Life Cycle Assessment of Advanced Insulation Materials towards NZEBs

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The company

Since 2015, IRES provides specialized services in the fields of **Environment, Health and Safety, Nanotechnology** and **Digitisation of Materials Characterisation**.

- **Life Cycle Sustainable Assessment**, Environmental & Carbon footprint, **Circular economy**
- **Nano(particle) concentration measurements** in specially designed exposure experiments
- Data driven solutions using **AI, Machine Learning, Computer Vision and Data management**

IRES participates in over 20 EU R&I projects, providing expertise to cutting-edge technologies **NZEBs, RES, Additive Manufacturing, Water Pollution and Wastewater Recycling**
• EU Horizon 2020 R & I project

• 1 March 2021, 48 months, 27 Partners

• Create an Open Access Ecosystem to develop, upscale and test innovations in building envelope materials and systems to reach Nearly Zero Energy Buildings (NZEBs) balance

• **9 Pilot Lines** for the production and upscaling of advanced building materials and components

• Thermal insulation, omni phobic coatings, TEGs, 3d-printed components, etc.

**IRES** leads the Task of **Sustainability of proposed solutions** including **LCA**

[https://iclimabuilt.eu/](https://iclimabuilt.eu/)
# Why LCA on Building Materials?

## Challenges

The largest energy consuming sector in the EU
40% energy consumption, 36% GHGs

85% of existing buildings will be standing in 2050,
with only 1% energy renovated annually

To meet EU climate goals buildings more energy efficient and less carbon-intensive over their Life Cycle

Attention is paid to Operational Energy rather than Embodied Energy of buildings, while:

*Chastas et al.*: the share of Embodied Energy in the life cycle energy of residential buildings ranged from 6% to 20% for conventional buildings, 11% to 33% for passive houses and 74% to 100% for nZEBs...

## Environmental Assessment

LCA is an **invaluable tool** for the environmental assessment of products, processes, services

LCA plays an important role in the design, development and selection of environmental-friendly building envelope materials and components in a life cycle perspective.

- Assess environmental performance
- Identify hotspots and trade-offs
- Propose mitigation solutions for all life cycle phases at early stage of technology development

Responsible Decision Making → Market development for sustainable building products
1. **Goal and Scope:** Preliminary assessment of the potential environmental impacts of new advanced building materials, achieving nZEBs with lower embodied carbon.

Examined iclimabuilt Materials

<table>
<thead>
<tr>
<th>iclimabuilt Material</th>
<th>FU</th>
<th>Process</th>
<th>Benefits</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellular Lightweight Concrete (CLC)</td>
<td>1 kg</td>
<td>Foaming Agent Production, Concrete Mixer</td>
<td>• ultralight concrete</td>
<td>Thermal Insulation for wall façades (i.e. in sandwich panels)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• low density</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• low thermal conductivity</td>
<td></td>
</tr>
<tr>
<td>Concrete for Textile Reinforced Concrete (TRC)</td>
<td>1 kg</td>
<td>Concrete Mixer</td>
<td>• high mechanical performance</td>
<td>Thermal Insulation for wall façades (for sandwich panels)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• high durability</td>
<td></td>
</tr>
<tr>
<td>Silica and Cellulose Aerogels</td>
<td>1 L</td>
<td>Sol-gel process, Supercritical Fluid Extraction</td>
<td>• high porosity</td>
<td>Thermal Insulation for wall façades (i.e. in sandwich panels)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• low thermal conductivity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Multiple insulation applications</td>
<td></td>
</tr>
<tr>
<td>Omni phobic coatings</td>
<td>1 m²</td>
<td>Plasma and Paint</td>
<td>• wide range of materials</td>
<td>Smart window applications, Solar Panels</td>
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<td></td>
<td></td>
<td></td>
<td>• straightforward self-cleaning, anti-soiling and anti-icing</td>
<td></td>
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</tbody>
</table>

2. Life Cycle Inventory (LCI)
Foreground data: Primary data from iclimabuilt partners, proxy values when necessary
Background data: Professional database Ecoinvent (3.7.1) and peer-reviewed literature

3. Life Cycle Impact Assessment (LCIA)
The CML-IA (baseline) method was used, providing the impact categories as included in EN 15804:2012

- Global warming potential (100a)
- Ozone depletion
- Acidification potential of soil and water
- Depletion of abiotic resources (elements)
- Depletion of abiotic resources (fossil fuels)
- Photochemical ozone creation potential
- Eutrophication potential
LCIA results – Cellular Lightweight Concrete (CLC)

- GWP = 0.574 kg CO2 eq / kg
- Hot spot analysis: The cement raw materials represent the largest share for all impact categories.
  - Cements contribute to GWP = 87%
- Foaming agent contributes to GWP and other impact factors like Eutrophication & Photochemical oxidation.
- Other materials (Synthetic Fibers) affect the Abiotic depletion (fossil fuels).
- Required electricity, water and generated waste not significant to the impact categories assessed.
- GWP results from our study lie in the same levels with similar studies from literature
- The examined TRL is medium
- Still large room for improving environmental performance of this material
**LCIA results – Concrete for Textile Reinforced Concrete (TRC)**

- **GWP** = 0.133 kg CO2 eq / kg
- Hot spot analysis: Cement, other materials and waste.
  - Cement contributes to GWP = 92%
  - Other materials (i.e. sand) contribute with 10-18% to impact categories of ODP, Acidification, Abiotic depletion (fossils) and Photochemical oxidation.
  - Waste mainly affects Eutrophication with a share of 60%, Cement follows.
- Required electricity and water not significant to the impact categories assessed.
  - **Next Step: Carbon Fiber Mat LCA**
LCIA results – Silica Aerogels

- **GWP = 0.88 kg CO₂ eq / L**
- **Hot spot analysis:** ethanol, sodium silicate and sCO₂
- **Ethanol:** Even though recycled (95%), still the main contributor in most of the impact categories assessed.
  - E.g. GWP with a share of 50%
- **sCO₂** significant to GWP (~28%) and ODP (~40%), even though assumed recycled at 95%
- **Sodium silicate** burdens apart from GWP and ODP, Acidification and Abiotic Depletion (elements).
- **Required electricity, water and generated waste** not significant to any of the impact categories assessed.
LCIA results – Cellulose Aerogels (ammonia solution)

• GWP = 0.87 kg CO₂ eq / L
• Ethanol: Even though recycled (95%), still a main contributor in many impact categories assessed.
  • E.g. GWP with a share of over 50%
  • The largest contributor to Abiotic depletion (fossil fuels) and Photochemical oxidation
• sCO₂ follows with lower contribution of 28% to GWP (assumed to be recycled at 95%).
• Ammonia is a contributor mainly to ODP, but also affects GWP (13%).
• Cellulose burdens mainly other impact categories like Eutrophication and Abiotic depletion.
• Electricity, water, waste negligible
LCI results – Cellulose Aerogels (sodium hydroxide)

- GWP = 0.85 kg CO₂ eq / L (slightly lower)
- Sodium hydroxide contributes more in ODP and Abiotic depletion (elements) than Ammonia
- Electricity, water, waste negligible
LCIA results – Omni phobic coatings

- **GWP = 1.23 kg CO₂ eq / m²**
- The electricity required is the main contributor to GWP with a share of over 50%, to ODP, Acidification and Abiotic depletion (elements).
- Ethanol burdens GWP with a share of over 30% and Abiotic depletion and Photochemical oxidation with over 50%.
- Waste mainly affects Eutrophication with 55%, not drastically affects other impact categories.
- Other materials contribute with a share of 17% to GWP, other impact categories with up to 20%.
Conclusions

Study: Life Cycle environmental impacts from the production of new advanced building materials.

Scope: Achieving nZEBs with lower embodied carbon.

Main outcomes:

• GWP by the examined CLC in the same levels with literature.

• Concrete for TRC low GWP, sustainable composition. Further investigation for carbon fiber mat.

• Not important differences in GWP by the different examined aerogels; cellulose is one of the most promising environmentally friendly compounds for thermal insulation → need for further examination and optimization.

• Electricity and water for thermal insulation materials not significant to environmental impacts, including GWP.

• Waste main contributor only to Eutrophication, for omni phobic coatings and TRC.

• Results in line with “Emissions of raw materials for building materials, processing in factory, replacement and transport to construction site constitute 86% of the emissions to total air” [BENLİ YILDIZ et al., 2020]

• Necessity to work towards LCI database for advanced building materials.
Future work

• Preliminary assessment, 1st project semester, work continues

• Receive more detailed data from iclimabuilt partners, implement LCA for all project materials and optimize modelling of the examined materials

• Medium TRL: Large potential of improvement

• Combination of materials will lead to the iclimabuilt Test Cases to be applied to demo buildings

✓ TRC/CLCi composite panels for smart building envelopes
✓ TRC/CLCi/Aerogel panels
✓ Other sandwich panels including Aerogels
✓ Smart windows and BIPVs with omni phobic coating technology
### Change on how we use energy in buildings

**1st half 2020**, electricity in residential buildings increased 20–30%, decreased 10% in commercial buildings (teleworking)

**Insulation sales fall, but bright spots DYI**

**1st half 2020**, global fall in sales of 5-20%

**Schools, open windows, energy demands**

### Need for flexible building materials

Adaptation to all environments

Ease DYI energy renovations

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**Table 2.1 Crisis-induced factors that could affect energy intensity in buildings**

<table>
<thead>
<tr>
<th>Type of effect</th>
<th>Factor</th>
<th>Potential impact on energy intensity improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity and structural</td>
<td>More activity in residential buildings; less in commercial buildings.</td>
<td>↓</td>
</tr>
<tr>
<td>Activity and structural</td>
<td>A greater share of services sector energy use comes from more energy-intensive services sub-sectors.</td>
<td>↓</td>
</tr>
<tr>
<td>Activity and structural</td>
<td>Commercial building ventilation rates are increased for health reasons.</td>
<td>↓</td>
</tr>
<tr>
<td>Technical efficiency</td>
<td>Economic recession and job losses lead to lost income for owners (partly due to lower rental payments) and tenants, and lower rates of building renovation and stock turnover.</td>
<td>↓</td>
</tr>
<tr>
<td>Technical efficiency</td>
<td>Continuing low fuel prices prolong the payback period for building energy efficiency upgrades.</td>
<td>↓</td>
</tr>
<tr>
<td>Technical efficiency</td>
<td>Continued health risks prevent professional energy efficiency contractors from accessing residential buildings, delaying building upgrades.</td>
<td>↓</td>
</tr>
</tbody>
</table>

[IEA, Energy Efficiency 2020]
Thank you all for your attention

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