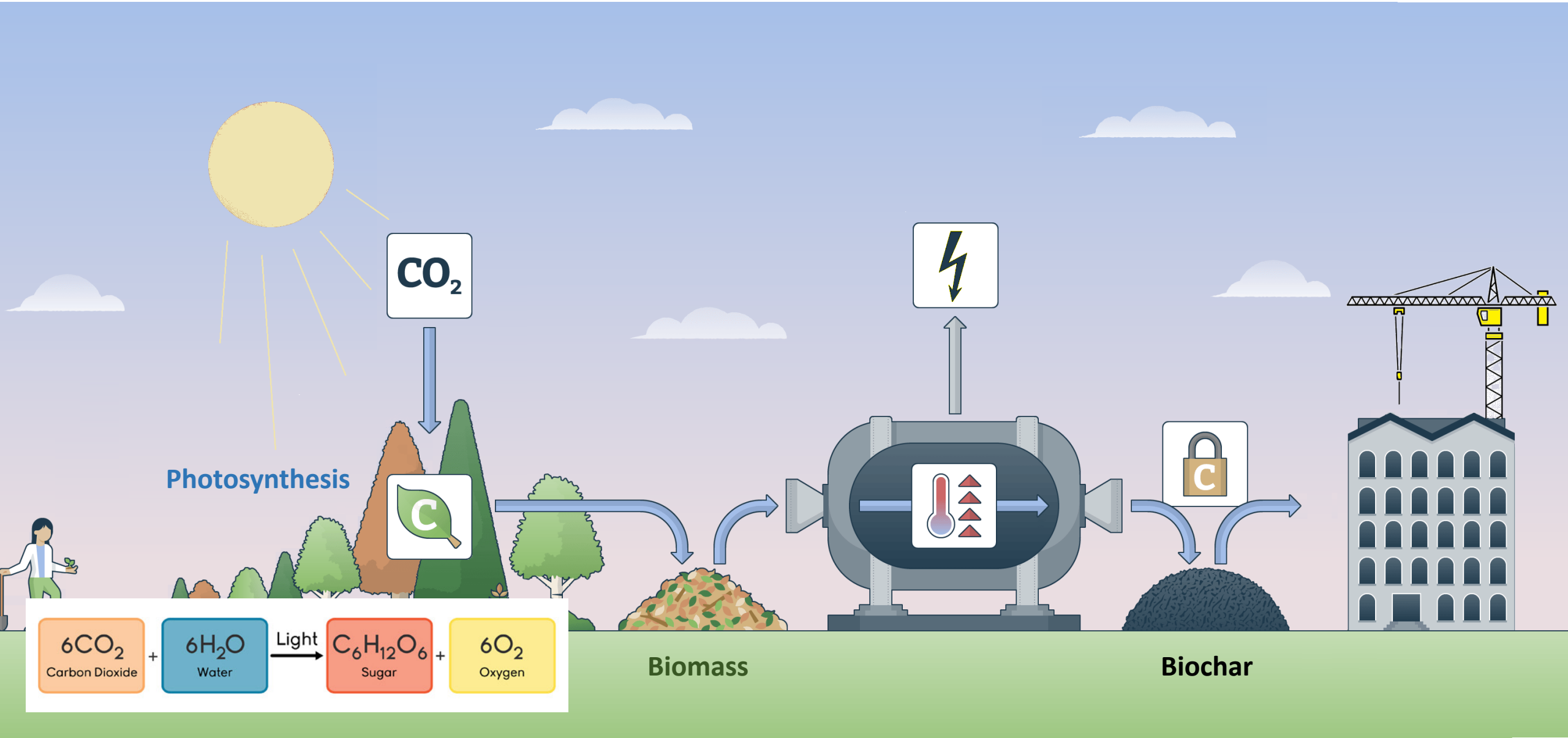
From Biomass to Biochar…



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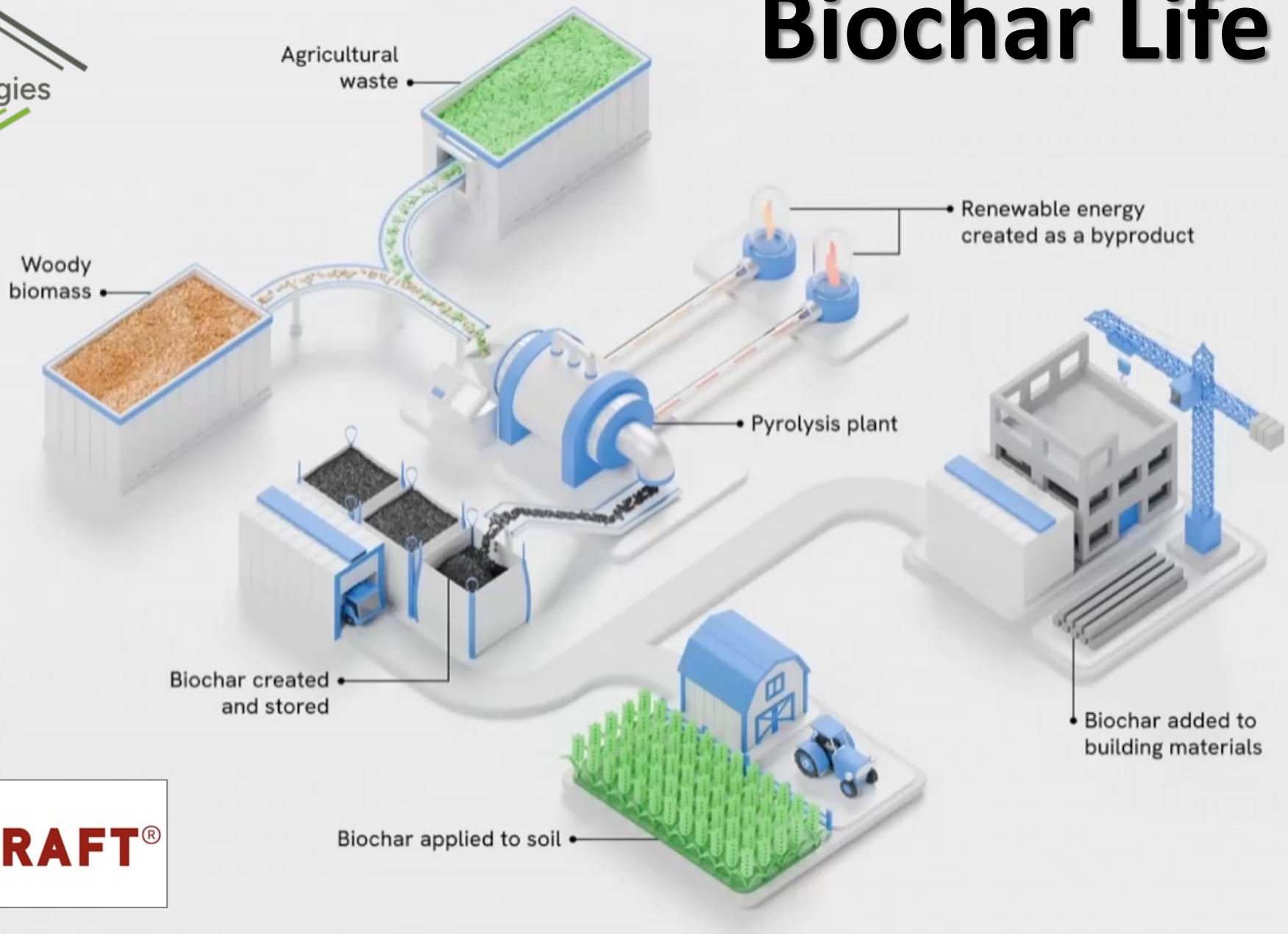
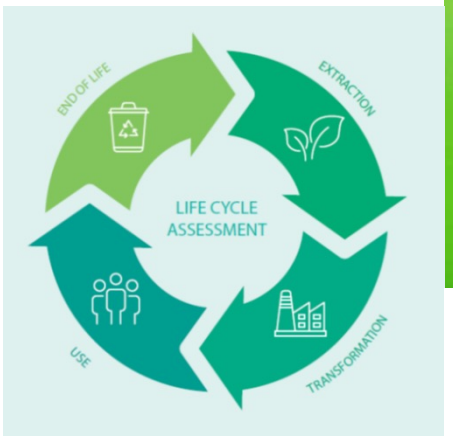
Biochar Life Cycle



SYNCRAFT®
Das Holzkraftwerk.

Biochar Registration

- Life Cycle Analysis



- Enviromental Product Declaration

EPD®

THE INTERNATIONAL EPD® SYSTEM

- Registration at EBI

EBI European Biochar Industry

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Biochar in concrete:
The ultimate CO2
footprint reduction
0 kg/m³
GEOPOLYMER!
<0 kg/m³

Footprint calculation

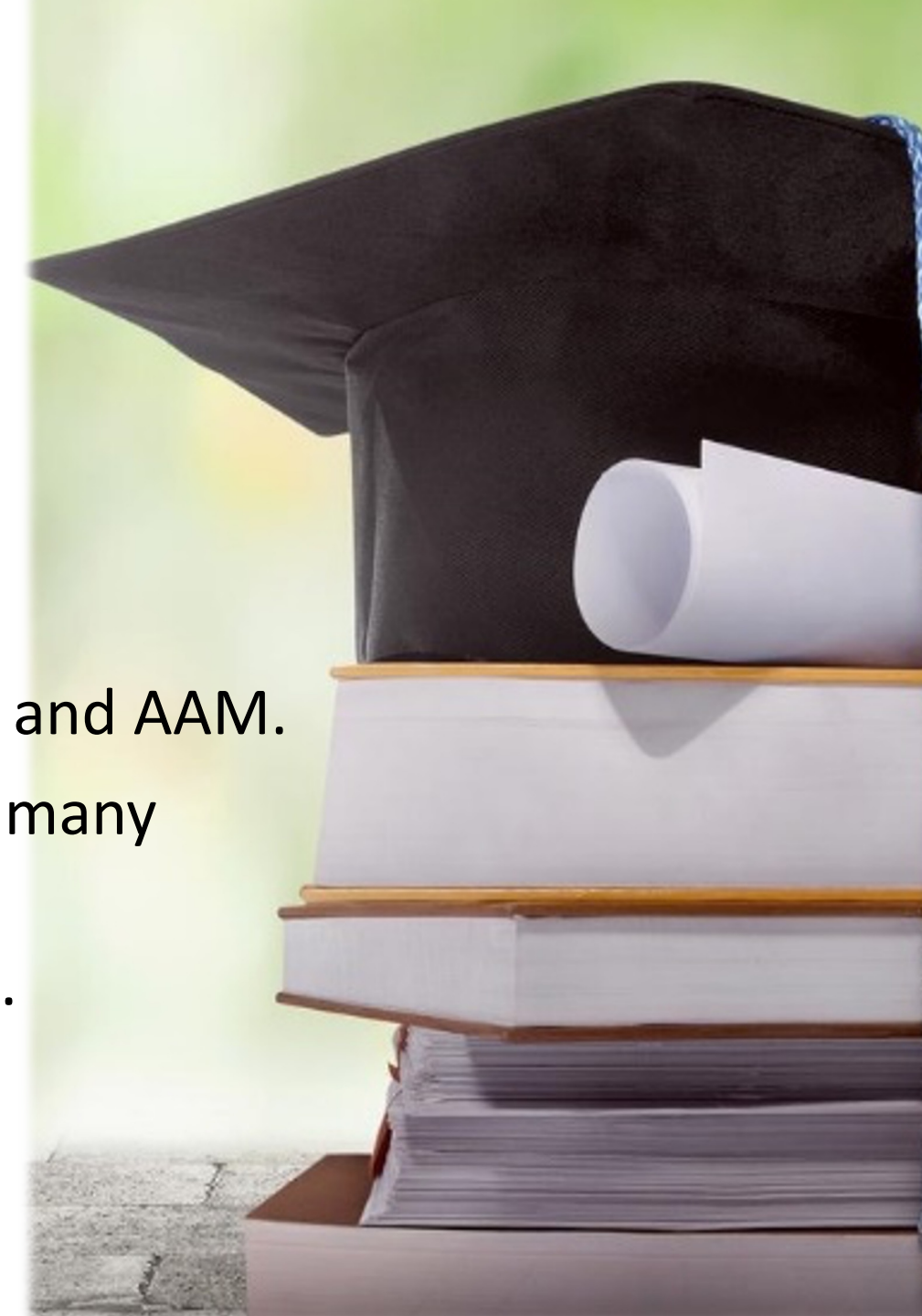
Traditional Dutch concrete: ~190 kg CO_2/m^3

Biochar: -2,75 kg CO_2 per kg
1% Biochar ≈ 23 kg x -2,75 = -63 kg/m^3
2% Biochar ≈ 46 kg x -2,75 = -127 kg/m^3
3% Biochar ≈ 69 kg x -2,75 = -190 kg/m^3

GEOPOLYMER: ~90 kg CO_2/m^3

Literature study for biochar in geopolymer

- Reviewed 32 articles between 2015 and 2025. We expect there to be many more.
- Most do not differentiate between geopolymer and AAM.
- Scientific interest in this topic is large, however many articles refer to others who did the testing.
- Absolute number of tests is therefore unknown.
- Test we found are basically all AAM.



Conclusions from literature (1)

- Mechanical properties
- Workability and curing
- Durability properties
- Variability and knowledge gaps
- Sustainability and environmental impact

Conclusions from literature (2)

- **Mechanical properties:**
  Several studies show that the addition of biochar (at doses up to approximately 5% by weight) can improve the compressive strength and splitting tensile strength of geopolymer concrete. This is attributed to:
  • The porous structure of biochar, which has a micro-filling effect.
  • Better adhesion between the matrix and the fillers. However, at higher doses (>5–10%), strength often deteriorates due to increased porosity and poor dispersion.
  Sources: Ahmad et al., 2020; Singh & Mandal, 2021; Zhang et al., 2023.
- **Workability and curing:**
  Biochar has a strong water absorption capacity, which often negatively affects the workability of concrete mixtures. In addition, biochar influences the curing kinetics of the mixture. Measures are needed such as:
  • Adjusting the water/binder ratio.
  • Application of superplasticizers.
  Sources: Zhang & Provis, 2017; Chen et al., 2020.

Conclusions from literature (3)

- **Durability properties:**
  When used correctly, biochar can make geopolymer concrete more resistant to:
  • Water penetration and freeze/thaw cycles.
  • Chloride penetration
  • Acidic environment
  These properties are beneficial for applications in aggressive environments.
  Sources: Al-Shukaili et al., 2021; Ranjbar & Kuenzel, 2018.
- **Variability and knowledge gaps:**
  The performance of biochar in geopolymer concrete is highly dependent on the type of biochar (feedstock, pyrolysis temperature, etc.). This makes it difficult to establish generic guidelines without thorough characterization. In addition, there are knowledge gaps in the areas of:
  • Long-term performance
  • Scale-up to industrial applications
  • Cost-benefit analysis
  Sources: Zhao et al., 2020; Ahmed et al., 2024.

Conclusions from literature (4)

Sustainability and environmental impact:
Biochar contributes to:

- Carbon sequestration
- Reduction of the CO_2 footprint of geopolymer concrete.
- Reuse of organic waste through valorization.

This makes biochar geopolymer concrete very suitable for circular construction strategies.

Sources: Tan et al., 2019; Yu et al., 2022.

Preliminary testing

Labtesting:

- AAM‘s and GP‘s
  - Clim@Add Biochar (1-3% by weight)
  - Flyash from recycling furnace
  - Agricem Calcinated Clay
  - Ecocem GGBS
  - 0-4 riversand
  - 4-16 rivergravel
  - NaOH, KOH
  - Geosil 34417, Geosil 14517
  - Prisms and 5 cm cubes
- Compressive strength: low
- Flow: not enough (at 3%)

Summary

- **Technical innovations:**
  Mechanical properties, workability, durability.
- **Environmental acceptance for biochar:**
  LCA and EPD.
- **Traditional concrete industry is using biochar in practice.**

  This is good, but footprint is now much lower than GP and AAM.
- **Pure Geopolymer / Biochar composite:** Work in progress

Thank you for you attention!