EMBODIED CARBON IN THE BUILT ENVIRONMENT:
SESSION 1 – INSULATION MATERIALS
March 22, 2019
Network Overview

Communication and knowledge building platform

440+ members from industry, nonprofits, governments, academia

Common mission to phase out emissions from buildings and construction materials
10 Focus Groups

Academic | Buildings | Construction | LCA Data/Tools | Materials

Nodo Hispano | Outreach | Policy | Renewables | Reuse
CARBON LEADERSHIP FORUM
Advancing low carbon construction through research, education and outreach

DIAMOND

GOLD

SILVER

SUPPORTERS

Embodied Carbon Network 2019 Webinar Series
Series Overview

Measuring and reducing carbon emissions attributed to building materials

- Six online sessions (2019)
- Subject matter experts from ECN focus groups
- AIA Continuing Education Credits
Webinar Series Disclaimer

This session is provided as part of the Embodied Carbon Network 2019 Webinar Series. We invite guest speakers to share their knowledge and insight on topics related to carbon emissions attributed to building materials. The series aims to introduce topics that lead participants to think and talk about building industry strategies for reducing carbon emissions.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use. Please note the opinions, ideas, or data presented by speakers in this series do not represent members of the Embodied Carbon Network or constitute endorsement by the Network.
• 15-minute Q & A session after presentations

• To receive AIA continuing education credit send your AIA member number to info@embodiedcarbonnetwork.org

• To access past webinar recordings, visit: www.embodiedcarbonnetwork.org/resources

• Save the Date! Upcoming webinar: Policy, May 17 at 9am PST
Webinar Overview

A study of embodied carbon and potential carbon storage in materials

Chris Magwood
Executive Director
Endeavour Centre

Insulating with hemp

Pamela Bosch
Founder
Highland Hemphouse

Stone wool insulation overview
application and impact

Christian Kofod
Sustainability Manager
ROCKWOOL & Rockfon

Embodied Carbon Network
ECN presentation
March 2019
World leader in Stone Wool insulation with a local presence

We create solutions to protect life, assets, and the environment today and tomorrow.
Your choice of insulation

Technical insulation solutions for process industry, marine and offshore
- Reduces heat loss and CO₂ emissions for industrial insulation
- It has a positive carbon footprint

Firesafe insulation for all types of buildings including ROCKWOOL wall systems
- 97% of stone wool can be recycled after use
- It does not burn or emit high levels of toxic smoke in a fire
- Provides firefighters critical extra time to save lives by slowing the spread of fire
- Durable and resilient
- Easy to fit and retrofit
- It has a positive carbon footprint

Core solutions Customised stone wool solutions to industrial partners
- It does not burn or emit high levels of toxic smoke in a fire
- Makes air-conditioning less noisy
More stone wool secrets unveiled

- Special fibres for e.g. automotive brakes
  - Securing your vehicle can come to a stop
  - Fully sustainable products throughout their life

- Precision growing for the horticultural industry
  - Support sustainable production of fresh and healthy vegetables
  - Multiplies yields and saves water

- Exterior cladding for buildings
  - Durable and resilient
  - Easy to fit and retrofit

- Acoustic ceiling and wall solutions
  - Reduces noise and echoes
  - Creates a comfortable indoor climate
ROCKWOOL products can be either flexible or rigid, they can deliver a full scale of solutions to match your needs.
Ecofys, a Navigant company, developed methodologies to calculate the energy and CO₂ savings in the lifetime of sold building insulation and technical insulation products. Ecofys endorsed that the 2017 energy savings calculated by ROCKWOOL correctly follow these methodologies. The methodologies are available on www.rockwoolgroup.com/carbon-impact.
We are in for the long-term

The thermal performance of ROCKWOOL stone wool remains unaltered for more than 55 years.

Thermal conductivity [W/mK]

- Gentofte/roof between rafters, 1956
- Neuburg/roof, 1984
- Roskilde/facade, 1990
- Alythus/facade, 1990

© ROCKWOOL International A/S
An ally to tackle important water issues

At ROCKWOOL we engineer stone wool with two distinct water capabilities.

- We can create products with water repellent properties that can keep you dry and protect you from humidity.
- Or alternatively offer you a wide range of solutions that can absorb, store, transport and release water in the most optimal way.

<table>
<thead>
<tr>
<th>Material</th>
<th>Absorption Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCKWOOL</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Gravel</td>
<td>38%</td>
</tr>
<tr>
<td>Lava</td>
<td>40%</td>
</tr>
<tr>
<td>ROCKWOOL</td>
<td>95%</td>
</tr>
</tbody>
</table>

ROCKWOOL stone wool can be engineered to absorb up to 95% of its volume in water.
This is our process
Circularity – the shape of the future

By recycling our own and other industries’ waste, we minimise the waste going to landfill and reduce our use of virgin raw materials.

And by making it easy for our customers to dismantle and recycle our products at the end of their useful life, we are taking part in the shift to a circular economy.
Main embodied carbon is emitted during production

<table>
<thead>
<tr>
<th>PRODUCT STAGE</th>
<th>CONSTRUCTION PROCESS STAGE</th>
<th>USE STAGE</th>
<th>END OF LIFE STAGE</th>
<th>BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Raw material supply</td>
<td>A2 Transport</td>
<td>A3 Manufacturing</td>
<td>A4 Transport from gate to site</td>
<td>A5 Assembly/install</td>
</tr>
<tr>
<td>EPD Type</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**GWP**

NAIMA EPD 2018

- **Light density**
- **Heavy density**
ROCKWOOL works with a Global approach

ROCKWOOL Group
Denmark

National listings w/o Mutual recognition

IBU
Germany

Mutual recognition

BRE
UK

ICMQ
Italy

UL
NA

The International EPD system
Sweden

EPD Norge
Norway

3rd party verifiers

Mutual recognition

IBU
Germany

The International EPD system
Sweden

National listings w/o Mutual recognition

IBU
Germany

3rd party verifiers

Mutual recognition

IBU
Germany

The International EPD system
Sweden

3rd party verifiers

Mutual recognition

IBU
Germany

The International EPD system
Sweden

3rd party verifiers

Mutual recognition
ROCKWOOL is “trying” to keep it simple and keeping it product specific weighted averages

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Scaling compared to reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAFE’n’SOUND</td>
<td>1.0</td>
</tr>
<tr>
<td>AFB</td>
<td>1.0</td>
</tr>
<tr>
<td>AFB evo</td>
<td>0.9</td>
</tr>
<tr>
<td>CAVITYROCK</td>
<td>1.6</td>
</tr>
<tr>
<td>COMFORTBATT R10</td>
<td>0.9</td>
</tr>
<tr>
<td>COMFORTBATT R14</td>
<td>0.9</td>
</tr>
<tr>
<td>COMFORTBATT R15</td>
<td>1.0</td>
</tr>
<tr>
<td>COMFORTBATT R22</td>
<td>0.9</td>
</tr>
<tr>
<td>COMFORTBATT R22.5</td>
<td>0.9</td>
</tr>
<tr>
<td>COMFORTBATT R23</td>
<td>1.1</td>
</tr>
<tr>
<td>COMFORTBATT R24</td>
<td>1.3</td>
</tr>
<tr>
<td>COMFORTBATT R24</td>
<td>0.9</td>
</tr>
<tr>
<td>COMFORTBATT R28</td>
<td>0.9</td>
</tr>
<tr>
<td>COMFORTBATT R30</td>
<td>0.9</td>
</tr>
<tr>
<td>COMFORTBATT R32</td>
<td>0.9</td>
</tr>
<tr>
<td>COMFORTBOARD 110</td>
<td>4.3</td>
</tr>
<tr>
<td>COMFORTBOARD 80</td>
<td>3.1</td>
</tr>
<tr>
<td>CONROCK</td>
<td>3.2</td>
</tr>
<tr>
<td>CONROCK 60</td>
<td>2.2</td>
</tr>
<tr>
<td>CURTAINROCK</td>
<td>1.3</td>
</tr>
<tr>
<td>CURTAINROCK 40</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Making it easy for customers to find all relevant information

Certifications and Listings
Buildings affect many important aspects of human existence.

Buildings affect many important aspects of human existence.

We spend roughly 90% of our lives indoors so the quality of the buildings contributes significantly to our health, our wellbeing and our productivity - at work and at home.

All ROCKWOOL stone wool insulation products are manufactured to meet and exceed quality, safety, sustainability and performance standards.

Learn about some of the key certifications and listings ROCKWOOL has.
Beware of comparing materials alone

- Insulation materials are always part of a system and should be compared in-situ
- And are inherently different:
  - Fire resiliency (stone wool melts at 2150 F)
  - Durability (microorganisms, sagging, R value)
  - Chemical footprint (binders, flame retardants, biocides, fungicides)
  - Vapour diffusitivity

Examples of Intended Use for Insulation products
- Interior walls
- Basement walls
- Exterior cavity walls
- Exterior rainscreen
- Exterior curtainwall
- Exterior metal buildings
- Firestopping/interior
- Exterior roofing

Davin Arkin, Arkin Tilt Architects
Do the numbers support using Embodied carbon as a selection tool yet?

<table>
<thead>
<tr>
<th>Kg CO2 eqv/ton material</th>
<th>Cement</th>
<th>Concrete</th>
<th>Masonry (LB)</th>
<th>Steel</th>
<th>Steel (recycled)</th>
<th>Timber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>195</td>
<td>33</td>
<td>74</td>
<td>1340</td>
<td>160</td>
<td>200</td>
</tr>
<tr>
<td>Max</td>
<td>1050</td>
<td>295</td>
<td>550</td>
<td>3808</td>
<td>1670</td>
<td>720</td>
</tr>
<tr>
<td>Difference</td>
<td>854</td>
<td>262</td>
<td>476</td>
<td>2468</td>
<td>1510</td>
<td>520</td>
</tr>
</tbody>
</table>

- Is the product with the lowest value: 
  - truly "best in class" or
  - simply calculated "smarter"

- Do users have the time to look into the EPDs and understand differences between results?

- How do we calculate the average and how does that impact industry average?
  - Weighted average
  - Simple average

Scrutinising embodied carbon in buildings: The next performance made manifest
Francesco Pomponi, Alice Moncaster

Comparability: EPDs from different programs may not be comparable. Full conformance with a PCR allows EPD comparability only when all stages of a life cycle have been considered. However, variations and deviations are possible. Example of variations: Different LCA software and background LCI datasets may lead to differences results for upstream or downstream of the life cycle stages declared.
Comparison of type III insulation EPDs

<table>
<thead>
<tr>
<th>Standards complement</th>
<th>Insulation EPDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction w incomplete information per ISO 14025</td>
<td>10/12 (83%)</td>
</tr>
<tr>
<td>Missing required information</td>
<td>7/12 (58%)</td>
</tr>
<tr>
<td>Incomplete system boundary definitions</td>
<td>10/12 (83%)</td>
</tr>
<tr>
<td>Incomplete impact factor information</td>
<td>4/12 (33%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>Insulation EPDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total comparisons</td>
<td>66</td>
</tr>
<tr>
<td>Valid comparisons</td>
<td>Same PCR: 2 (3%)</td>
</tr>
<tr>
<td></td>
<td>Different PCR 5 (7.5%)</td>
</tr>
<tr>
<td>Invalid comparisons</td>
<td>Same PCR: 2 (3%)</td>
</tr>
<tr>
<td></td>
<td>Different PCR 57 (86%)</td>
</tr>
</tbody>
</table>
Facility specific EPDs as introduced by the Buy Clean California will open up brand new challenges

Facility Specific EPDs not used in any current sustainability codes, standards…

Manufactures facilities can not always guarantee that your product will be sourced from a specific facility

Limited access to specific data for raw materials (A1):

- Metal coils
- Aggregates
- Energy sources
- Oil based Polymers
- Wood

Cost!
A whole system LCA is needed to identify the tipping point:

<table>
<thead>
<tr>
<th></th>
<th>No Insulation</th>
<th>RW40</th>
<th>RW80</th>
<th>RW120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal</td>
<td>4.3</td>
<td>4.3</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Construction</td>
<td>50</td>
<td>59</td>
<td>69</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>21%</td>
<td>28%</td>
<td>32%</td>
<td>36%</td>
</tr>
<tr>
<td>Operational energy</td>
<td>160</td>
<td>130</td>
<td>120</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>69%</td>
<td>61%</td>
<td>57%</td>
<td>53%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>8%</td>
<td>9%</td>
<td>9%</td>
<td>9%</td>
</tr>
<tr>
<td>Total</td>
<td>233</td>
<td>212</td>
<td>211</td>
<td>215</td>
</tr>
</tbody>
</table>

Life cycle impact assessment (kg CO2 eqv) of three stone wool insulation thicknesses: 40, 80 and 120 mm (functional unit of 1 m2 of living area over a period of 50 years). (Rodrigues and Freire, 2014, p. 213)
Final comments

• Positive that we are seeing an ROI of our EPD investment
• Large degrees of freedom for "Program operators" to develop PCRs
• Question if the maturity of the "science" supports the use of EPDs/GWP/Embodied Carbon as decision tools to choose between specific materials
• Costs!
• Beware of the rabbit holes!
Please go to your supplier if you have questions to a specific product.
Thank you

Christian Kofod
Sustainability Manager ROCKWOOL/Rockfon North America

Mail: christian.kofod@rockwool.com
Phone: +1 905 467 5227
A study of embodied carbon and potential carbon storage in materials

1. Create embodied carbon models:
   a. Two buildings
   b. Four assemblies
   c. Two levels of efficiency

2. Create energy models of all the model buildings

3. Examine combined embodied and operational emissions until 2050

Multi-family residential, 8 unit
10,300 square feet F.A.
Four story

Single family residential
2,000 square feet F.A.
Bungalow with full basement
- Floor area was kept constant
- Insulation materials were evaluated at appropriate thickness to match R-value requirements
- Baseline models meet 2019 Ontario Building Code minimums (CC)
- High performance models had improved insulation to match practices of builders offering efficient homes (HP)

### Model Parameters

<table>
<thead>
<tr>
<th></th>
<th>Multi-Unit CC</th>
<th>Multi-Unit HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>R-60</td>
<td>R-80</td>
</tr>
<tr>
<td>Walls</td>
<td>R-23 (R-13+R-10)</td>
<td>R-30 (R-20+R-10)</td>
</tr>
<tr>
<td>Fdn Walls</td>
<td>R-15</td>
<td>R-20</td>
</tr>
<tr>
<td>Sub-slab</td>
<td>R-15</td>
<td>R-15</td>
</tr>
<tr>
<td>Doors</td>
<td>U-0.45</td>
<td>U-0.45</td>
</tr>
<tr>
<td>Windows</td>
<td>U-0.29</td>
<td>U-0.20</td>
</tr>
<tr>
<td>Leakage</td>
<td>3.0 ACH/50</td>
<td>1.0 ACH/50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Single-Family CC</th>
<th>Single-Family HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>R-60</td>
<td>R-80</td>
</tr>
<tr>
<td>Walls</td>
<td>R-24 (R19+R5)</td>
<td>R-40</td>
</tr>
<tr>
<td>Fdn Walls</td>
<td>R-20</td>
<td>R-30</td>
</tr>
<tr>
<td>Sub-slab</td>
<td>R-10</td>
<td>R-20</td>
</tr>
<tr>
<td>Doors</td>
<td>U-0.28</td>
<td>U-0.18</td>
</tr>
<tr>
<td>Windows</td>
<td>U-0.28</td>
<td>U-0.18</td>
</tr>
<tr>
<td>Leakage</td>
<td>2.5 ACH/50</td>
<td>1.0 ACH/50</td>
</tr>
</tbody>
</table>
- Over 300 materials modeled
- Assemblies reflect current practices
- Sources of data:
  a. Industry average EPD for North America
  b. Average of product-specific EPDs for North America
  c. Industry average EPD for Europe
  d. Average of product-specific EPDs for Europe
  e. LCA data from peer reviewed sources, averaged
<table>
<thead>
<tr>
<th>Model Building Assemblies for Embodied Carbon Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Highest Carbon</strong></td>
</tr>
<tr>
<td>Foundation</td>
</tr>
<tr>
<td>Foundation insulation</td>
</tr>
<tr>
<td>Exterior wall assembly</td>
</tr>
<tr>
<td>Exterior cladding</td>
</tr>
<tr>
<td>Interior wall framing</td>
</tr>
<tr>
<td>Interior wall cladding</td>
</tr>
<tr>
<td>Windows</td>
</tr>
<tr>
<td>Floors</td>
</tr>
<tr>
<td>Roof/attic insulation</td>
</tr>
<tr>
<td>Roofing/ceiling</td>
</tr>
</tbody>
</table>
What can this mean...

Worst Case Scenario at +345.9 kg/m$^2$

= +83.4 million tonnes of CO2e
= Adding emissions of 23 coal plants*

Best Case Scenario at -150.7 kg/m$^2$

= -36.3 million tonnes of CO2e
= Removing emissions of 10 coal plants*

*500 MW Plant with 3.5 million tons of CO2e Emissions Annually
241.1 million square meters new low-rise residential construction in US, 2017
U.S. Census Bureau/U.S. HUD, CB19-21
What’s not showing up here?

Figures are based on a “Cradle-to-Gate” analysis

- Does not include transportation to site
- Does not include site energy inputs/emissions
- Does not include end-of-life impacts

These matter too, but can only be calculated according to specific location and practices. It’s up to each of us to add this piece to our calculations.
What are these magical, carbon-storing materials?

- Timber (sustainably harvested)
- Wood fiber board
- Hempcrete
- Cork
- ReWall (waste drinking boxes)
- Cellulose (waste paper fiber)
- Waste textiles
- Straw (waste ag fiber)
- Bamboo BamCore
- Rice hulls (& coconut, palm kernel, etc)
2.16 billion tons of grain straw were grown globally in 2016. That’s enough carbon storage to offset all current transportation GHG emissions and more than replace all current insulation materials.
Looking at operational and embodied emissions...

This building can be a major contributor to climate change, or... This building can be a major contributor to climate drawdown.
Trillium-Lakelands Elementary Teachers’ Union office building
Lindsay, Ontario
2,400 sf, $208/sq.ft

71 tons net CO$_2$ storage

Carbon-storing strategies include:

- Straw-cell walls (2x6 framing with cellulose plus straw bale)
- Cellulose floor and ceiling insulation
- Wood fiberboard exterior insulation
- FSC-certified wood flooring and siding
- Local timber frame
In practice...

Zero House project, 2017
Clarksburg, Ontario
1,100 square feet, $254/sq.ft
24 tons of CO\textsubscript{2} storage

Carbon-storing strategies include:
- Straw bale SIPs
- Cellulose & wood fiberboard SIPs
- Cellulose roof & floor insulation
- ReWall interior sheathing
- FSC plywood interior finishes
- FSC wood flooring

http://endeavourcentre.org/2019/01/zero-house-slide-show/
1. Build with carbon-storing materials to turn our buildings into carbon banks.
2. Work with regenerative agriculture and silviculture practices to preserve soil carbon as we harvest plant-based low-toxicity materials.
3. Invest in farm and forest products to empower economically-disenfranchised rural communities and revitalize regional-scale manufacturing.
4. Welcome climate refugees as we all will be climate refugees - and work together to build the regenerative tomorrow.
5. Work for social equity, ecological repair, and justice, in all you do.

Make a commitment to carbon-storage!

https://newframeworks.com/

http://endeavourcentre.org/

Watch for the upcoming publication of Opportunities for Carbon Capture and Storage in Building Materials, which will include the complete data sets used for this presentation...
Insulating with Hemp

Presented for Embodied Carbon Network Materials webinar
March 22, 2019

Pamela Bosch
Highland Hemp House
www.highlandhemphouse.com
A pioneering residential project using hemp and lime
Bellingham, Washington
psbosch@gmail.com
Batt insulation from hemp fibers

- Sustainable, non-toxic, rapidly renewable
- Non-hazardous work environment
- Noise resistant
- Naturally pest resistant
- Fire resistant (salts added)
- Resists settlement
- **Mold resistant.** Hemp can naturally absorb up to 20% of its weight in moisture.
- **Higher thermal phase displacement**
- Thermal conductivity of **0.039 W/m°K.**
- May include other natural fibers such as kenaf, flax and in some cases polyester
Thermal acoustic panels, loose fill, blocks

<table>
<thead>
<tr>
<th>FEATURES</th>
<th>ETA-13/0518</th>
</tr>
</thead>
<tbody>
<tr>
<td>European admission</td>
<td>EN 1602</td>
</tr>
<tr>
<td>Composition HempFlax Plus</td>
<td>EN 12 667</td>
</tr>
<tr>
<td>Density</td>
<td>EN 13 501-1</td>
</tr>
<tr>
<td>Thermal conductivity (A)</td>
<td>EN ISO 10456</td>
</tr>
<tr>
<td>Fire class</td>
<td>EN ISO 354</td>
</tr>
<tr>
<td>Flame retardant (&lt; 1%)</td>
<td>EN 12 086</td>
</tr>
<tr>
<td>Thermal storage capacity (c)</td>
<td>EN 29 053</td>
</tr>
<tr>
<td>Sound absorption factor (aw)</td>
<td>EN 822</td>
</tr>
<tr>
<td>Vapour diffusion resistance factor (μ)</td>
<td>EN 822</td>
</tr>
<tr>
<td>Air flow resistance</td>
<td>EN 823</td>
</tr>
<tr>
<td>Mould formation</td>
<td>EN 822</td>
</tr>
<tr>
<td>Dimensional tolerance:</td>
<td>EN 822</td>
</tr>
<tr>
<td>- length</td>
<td>EN 823</td>
</tr>
<tr>
<td>- width</td>
<td></td>
</tr>
<tr>
<td>- thickness</td>
<td></td>
</tr>
<tr>
<td>Energy input (m³ material)</td>
<td>50 - 80 (kWh/m³)</td>
</tr>
</tbody>
</table>
Highland Hemp House
Bellingham, WA

2400 sq. ft. addition: 2018
800 sq. ft. renovation 2019
Hempcrete: A marriage of plant and mineral

Insulating and hygroscopic due to the micro-structure of both elements.

- **Pits**
- **Hydrophobic cell membranes**

Hemp pith is nature’s design to move moisture

Lime retains a porous microscopic structure, facilitating humidity movement and acoustic absorption.
Hydrated lime that is used in building has a mineral content of 90%+ calcium. It is calcined to about 900°C. Lime used in producing cement is calcined to over 1250°C, using 80% more energy.

Lime sets with air by reabsorbing the CO2 that is driven off in calcining.

Upon setting, pure lime once again becomes CaCo3 or limestone.
Lime Cycle

Carbonation:

\[ \text{Ca(OH)}_2 + \text{CO}_2 = \text{CaCO}_3 \]

Calcination or burning:

Heat at 1100 °C

\[ \text{CaCO}_3 + \text{HEAT} = \text{CaO} + \text{CO}_2 \]

Hydration or slaking:

\[ \text{CaO} + \text{H}_2\text{O} = \text{Ca(OH)}_2 + \text{HEAT} \]
Hemp begins sequestering carbon the moment it is seeded; conservatively, hemp cultivation yields a sequestration ratio of about 1.5 units of sequestration per unit produced. In Layman's terms, one ton of harvested hemp fiber should sequester 1.62 tons of CO2.

Over time, materials in hempcrete undergo calcination, absorbing more CO2. Calcination is the process where materials heat up, below its boiling point, to drive off volatile matter or to effect changes. During this process, and under the same circumstances previously mentioned, the 120 square foot hempcrete wall should sequester 2400 pounds of CO2, leaving only 1480 pounds of CO2 created by the process. Those 1480 pounds are easily offset by the carbon sequestered in hemp production, leaving the entire project carbon negative.

According to a paper provided by Holon Ecosystem Consultants, hemp might give as much as 13 tons of charcoal per hectare annually, which would triple the output of Salix (a popular biomass crop) plantations.
In a study conducted by K. Ip et al. [3], it was found that the LHC wall they studied had a total carbon sequestration of 275.7 kg of CO$_2$ for 1 m$^3$ of LHC. They also concluded that, for their manufacturing process, a functional unit of dimensions 1m x 1m x 0.3m sequestered 82.71kg of CO$_2$, thereby compensating for 46.43kg of manufacturing CO$_2$ emissions and also enabling a further storage of 36.08 kg of CO$_2$.

In a life cycle assessment study, it was found that 1 kg of hemp shives sequester an equivalent of 2.1 kg of CO$_2$, and a functional unit of dimensions 1m x 1m x 0.3m was able to sequester 75.7 kg of CO$_2$, thereby amounting to 251.67 kg of CO$_2$ equivalent for 1 m$^3$ of LHC [4, 5]. The net emissions incurred when constructing a LHC – timber frame structure, inclusive of transport, construction and manufacturing processes were found to be -35.5 kg of CO$_2$ equivalent per m$^3$ of LHC [4, 5].
Theoretical estimation of carbon consumption through carbonation of lime

The carbonation of lime is governed by the following double replacement reaction:
\[ \text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} \]

**Determination of percentage of carbon in Hemp Shives**

To determine the amount of carbon dioxide equivalent present in the Hemp component of the mixture, it is necessary to determine the percentage of carbon that hemp shives are constituted of. This quantity of carbon is translated into an equivalent quantity of carbon dioxide consumed by the hemp component through photosynthesis, which is governed by the following equation:
\[ 6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O} \]

Jami and Kumar
Hemp Fibres for Green Products – An assessment of life cycle studies on hemp fibre applications

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Pictures
High Carbon Capture by Hemp insulation (Hock, Germany)
Natural fibre door panel for BMW 5 Series, compress
moulding (nova-Institute, Germany)

Layout
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Figure 2: Primary energy use in the different stages of hemp fibre production (total fibre line) given in GJ/t hemp fibre (according to Carus et al. (2008)).
HEAT PROTECTION

- Outside temperature
- Inside temperature HempFlax 270 mm, 10% wood, Rₜ 5.7m²K/W
- Inside temperature EPS 200 mm, 0% wood, Rₜ 5.7m²K/W

Assumptions:
- HempFlax 270 mm, 10% wood, Rₜ 5.7m²K/W, 35.5 kg/m³, 1800 J/kg K
- EPS 200 mm, 0% wood, Rₜ 5.7m²K/W, 30.0 kg/m³, 1500 J/kg K
Hempcrete, a hemp and lime monolithic insulating wall system

- Simple composition of hemp hurd (wood, shiv, core), lime, sand, water, pigment, and sometimes clay
- Annually renewable bio-aggregate, an agricultural byproduct when grown for fiber, CBD, or THC cannabis
- No VOCs
- Hygroscopic (moisture permeable)
- Mold resistant
- Pest resistant
- Fire resistant
- Sequesters carbon
- Acoustic benefits
- Seismic support to stick frame construction (not structural—does not have compaction strength of concrete)
- Enduring (Like Waddle and Daub)
- Recyclable

- Revives artisan skills
- Potential for local production of materials with well-planned processing infrastructure
- Compliments parallel industries like plant-based plastic development, bio-fuels, bio-char, fiber, fiber reinforced materials, medicinal and recreational uses of cannabis, rural economic development
- Requires little or no pesticides and herbicides in growing
- Deep root crop rotation benefits
- Phytoremediation crop
An investigation of the thermal properties of hemp and clay monolithic walls

Ruth Busbridge  University of East London
Ranyl Rhydwen  University of East London

January 2010

Figure 5: Comparison of figures for hemp-clay and Tradical Hemcrete.

University of East London Institutional Repository: http://roar.uel.ac.uk
A study in 2003 by the University of Toronto found that we could save 50,000 MJ, or 3 tons of CO2, per ton of thermoplastic by replacing 30% glass fiber reinforcement with 65% hemp fiber. We can also address the carbon storage capabilities in these natural fiber composites. The same writers of the University of Toronto's study estimated a carbon storage potential of 715 pounds per metric ton of hemp-based polypropylene composite. This means that the carbon is not sent back into the atmosphere but trapped in the material for years and years.
Spray Infill Blocks
Forms

Spray

Panels

Clay/lime bricks

Hemp-lime construction
Hemp as insulation

Pamela Bosch
Highland Hemp House
March 22, 2019
Q&A
Thank you!

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