Life Cycle Assessment of Advanced Insulation Materials towards NZEBs

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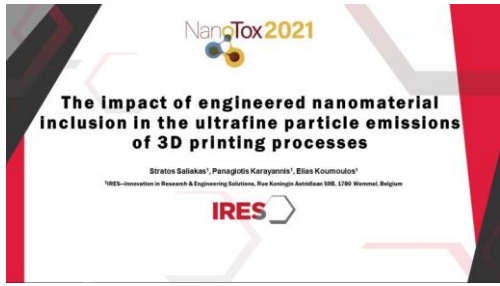
The company

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**

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iclimabuilt ecosystem services

https://iclimabuilt.eu/

- 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**

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**…

Research towards NZEBs

Embodied Energy

Building materials

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

Study: LCA on building material level

ISO 14040 / 44 and International Reference Life Cycle Data System (ILCD) Guidelines

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

	Iclimabuilt Material	FU	Process	Benefits	Applications
RISE	Cellular Lightweight Concrete (CLC)	1 kg	Foaming Agent Production, Concrete Mixer	• ultralight concrete • low density • low thermal conductivity	Thermal Insulation for wall façades (i.e. in sandwich panels)
HTWK Leipzig	Concrete for Textile Reinforced Concrete (TRC)	1 kg	Concrete Mixer	• high mechanical performance • high durability	Thermal Insulation for wall façades (for sandwich panels)
TUHH Technische Universität Hamburg	Silica and Cellulose Aerogels	1 L	Sol-gel process, Supercritical Fluid Extraction	• high porosity • low thermal conductivity • Multiple insulation applications	Thermal Insulation for wall façades (i.e. in sandwich panels)
cidetec	Omni phobic coatings	1 m^2	Plasma and Paint	• wide range of materials • straightforward self-cleaning, anti-soiling and anti-icing	Smart window applications, Solar Panels

Study: LCA on building material level

1. Goal and Scope: Examined **system boundaries** (cradle-to-gate): Life cycle stages based on EU standards for Sustainability of Construction Works: EN 15804:2012+A1: 2013; EN 15978: 2011

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

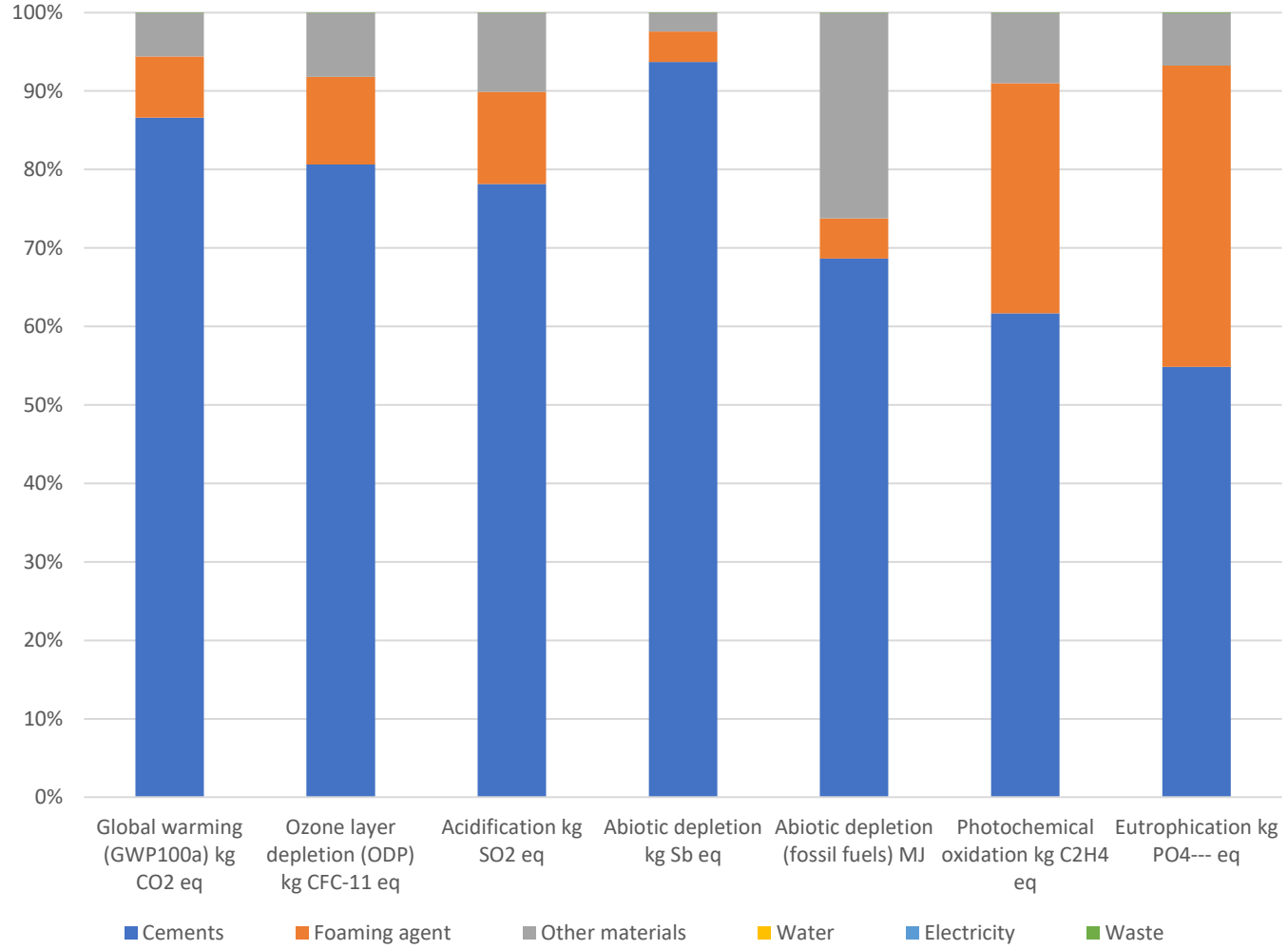
SimaPro 9.1.1.7

System Boundaries	Cradle to Cradle				
	Cradle to Grave				Benefits and Loads Beyond the System Boundary (D)
	Cradle to Gate	Gate to Grave			
LCA information modules	Product stage (A1–A3)	Construction process stage (A4–A5)	Use stage (B1–B7)		End-of-life stage (C1–C4)

LCA Information Modules		Life Cycle Stage Designation and Description
Product stage (A1–A3)	A1	Raw material extraction and processing, processing of secondary material input
	A2	Transport to the manufacturer
	A3	Manufacturing
Construction process stage (A4–A5)	A4	Transport to the building site
	A5	Installation in the building
Use stage (B1–B7)	B1	Use or application of the installed product
	B2	Maintenance
	B3	Repair
	B4	Replacement
	B5	Refurbishment
	B6	Operational energy use
	B7	Operational water use
End-of-life stage (C 1–4)	C1	De-construction, demolition
	C2	Transport to waste processing
	C3	Waste processing for reuse, recovery and/or recycling (3R)
	C4	Disposal
Benefits and loads beyond the system boundary (D)	D	Reuse, recovery and/or recycling (3R) potential

- 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.

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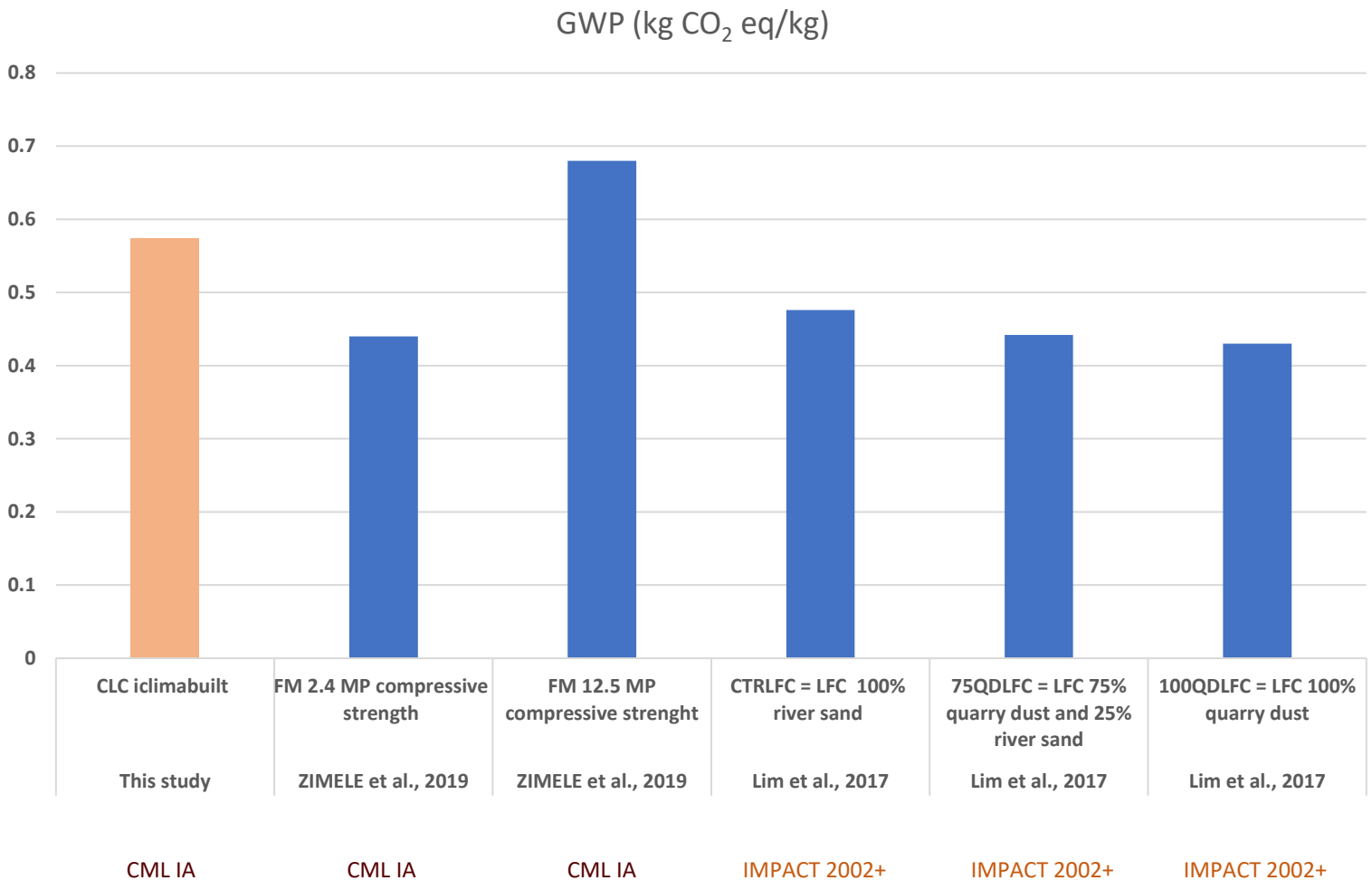
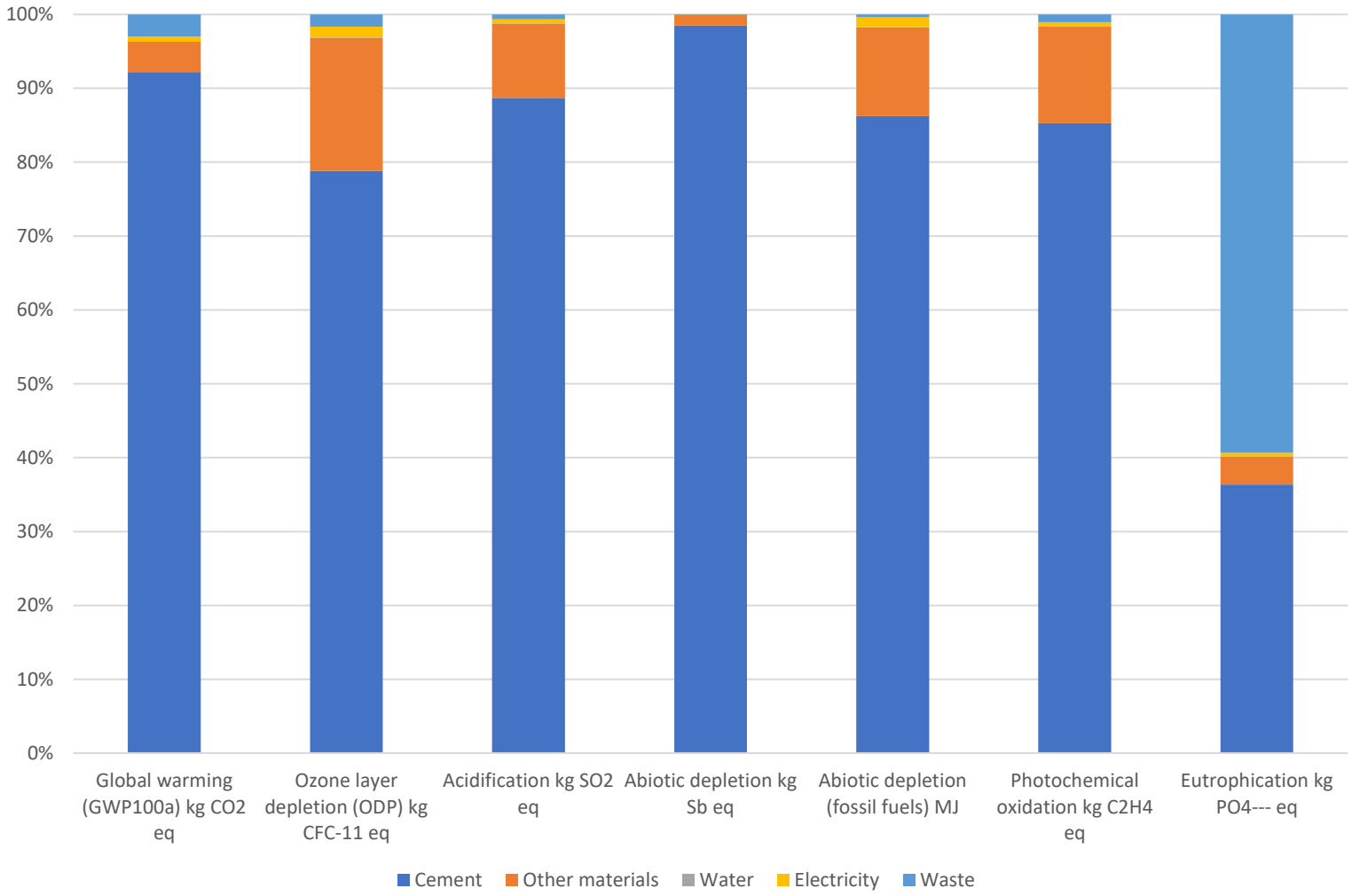
GWP results compared to references



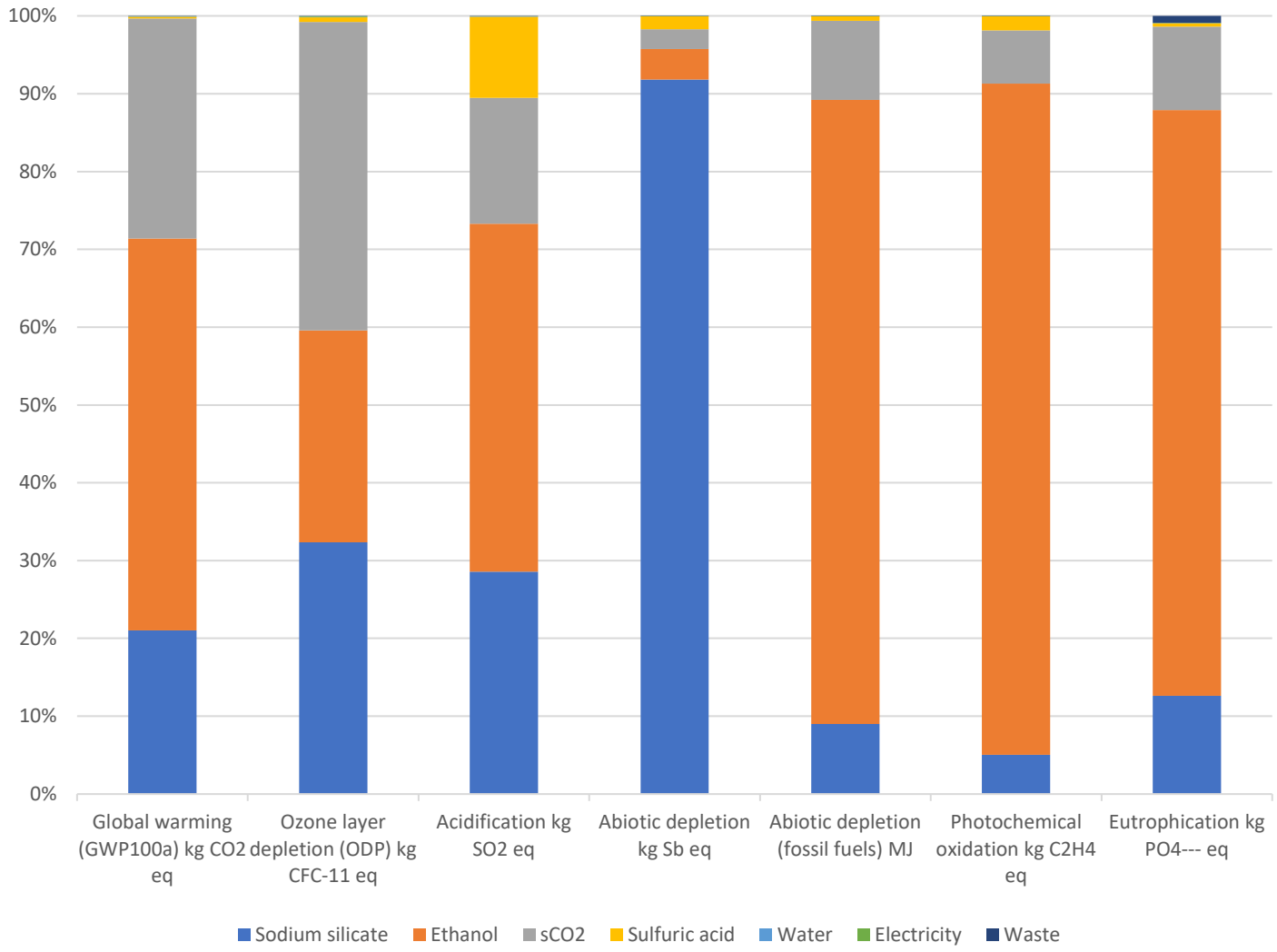
- GWP results from our study lie in the same levels with similar studies from literature
- The examined TRL is medium
- Still large room for improving environmental performance of this material

LCIA results – Concrete for Textile Reinforced Concrete (TRC)



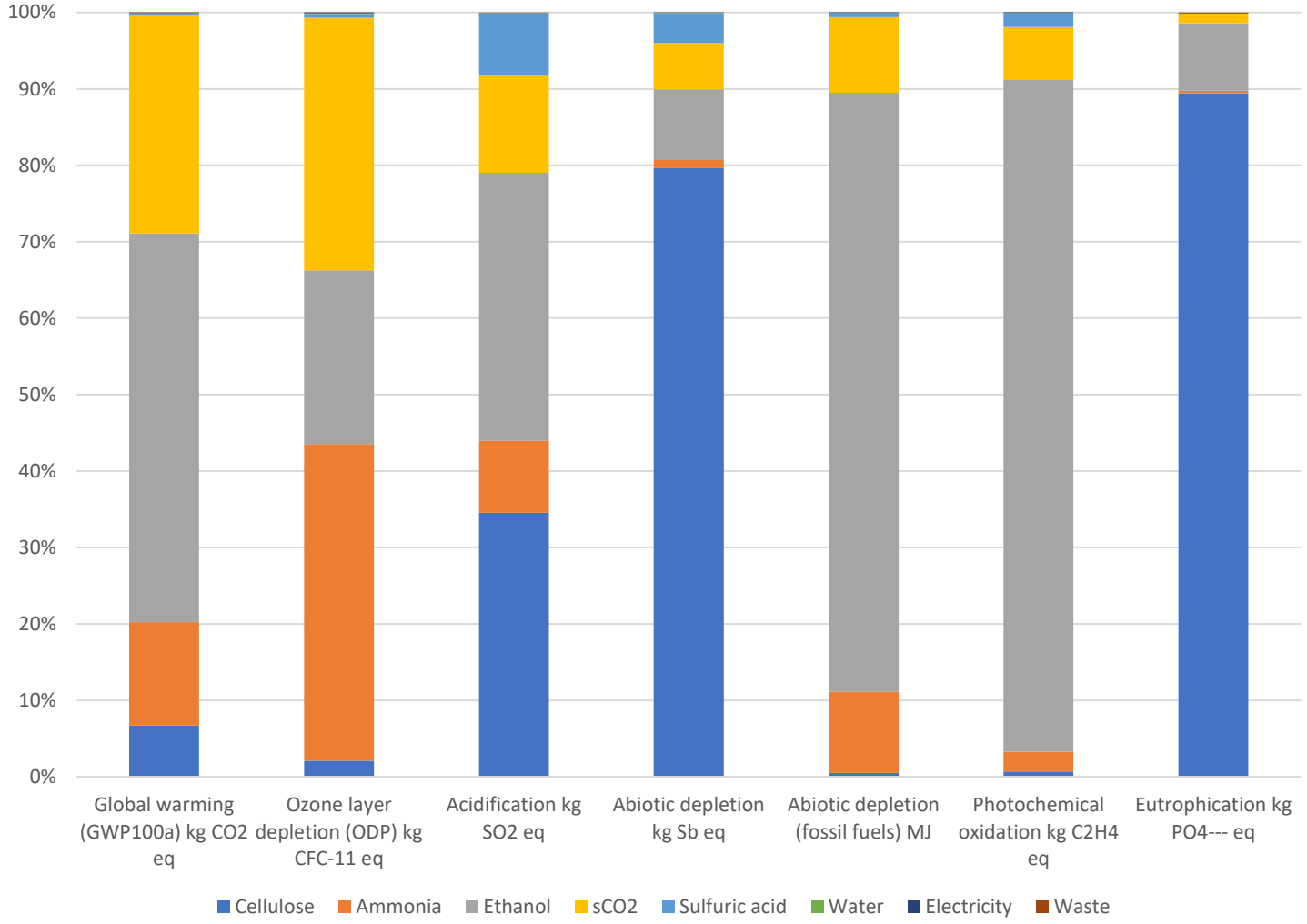
- GWP = 0.133 kg CO2 eq / kg
- Hot spot analysis: Cement, other materials and waste.
  - Cement contributes to GWP = 92%
  - Other materials (i.e. sand) contribute with 10-18% to impact categories of ODP, Acidification, Abiotic depletion (fossils) and Photochemical oxidation.
  - Waste mainly affects 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



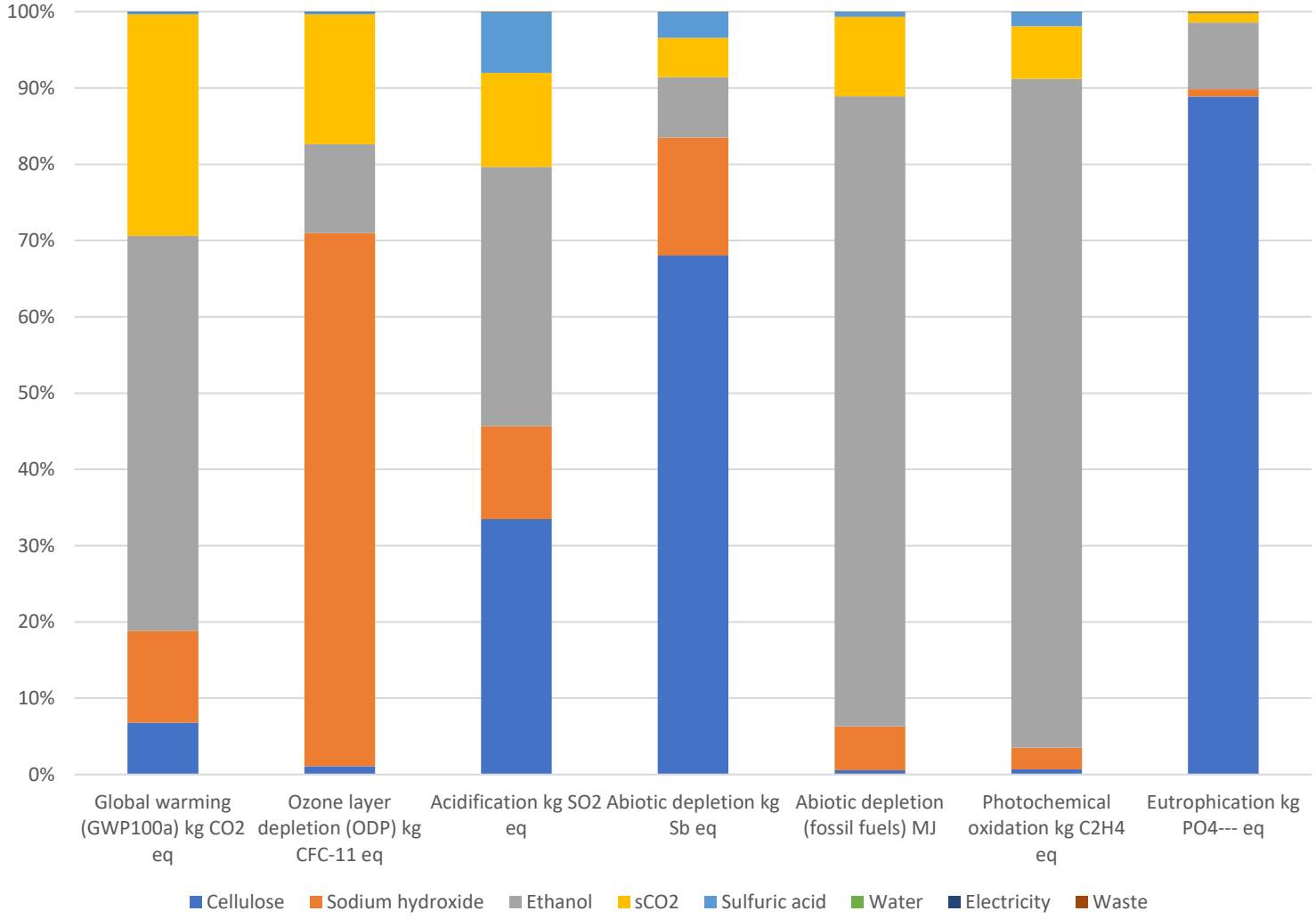
- GWP = 0.88 kg CO_2 eq / L
- Hot spot analysis: ethanol, sodium silicate and sCO_2
- Ethanol: Even though recycled (95%), still the main contributor in most of the impact categories assessed.
  - E.g. GWP with a share of 50%
- sCO_2 significant to GWP (~28%) and ODP (~40%), even though assumed recycled 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)



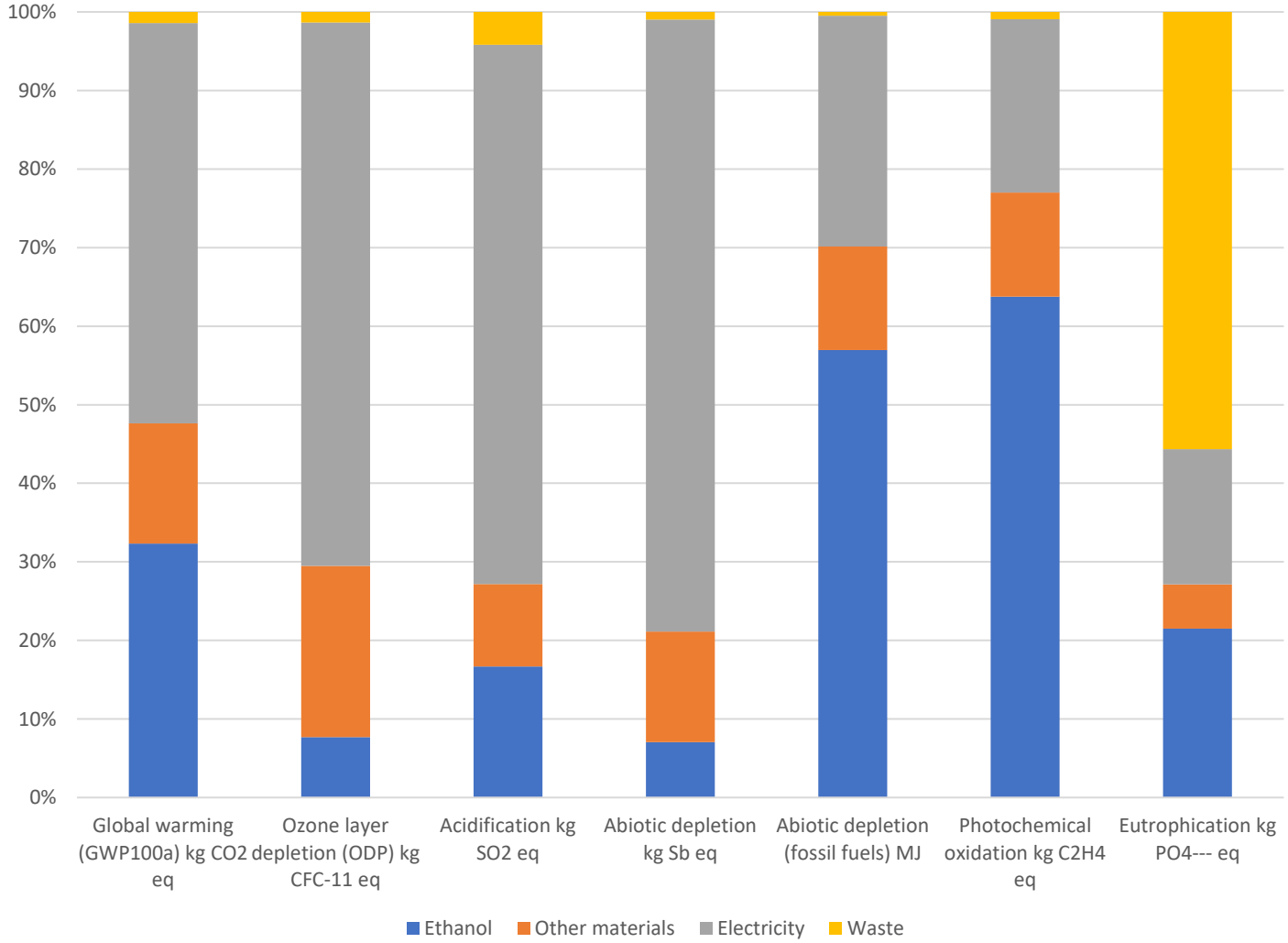
- GWP = 0.87 kg CO_2 eq / L
- Ethanol: Even though recycled (95%), still a main contributor in many impact categories assessed.
  - E.g. GWP with a share of over 50%
  - The largest contributor to Abiotic depletion (fossil fuels) and Photochemical oxidation
- sCO_2 follows with lower contribution of 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

LCIA results – Cellulose Aerogels (sodium hydroxide)



- GWP = 0.85 kg CO_2 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 CO_2 eq / m^2
- 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

LCA on material level → **LCA on test case level to be applied to buildings** → **LCA on building level**

New Challenge: Covid-19

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

Type of effect	Factor	Potential impact on energy intensity improvement
Activity and structural	More activity in residential buildings; less in commercial buildings.	↓
	A greater share of services sector energy use comes from more energy-intensive services sub-sectors.	↓
	Commercial building ventilation rates are increased for health reasons.	↓
Technical efficiency	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.	↓
	Continuing low fuel prices prolong the payback period for building energy efficiency upgrades.	↓
	Continued health risks prevent professional energy efficiency contractors from accessing residential buildings, delaying building upgrades.	↓

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

[IEA, Energy Efficiency 2020]

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