Structure

Our shared vision – a desire to use more nature-based materials

Where, when, how, and who? - BRE CICM research centre history and research projects

Future opportunities - Circularity in construction

Motivation - Our energy impact

- Operational energy use in buildings represents about 30% of global final energy consumption.
- Despite progress on energy efficiency and the decarbonisation of electricity generation, these measures are not enough to curb the growth in CO_2 emissions from building operation.

Material depletion

- The UK's annual construction output requires 170 million tonnes of primary materials and products.

- Equivalent to more than 40x the Palace of Parliament; the worlds heaviest building.

- 23 million tonnes of $C0_2$ are emitted to manufacture and deliver these materials.

Photo: PetrascuHoriaMariusP / stock.adobe.com

Building and construction activities worldwide consume 3 billion tonnes of raw materials each year

- 60% of the raw materials derived from the lithosphere are used in civil engineering and building construction.
- The building industry accounts for 24% of the total extraction
- The manufacturing of construction materials accounts for more than 80% of the energy consumption of building construction

Impact of buildings and building materials

- The International Energy Agency (IEA) projects the global building floor area to grow by 75% in the next 30 years.
- Despite the substantial corresponding increase in energy demand by mid-century, total direct emissions from the building sector need to contract sharply.
- In 2022, buildings sector energy use increased by around 1%.

Nature based materials

- A building material is said to be bio-based when it incorporates plant or animal biomass: material of biological origin, with the exception of materials of geological or fossil formation.
- Their raw material is therefore largely derived from renewable resources and mainly uses co-products from agriculture or the wood industry.

Beyond operational energy performance

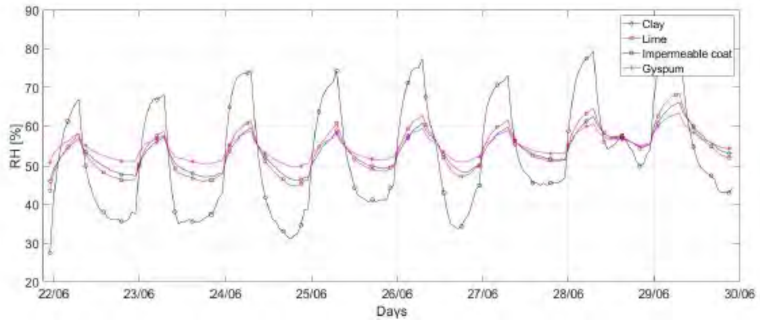
- A brick wall requires more than nine times more primary energy than a straw bale wall.*
- Embodied energy accounts for up to 46% of the life cycle energy use (service life of 50 years) in the case of low energy buildings.**

*Brojan, L & Petric, A & Clouston, P. (2013). Comparative study of brick and straw bale wall systems from environmental, economical and energy perspectives. Journal of Engineering and Applied Sciences. 8. 920-926.

**Rosaline L-L, Pierre B, Ben, A., Evaluating the importance of the embodied impacts of wall assemblies in the context of a low environmental impact energy mix, Building and Environment, 207, 2022. https://doi.org/10.1016/j.buildenv.2021.108534

Beyond operational energy performance

- Unlike other types of insulation materials, most bio-based materials exhibit hygroscopic behaviour, combining high water vapour permeability and moisture regulation potential.
- The history of bio-based building materials dates back thousands of years when early human civilizations used natural materials to construct their homes and structures. Wood and earthen materials were readily available, renewable, and biodegradable.



RH variation in a simulated room with different wall finishes.

A building is a complex system consisting of many different materials.

The material selection, therefore, has a significant role in sustainable building design.

Drivers and opportunities for bio-based materials in modern construction

- Reduced GHG emissions
- Lower embodied carbon
- Better environmental performance
- Healthier buildings
- Resource efficiency
- Renewable
- Reduced waste – circular construction
- New markets (agriculture)

Building Research Establishment Centre for Innovative Construction Materials
(BRE CICM)

Our Research Centre aims

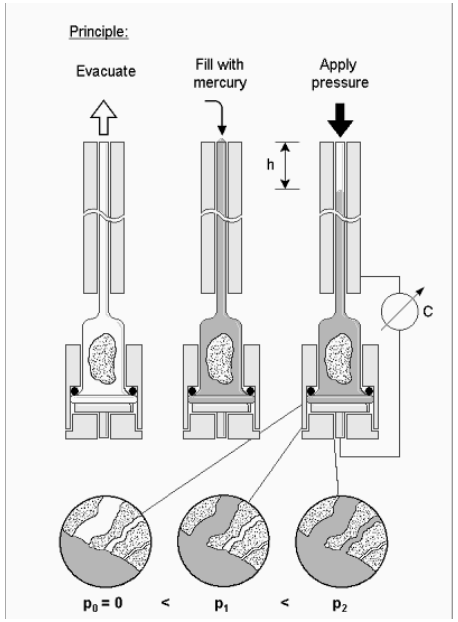
- Establish a centre with a strong innovative and sustainability profile in all its activities.
- Develop national and international collaboration with other research groups.
- Develop and support careers of new staff members in the centre.
- Provide specialist knowledge to support teaching.
- Promote nationally and internationally work of the centre, university and BRE.

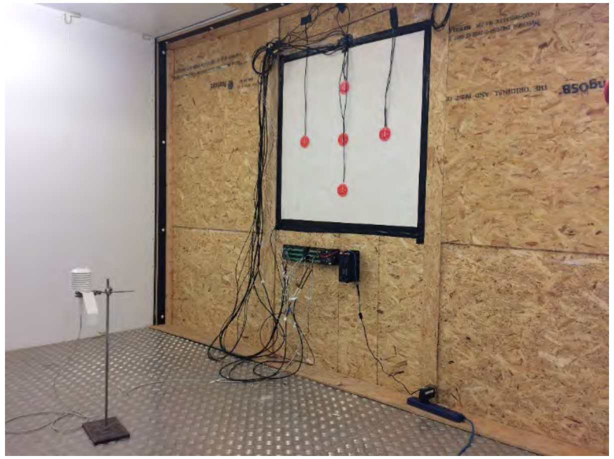
Centre expertise and activities

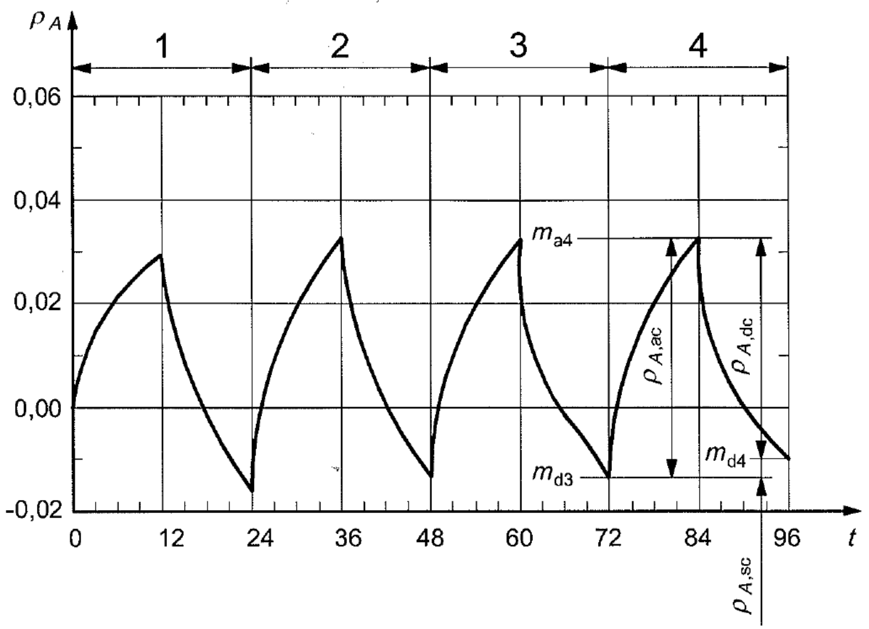
- Straw bale building systems
- Hemp based composite materials
- Engineered bamboo
- Unfired clay masonry and rammed earth construction
- Structural masonry, concrete and cements
- Cork, mycelium, and other innovative insulation materials
- Timber engineering
- Material characterisation and in-situ performance
- Pioneering net-zero buildings

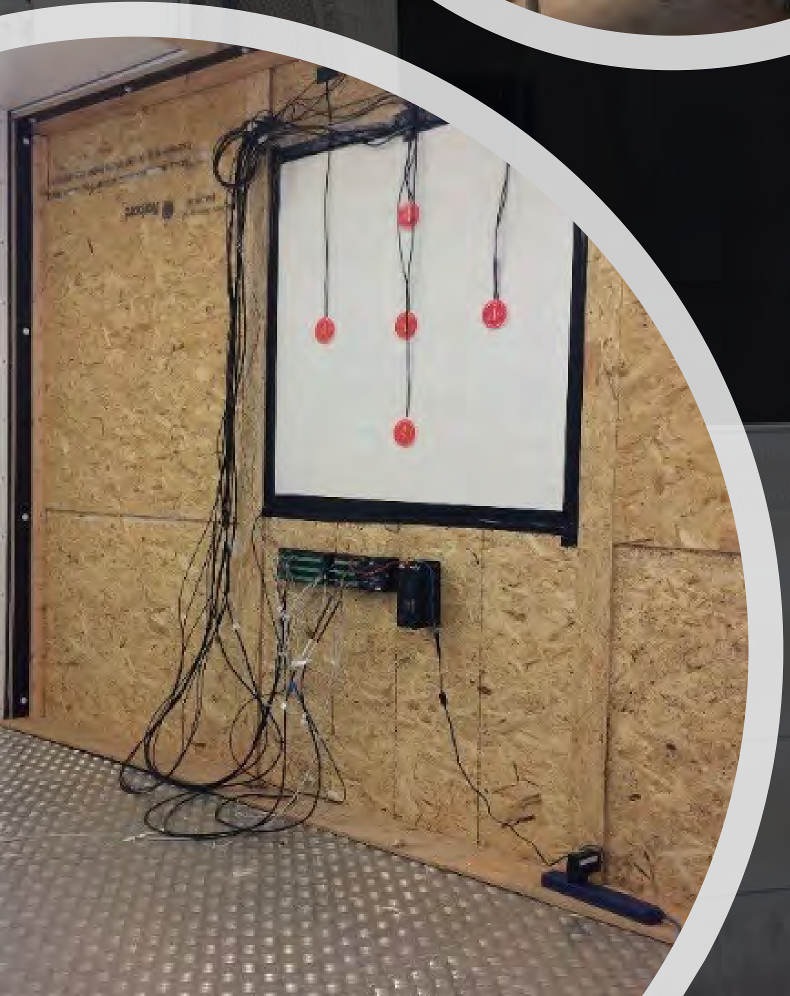
Centre expertise and activities

- Laboratory activities
  - Moisture Buffering (MBV)
  - Binder optimisation e.g. for rapid drying
  - Mechanical performance
  - Hygrothermal evaluation
  - Porosimetry (MIP)
- Field testing
  - Full scale hygrothermal performance
  - In-situ thermal transmittance
  - Preliminary tests for product certification
  - Thermographic studies









University of Bath
Research facilities:
Building Research Park

Large scale structural and building physics test facilities

Performance testing and lab-based characterisation

Straw fibre orientation evaluation

Computed Tomography Scanning

"Optimising orientation of the straw fibres in bales has successfully reduced thermal conductivity, compared to conventional agricultural bales, by 38%"

Prefabricated Straw Bale: BaleHaus@Bath

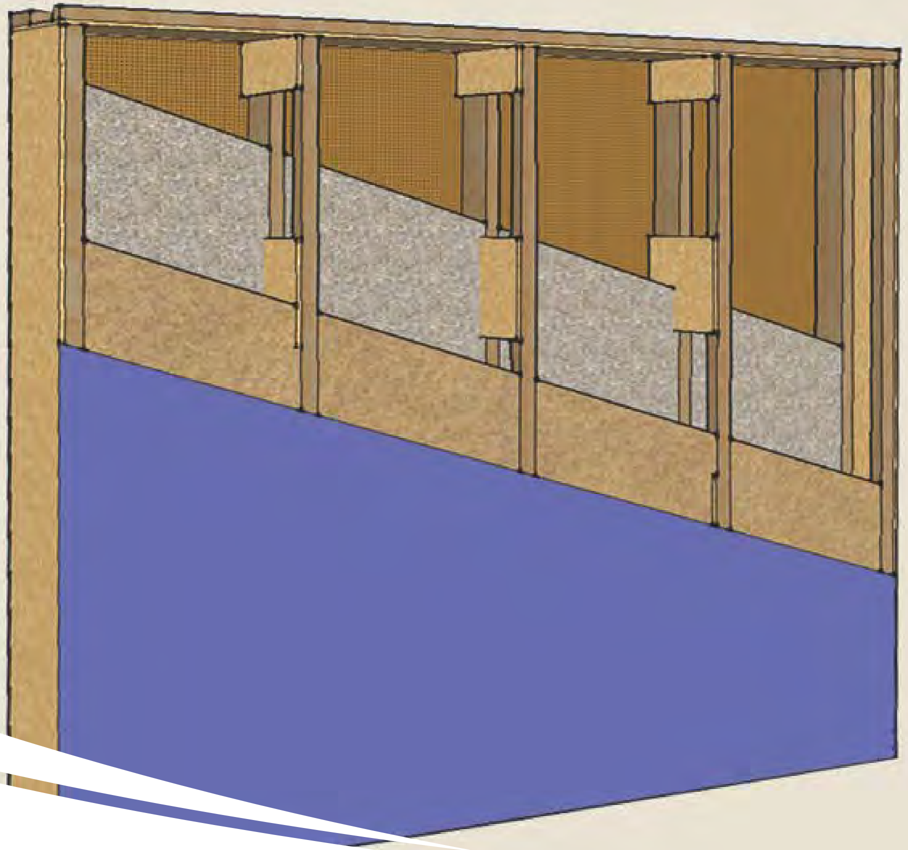
- Strawbale construction
- Lime plastered
- Fabricated offsite but locally using a ‘Flying Factory’
- Wall thermal transmittance measured at 0.18 W/m^{2}K

LILAC, Leeds UK – Strawbale ‘ModCell’

Real building development

LILAC
Low Impact Living Affordable Community

Hemp-lime

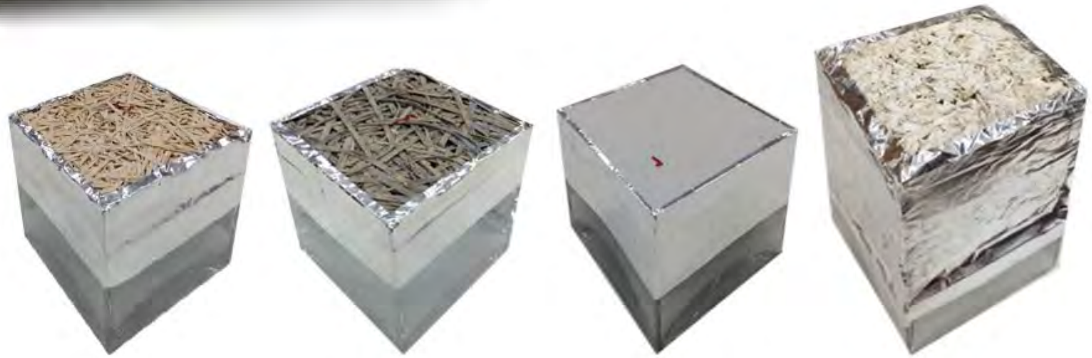


HEMPSEC

Co-funded by the Eco-innovation Initiative of the European Union

HEMPSEC
Pre-Fabricated hemp-lime composite panels

Performance testing and lab-based characterisation



- Vapour diffusion resistance factor
- Compressive strength
- Thermal diffusivity and conductivity

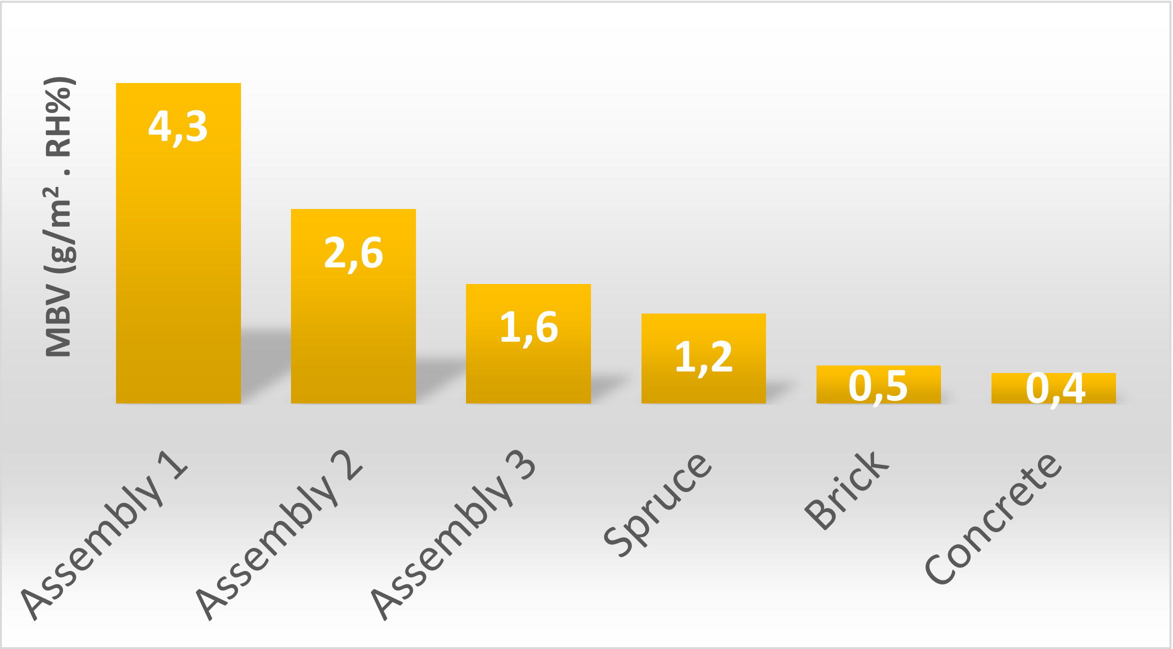
HEMPSEC

Performance testing and lab-based characterisation

Assembly 1
Exposed hemp-lime

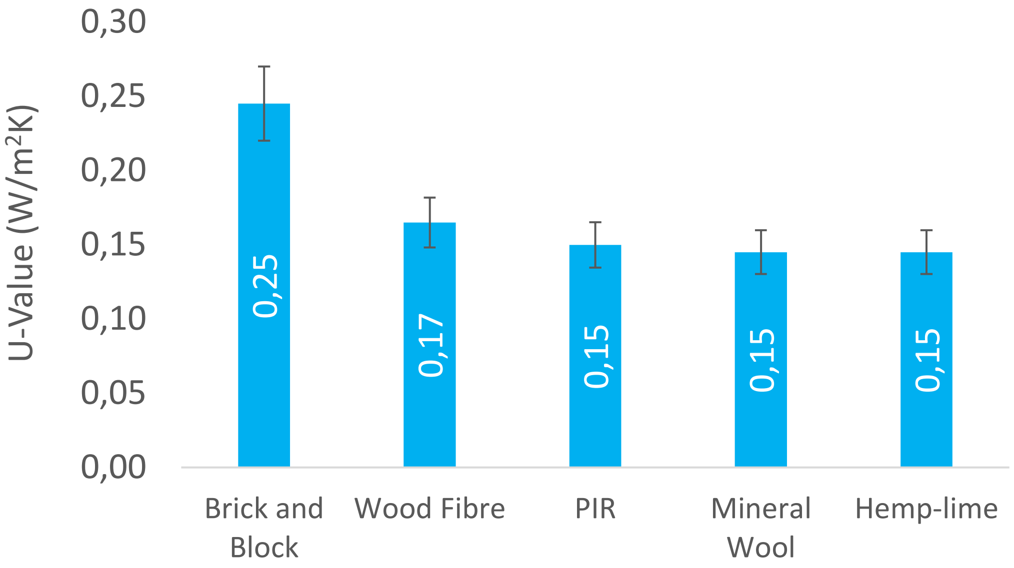
Assembly 2
Lime plastered

Assembly 3
Gypsum board



HEMPSEC

Large scale testing.



HEMPSEC

Demonstrating performance: International collaboration

KUBIK – Bilboa, Spain

The HIVE - Swindon, UK

HEMPSEC

Real building development:
M&S retail store Cheshire Oaks 'Eco Store', UK.

UNIVERSITY OF BATH
PRIFYSGOL BANGOR UNIVERSITY
tecnalia Inspiring Business
modcell
Greenovate! EUROPE
CLAYTEC® Baustoffe aus Lehm.
Fraunhofer IBP
nesocell
kronospan
SKANSKA
bre
acciona Infraestructuras

ECO-SEE

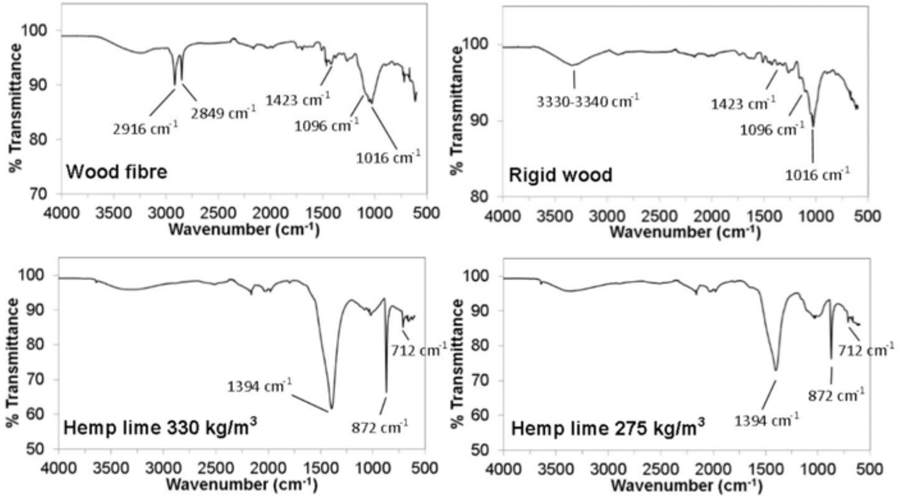
"The ECO-SEE project aims to develop new eco materials and components for the purpose of creating both healthier and more energy efficient buildings."

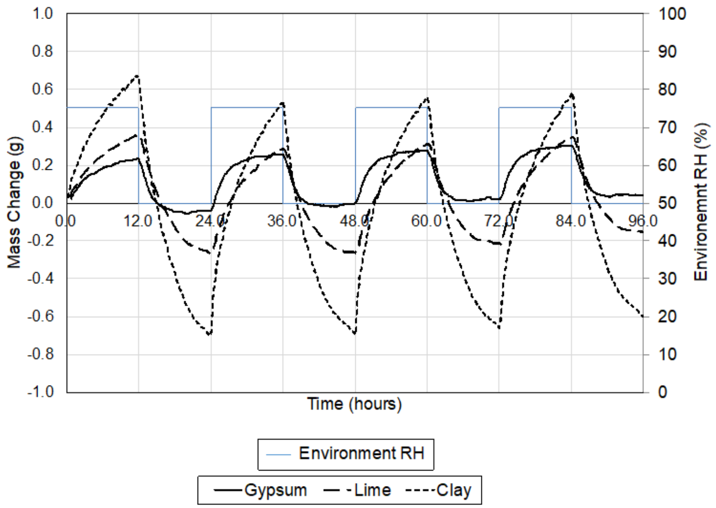
ECO-SEE is co-financed by the European Commission under the 7th Framework Programme for Research and Technological Innovation.

ECO-SEE

Tenax tube

2, 4-DNPH cartridge





IEQ evaluation

- VOCs are trapped in Tenax tubes and analysed by gas chromatography and mass spectroscopy (ISO 16000-6)
- Formaldehyde is absorbed in a 2,4-DNPH cartridge and then analysed by high performance liquid chromatography (ISO 16000-3)
- Moisture buffering of popular finishing materials – Gypsum, Lime, and Clay plaster (ISO 24353)

ECO-SEE Materials: Insulation & panel development

- Cellulose (flakes)
- Wood fibre
- Mineral wool
- Hemp-fibre
- Hemp-lime
- Sheep's wool

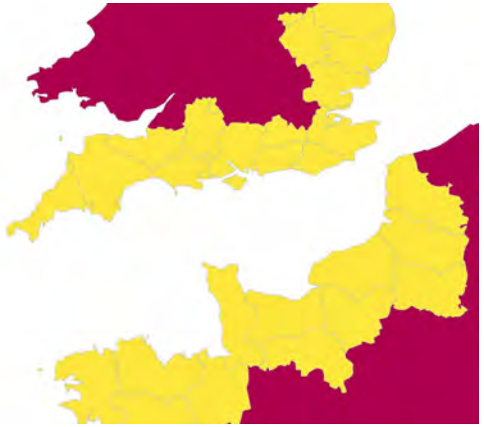
Sustainable Bio & Waste Resources for Construction

SB&WRC Sustainable Bio & Waste Resources for Construction

Interreg France (Channel Manche) England

European Regional Development Fund

Opportunities for addressing material use and waste in construction.



Co-products & waste

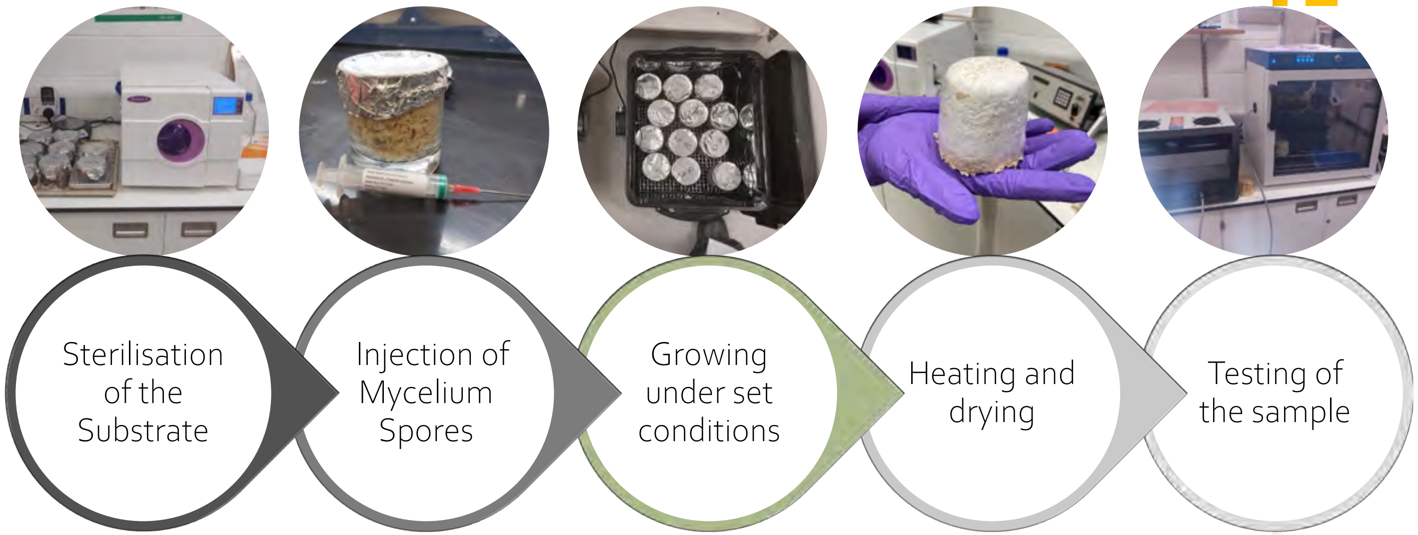
Aim to develop prototype construction materials from agricultural co-products:

- Wheat straw
- Maize pith
- Recycled polyester duvets

Waste reduction and bio-remediation: Mycelium use in construction

Aim to characterise fungal strains and investigate substrate options/environmental conditions:

- Waste wood – sawdust
- Hemp shiv
- Straw
- Cellulose (waste paper)





Waste reduction and bio-remediation: Mycelium use in construction – future work

- Scale-up to building-scale insulation panels
- Seeking to improve thermal performance
- Life Cycle Assessment

Centre for Innovative Construction (CICM) Achievements (2006-2023)

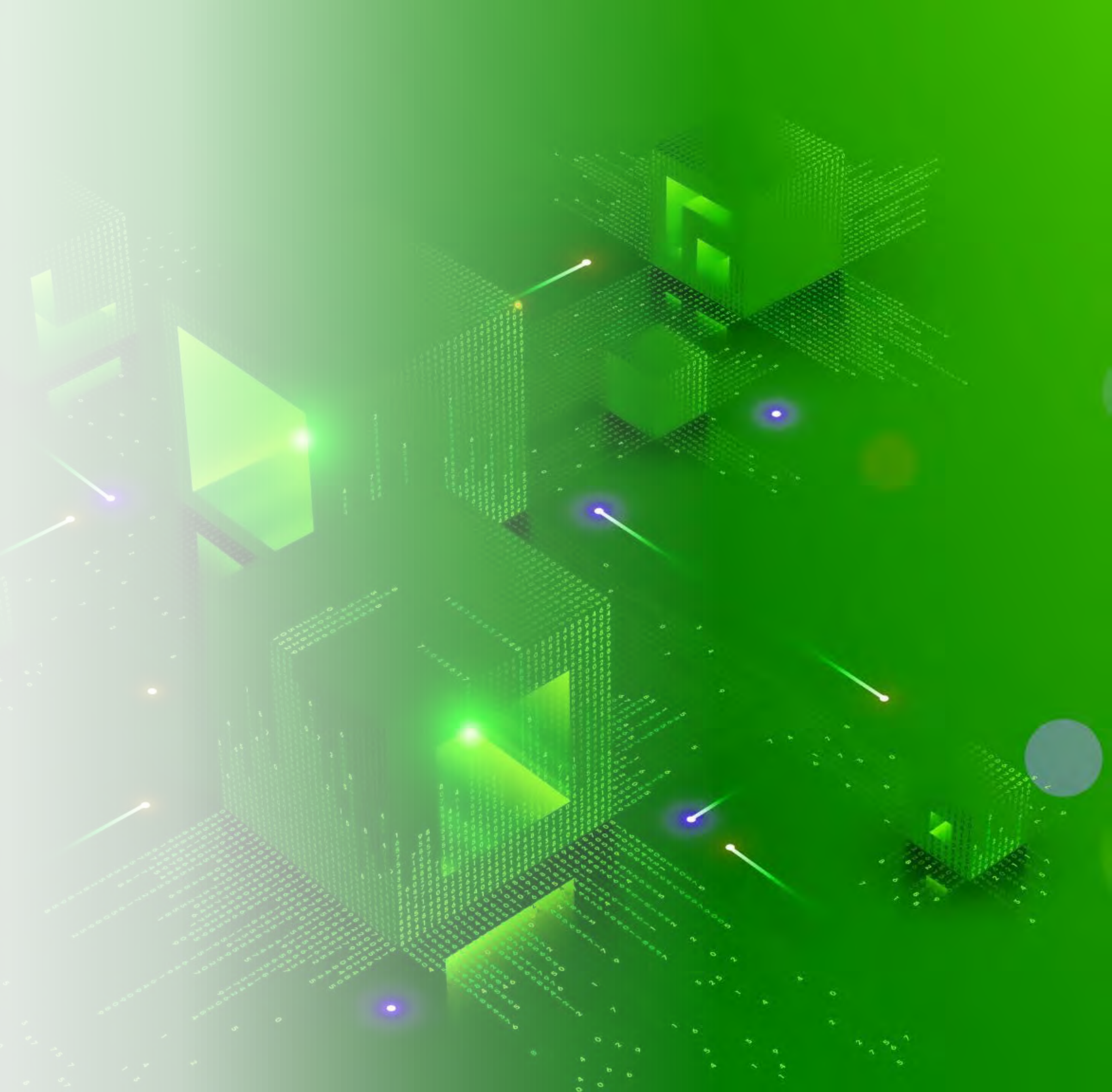
At our peak:

- Around 16 full-time academic staff
- 7 research staff
- Around 40 research students

- Research income over €26 M
- 72 PhD graduates
- 25 Books
- 230 Book chapters
- Over 300 Conference papers
- Over 700 Journal papers

New Faculty Research Centres – Challenge led

- Bioengineering and Biomedical Technologies
- **Climate Adaptation and Environment Research**
- Digital, Manufacturing and Design
- Integrated Materials, Processes and Structures
- **Regenerative Design and Engineering for a Net-Positive world**
- Propulsion and Mobility
- **Sustainable Energy Systems**

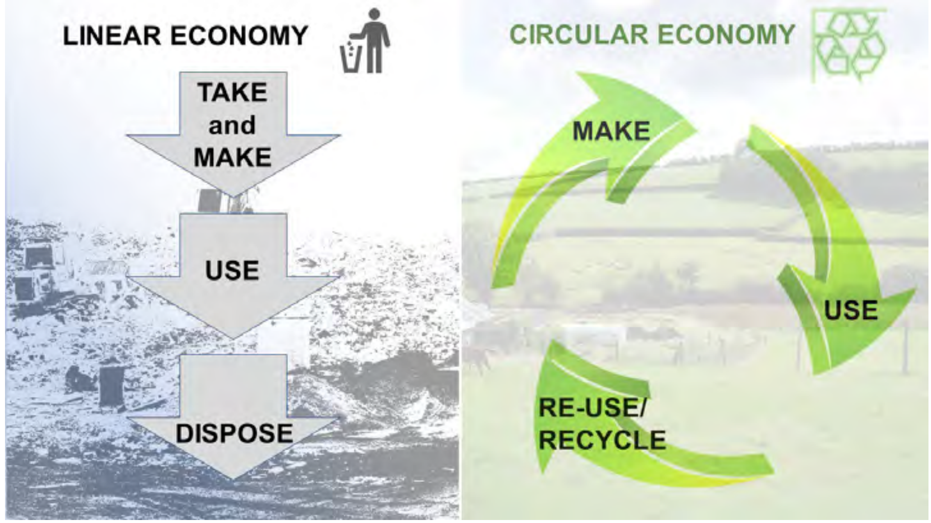


Future opportunities
Circularity in construction

Construction and the circular economy

Circular construction:

- Construction in a sustainable manner,
- Materials re-used or recycled,
- Buildings disassembled or adapted after first design life



Challenges

- High initial costs of materials
- Contractual and risk issues may result in circular or bio-based elements being value-engineered out of projects
- Upscaling production – available quantities
- Material research, certification, and accreditation
- Knowledge of material properties, especially upon re-use
- Life Cycle Assessment

Opportunities

Potential to improve occupant wellness

New stakeholders engaging and partnering with established stakeholders.

Modern methods of construction - designing for disassembly and adaptability

Connections - increased use of dry mechanical, gravity, and interlocking connections

Material inventories and databases, EPCs etc.

Localise construction - use of local materials

Make construction a key component of tackling climate change and reaching international carbon targets

Conclusions

Upscaling of circular bio-based construction has potential to reduce the carbon footprint of construction

Policy both at national and regional levels is crucial to drive growth of bio-based circular construction

Challenges: High initial costs, opposition within client organisations, risk, knowledge, status of construction on policy agendas

Opportunities: Legislation, long-term economic gains, the wellness agenda, regenerating local economies, sustainability demonstrated in planning applications.

Required: Increase and promotion of case studies and accreditation of materials

Kiitos

Dr Andy Shea
a.shea@bath.ac.uk

Photo: Laura Vanzo, Visit Tampere https://www.tampere-talo.fi/en/visitors/moominmuseum/

Calling researchers and practitioners

Future Special Issue - Sustainable Technologies and Systems for Net Zero Carbon.

Honorary Special Issue Editor

Dr Rokia Raslan The Bartlett, UCL Faculty of the Built Environment, London, UK

Co-Editors for this special issue:

- Lori McElroy, Strathclyde University, Scotland
- Mohamed Hamdy, NTNU Norway
- Muthukumar Ramaswamy, Practitioner, India.