ECO-SEE

# INNOVATIVE ECO-MATERIALS FOR BETTER QUALITY BUILDINGS

Pete Walker
BRE Centre for Innovative Construction Materials
Dept. Architecture & Civil Engineering
University of Bath



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# ECO-SEE:

## Eco-innovative, Safe and Energy Efficient wall panels and materials for a healthier indoor environment



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# ECO-SEE CONSORTIUM

UNIVERSITY OF BATH

BCB
Une Société du Groupe Lhoist

bre

acciona
Infraestructuras

Black Mountain
NATURAL INSULATION

ENVIRONMENT PARK
Parco Scientifico Tecnologico per l'Ambiente

SKANSKA

CLAYTEC®
Baustoffe aus Lehm.

Fraunhofer
IBP

PRIFYSGOL
BANGOR
UNIVERSITY

Greenovate!
EUROPE

kronospan

modcell

nesocell

tecnalia
Inspiring Business



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# Acknowledgements (UBATH)


Lots of people to thank, including:

- Caroline Ang
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- Pete Hompstead
- Maria Korea
- Mike Lawrence
- Cheng Long
- Dan Maskell
- Francis Moran
- Helen Perryman
- Andy Shea
- Eloise Spark
- Andrew Thomson




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# BRE Centre for Innovative Construction Materials

- Research Centre in partnership with BRE (formerly Building Research Establishment) since 2006
- 17 academic staff; 40+ researchers
- Research fields:
  - Low carbon cements and concrete materials
  - Innovative concrete structures
  - Timber Engineering
  - Eco-materials (bio-based; mineral based)
  - Energy performance materials
- Coordinators of the ECO-SEE project



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# Indoor Air Quality

We spend 80-90% living indoors:

- Measures of indoor air pollutant levels are often higher than outdoor levels
- Indoor air pollutants have been ranked among the top five environmental risks to public health
- 30% percent of new and remodelled buildings worldwide may be the subject of excessive complaints related to indoor air quality

Various studies have confirmed that airtight buildings with low air exchange rates lead to deterioration in indoor environmental quality for occupants



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# Unintended consequences of airtight buildings

Several factors influence the quality of our indoor environment:

- Volatile Organic Compounds (VOCs)
- Radon
- Fibres
- Particulate matter
- Moisture and humidity levels
- Rotting and microbiological/mould matter
- Temperature
- Acoustics

Contaminants in the indoor environment are around a 1,000 times more likely to be inhaled than outdoors.



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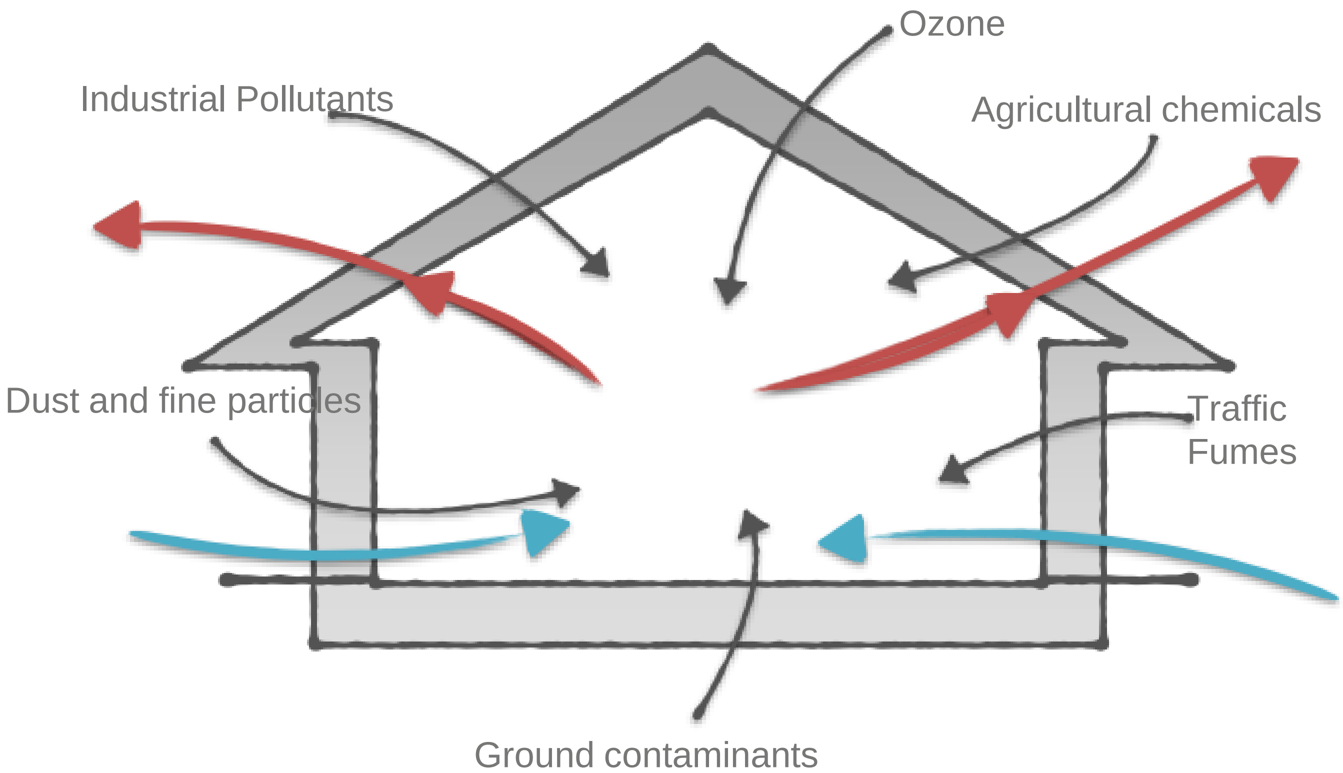


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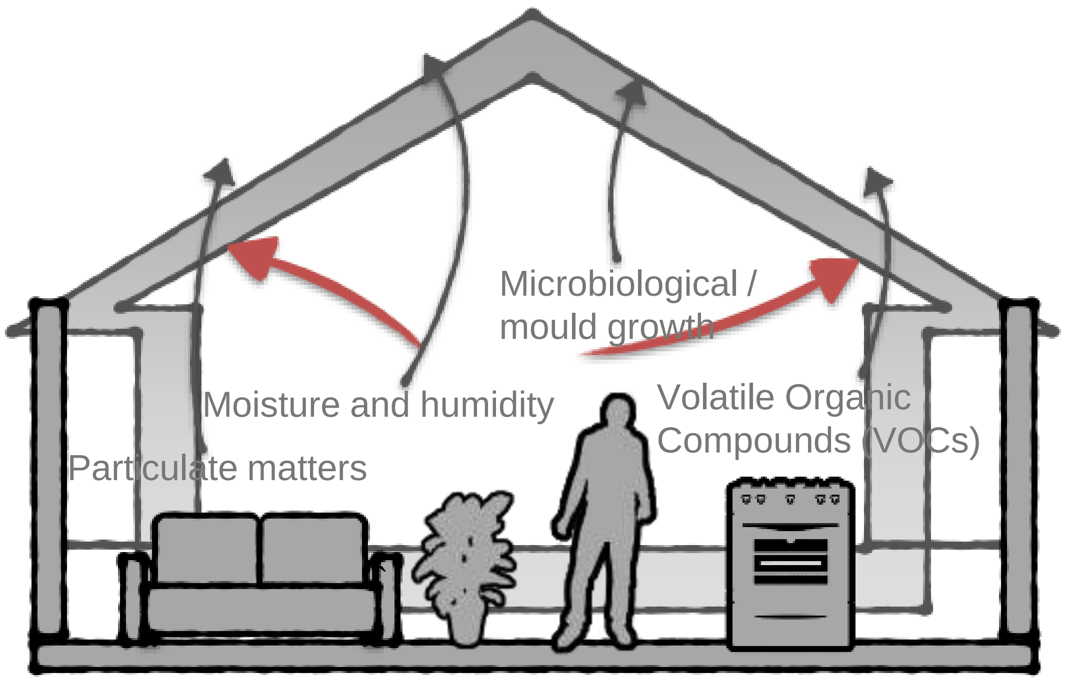
Microbiological /
mould growth
Moisture and humidity
Volatile Organic
Compounds (VOCs)
Particulate matters

## Business costs:

1% energy

10% rent

85% staff cost

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**100%** Cognitive improvement due to low levels of $CO_2$ and Volatile Organic Compounds (VOCs)

**£30 billion** cost to UK due to unproductive staff

**NHS** Recognised chronic health effects of indoor pollutants even at low levels of exposure

**1 in 8** of total global deaths due to air pollution

SEVENTH FRAMEWORK PROGRAMME

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| | | |
|---|---|---|
| RH | <40% | Respiratory infections Ozone |
| | 60%> | Fungi, Mites, Chemical interactions |
| $CO_2$ | 250-350ppm | Normal outdoor level |
| | 600-1,000ppm | Headaches |
| | 1,000-2,000ppm | Drowsiness and poor air |
| Particulates | $PM_{2.5}$ | 10 µg/m$^3$ annual mean |
| | | 25 µg/m$^3$ 24-hour mean |
| | $PM_{10}$ | 20 µg/m$^3$ annual mean |
| | | 50 µg/m$^3$ 24-hour mean |
| VOCs | < 90 ppb | Minimal discomfort |
| | 90 - 800ppb | Irritation |
| | 800 - 6600ppb | Discomfort and headaches |
| | >6600 ppb | Toxic |

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# WHY ECO-MATERIALS?

Beneficial properties:

- Low carbon/low energy
- Life Cycle Impact
- Thermal Insulation
- Hygrothermal properties
- Vapour permeability


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# AIM & OBJECTIVES FOR THE ECO-SEE PROJECT

Aim:

Use materials to improve indoor environmental quality, reducing reliance on active measures

Objectives:

- 15% lower embodied energy
- 20% longer life
- 20% lower build costs



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# ECO-SEE project structure

WP1: Characterising existing eco-materials in passive indoor environmental control

WP2: Innovative photocatalytic coatings for indoor air quality improvement

WP3: Novel eco-materials for passive indoor environmental control

WP4: Design tools for holistic assessment of IEQ

WP5: Scale-up of eco-materials/products

WP6: Field test validation and energy performance simulation

WP7: Demonstration and implementation work

WP8: LCA/LCC

WP9: Dissemination and exploitation

WP10/WP11: Management and coordination


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# WHAT ARE ECO-MATERIALS?

**Low carbon/low energy/renewable/plentiful traditional materials**

- Bio-based materials
  - Crop residues (straw, hemp)
  - Bamboo
  - Wood
  - Wool
- Mineral based materials
  - Clay/earth based (plasters, blocks, monolithic)
  - Natural stone

**Lower energy/carbon developments of industrial materials**

- Lower carbon cements and concretes
  - Cement replacements
  - Geopolymers
- Recycled products
  - Recycled metals
  - Reuse of waste materials


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# ECO-SEE Innovative materials and products

- Bio-based insulation with enhanced capability
- Novel coatings with improved environmental regulation
- Photocatalytic panels
- Low VOC wood panels
- ECO-SEE wall panels
- Design tools for holistic indoor environmental quality



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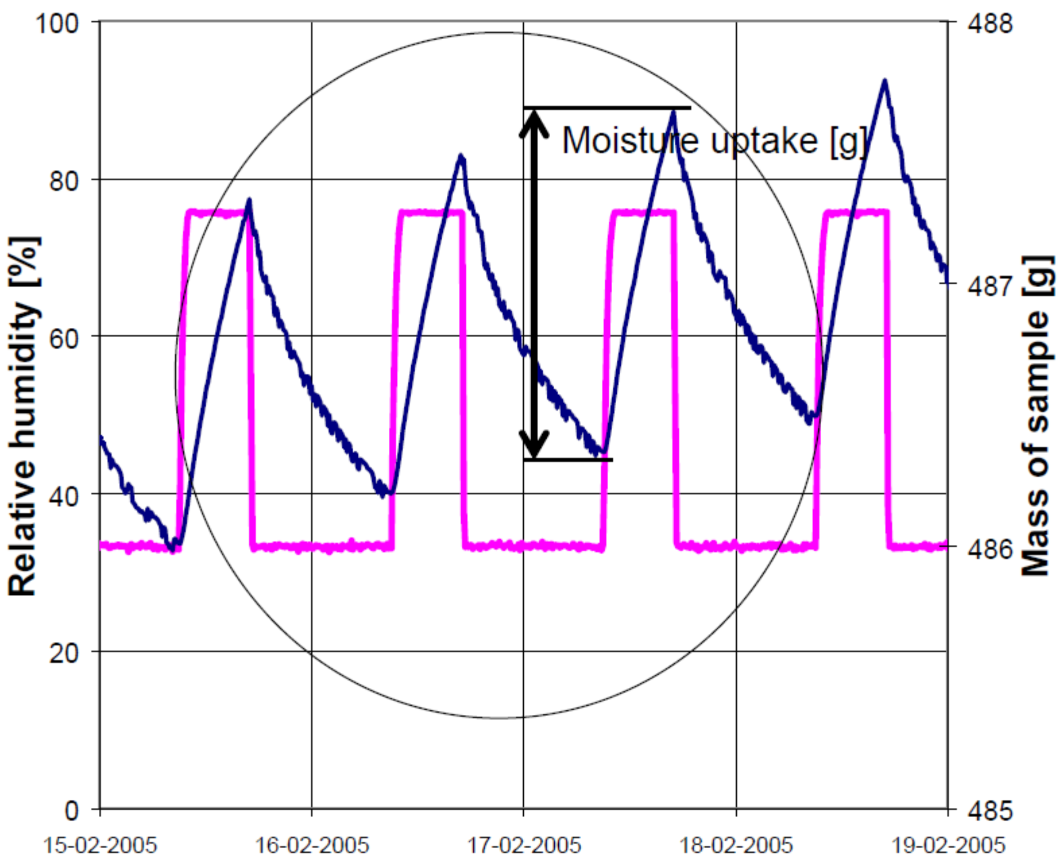
# Moisture buffering


From Rode et al., 2005



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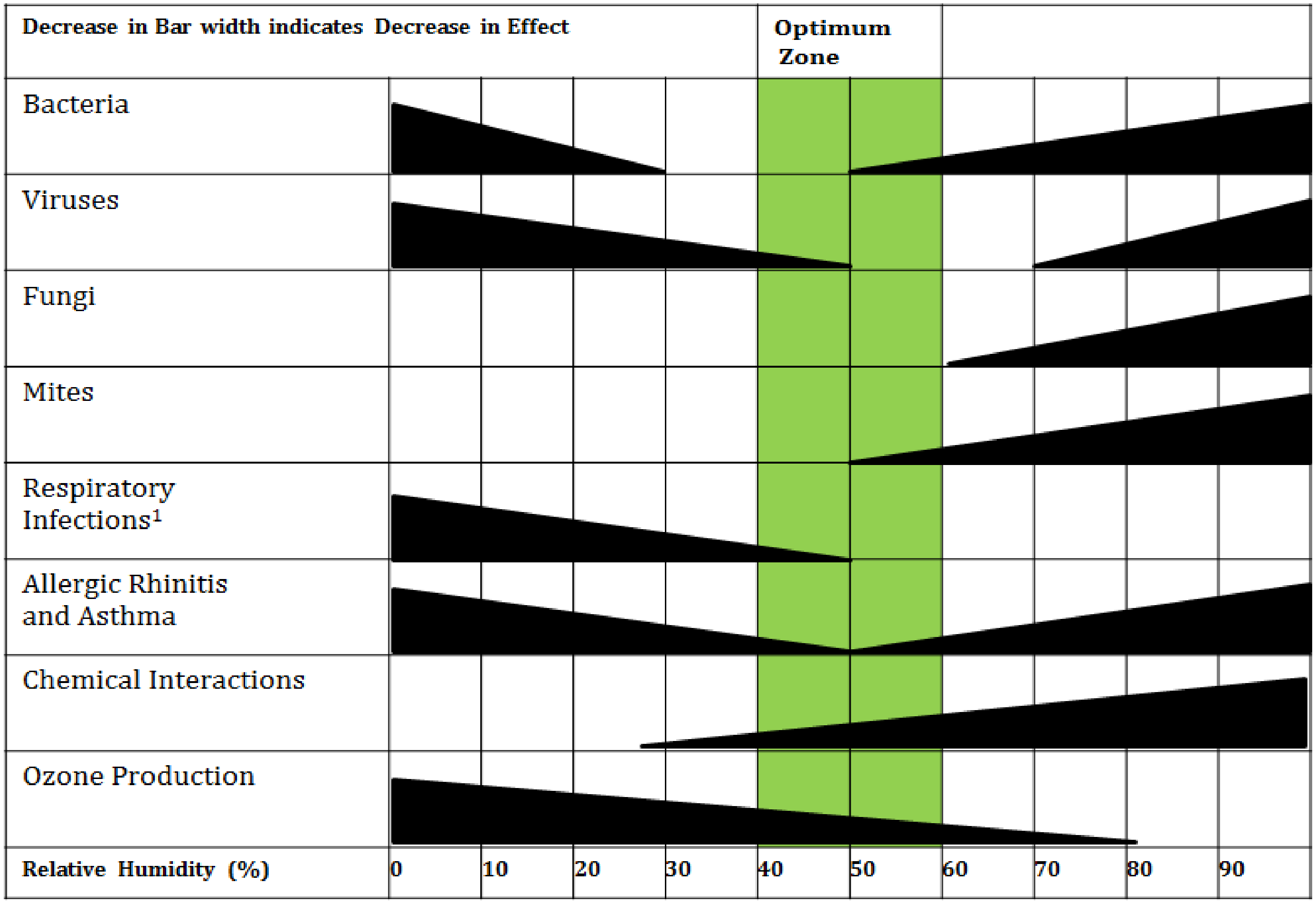
# Benefits of moisture buffering



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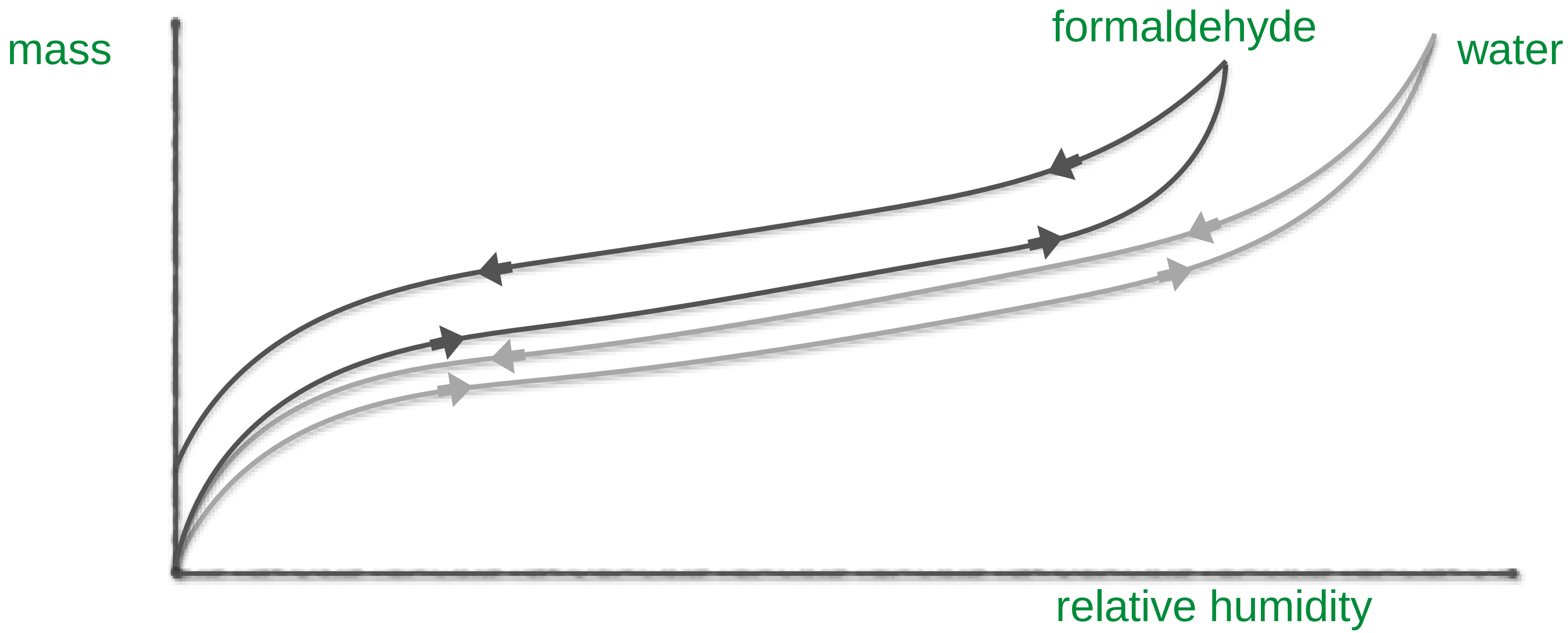
# VOC Capture



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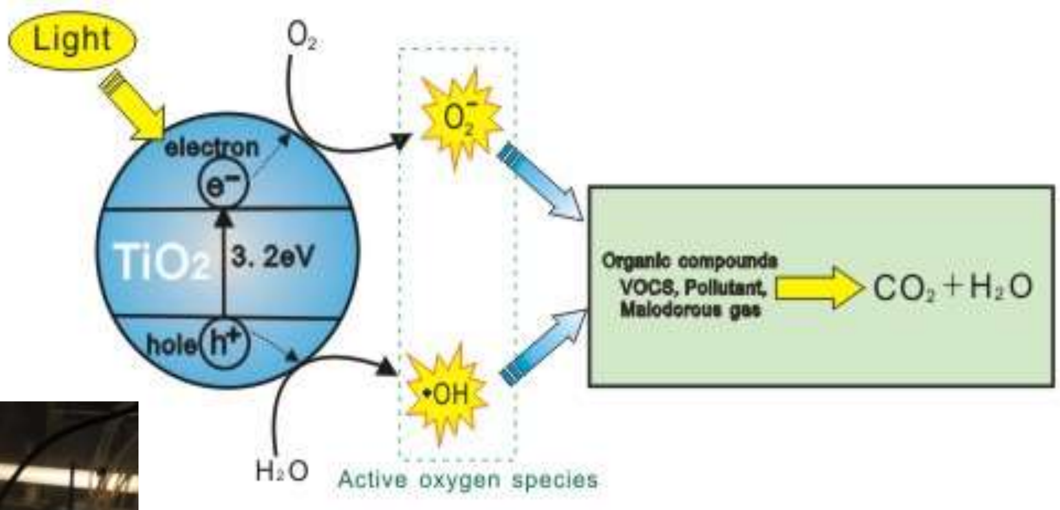
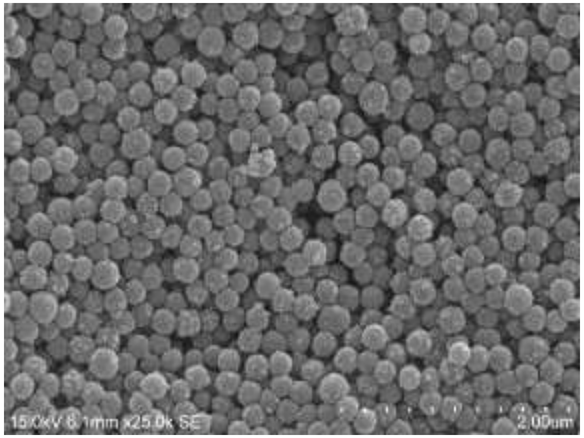
# Photocatalytic materials









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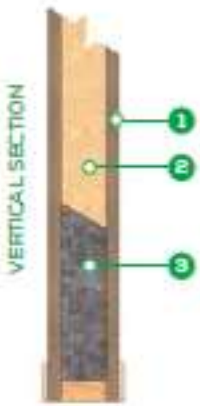
# ECO-SEE PANEL DESIGNS

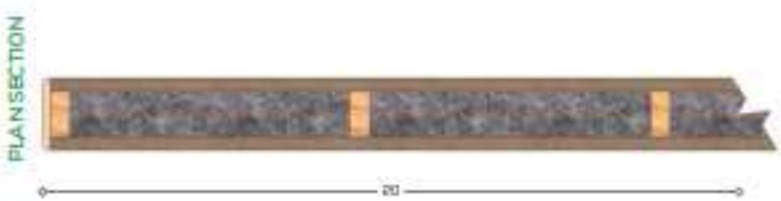
## INTERNAL




**1. ECO-SEE wall liner**
There are three liner finishes; Photocatalytic Lime, Clay, Photocatalytic Timber Boards.

**2. ECO-SEE internal panel timber frame**
The panel is made up of a softwood timber frame. In new buildings internal panels may be prefabricated as either open or closed elements. For installations in both new and retrofit projects the final finish will be installed in-situ once the building is weather tight and risk of surface damage is low.

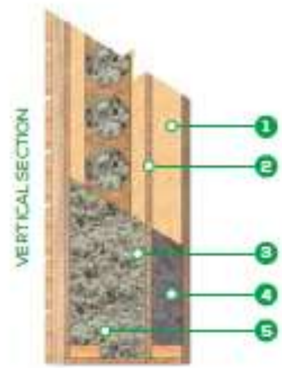
**3. ECO-SEE internal panels use enhanced**
Sheep's Wool insulation for acoustic separation. This inner blanket helps to buffer humidity and to degrade VOCs, which permeate through the vapour permeable liners.




## EXTERNAL

**1. ECO-SEE wall liner**
There are three liner finishes; Photocatalytic Lime, Clay, Photocatalytic Timber Boards.

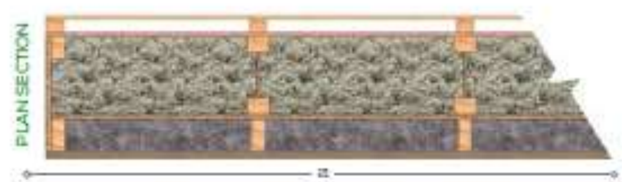
**2. ECO-SEE external panel timber frame**
The timber frame is made up of two sections; an outer chamber formed with timber I-Joists and an inner chamber. The two are separated with an OSB diaphragm which controls water vapour movement into the colder outer chamber while still allowing themoisture buffering properties of the inner insulation to be coupled with the internal environment.




**3. Outer layer of ECO-SEE insulation**
Uses either factory installed hemp fibre or Nesocell cellulose, which is blown in on-site.

**4. Inner layer of ECO-SEE insulation**
Uses enhanced Sheep's Wool insulation. This inner blanket helps to buffer humidity and to degrade VOCs, which permeate through the vapour permeable internal liner.

**5. External cladding**
Provides weather protection to the external ECO-SEE panels. Cedar cladding is shown but a wide range of materials and finishes can be used.



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# Unfired clay as a modern building material



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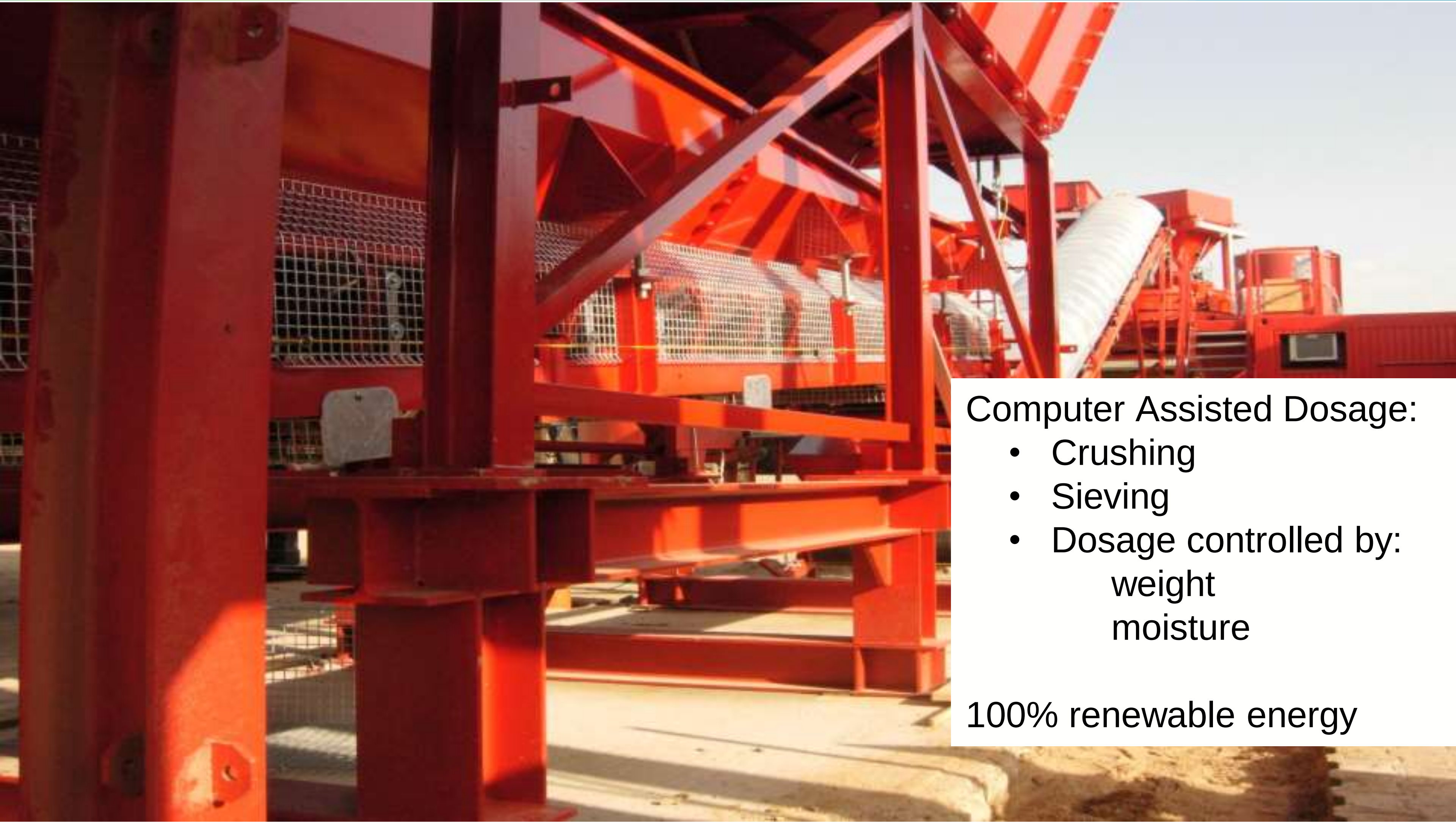

Computer Assisted Dosage:

- Crushing
- Sieving
- Dosage controlled by:
  - weight
  - moisture

100% renewable energy



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# Properties of clay coatings

- Water vapour adsorption and desorption
- Passive indoor humidity regulation
- Healthy in use
- Low embodied energy
- Re-plastification at any time
- Readily re-usable



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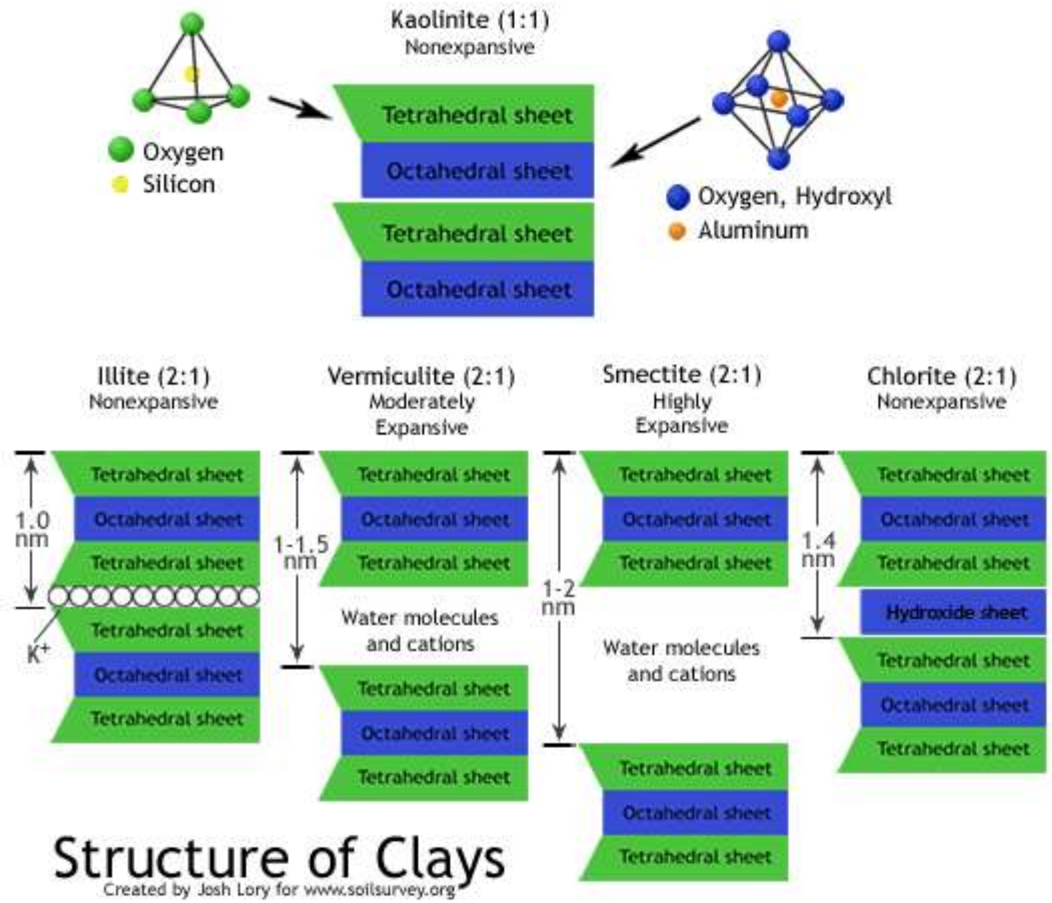


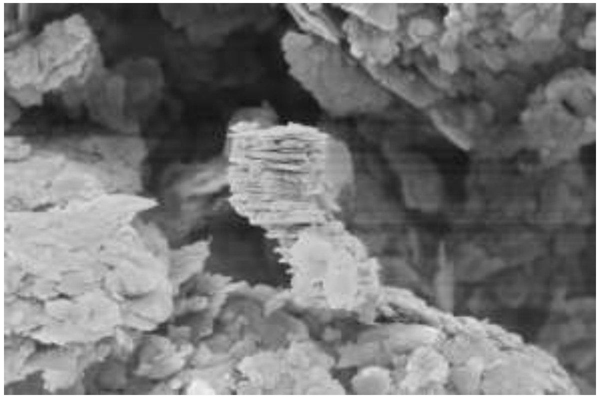



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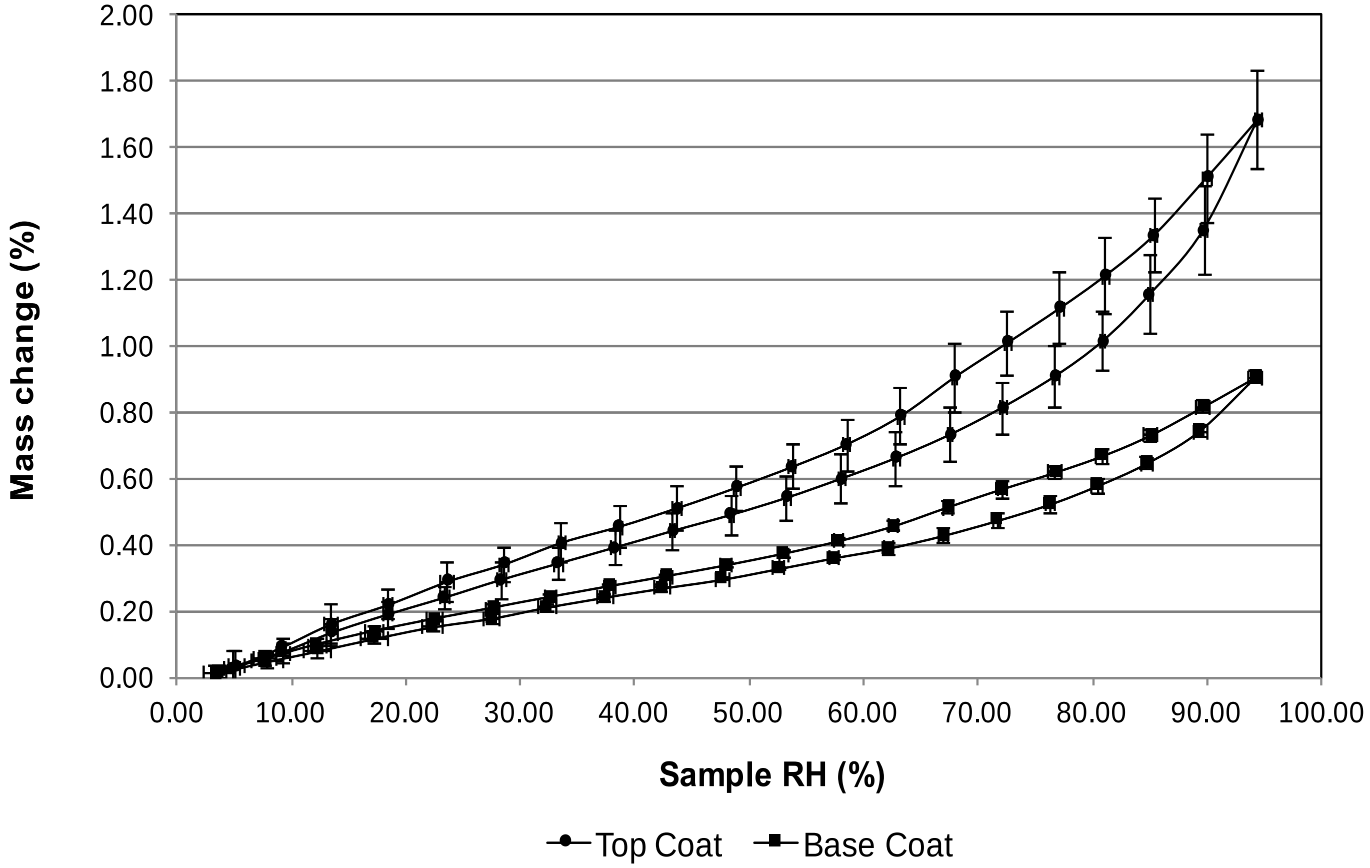
# Sorption

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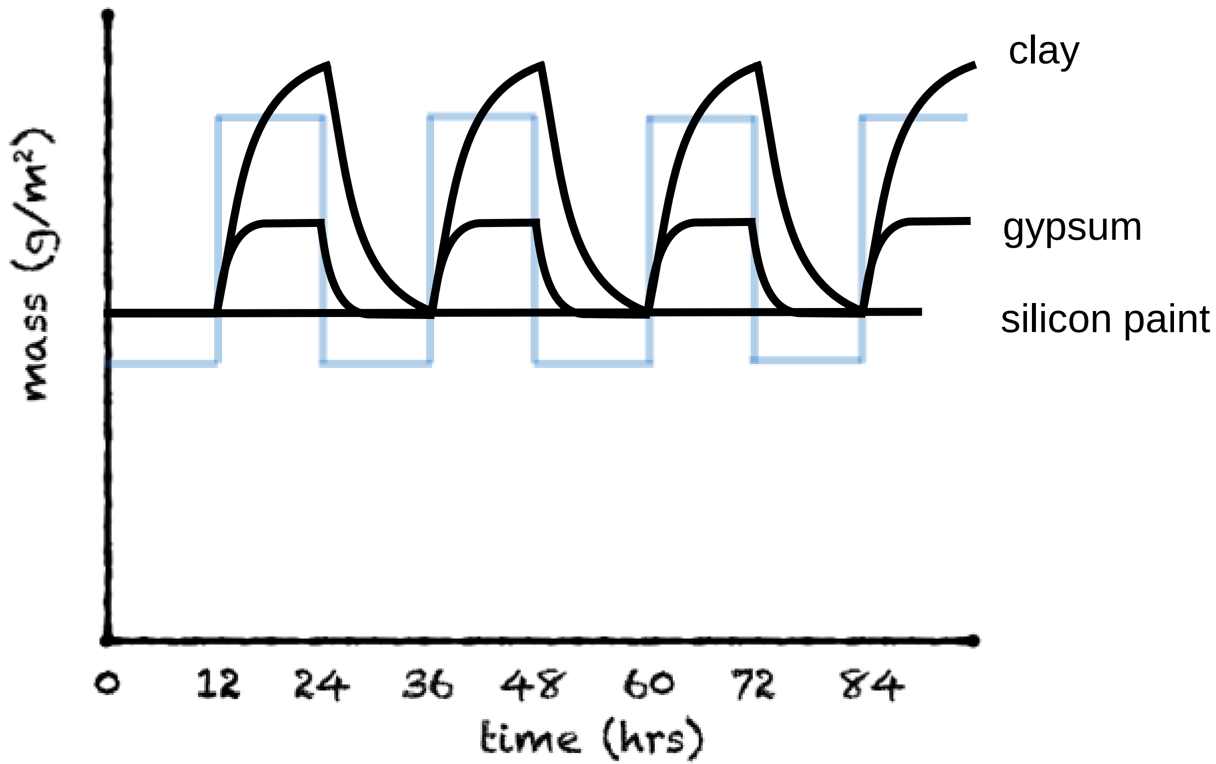
# Moisture buffering



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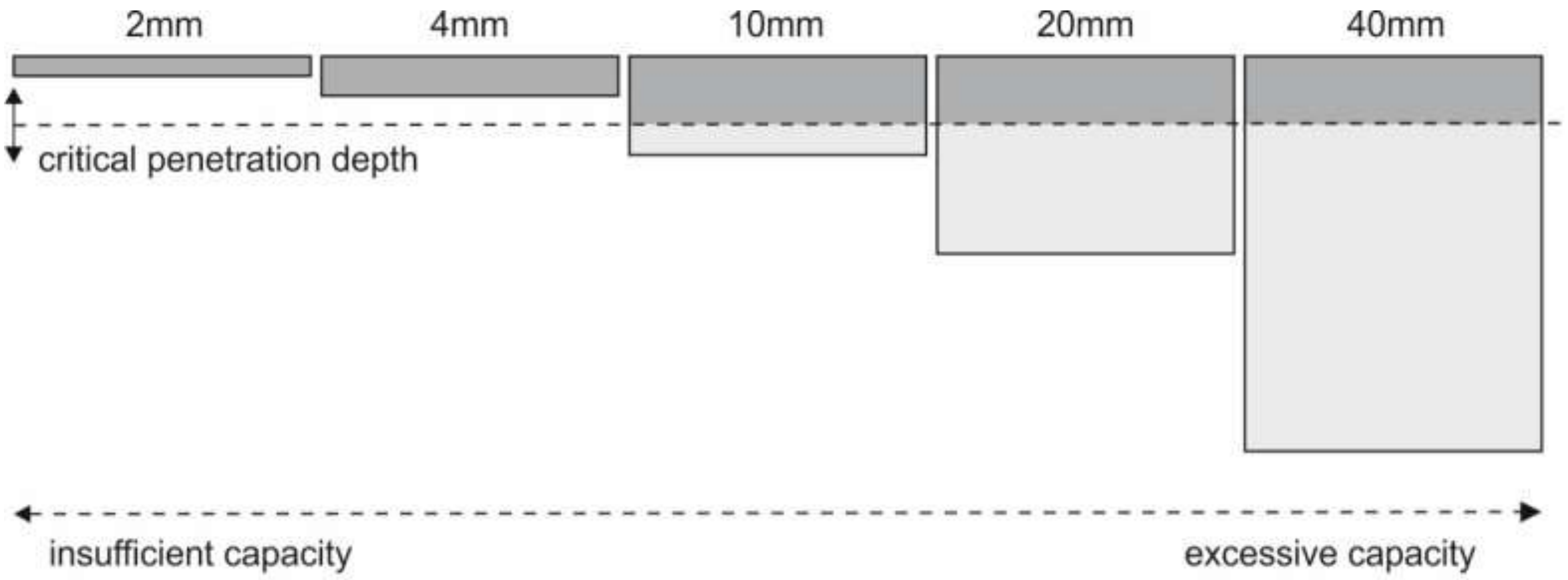
# How thick is thick enough?

## Experimental penetration depth



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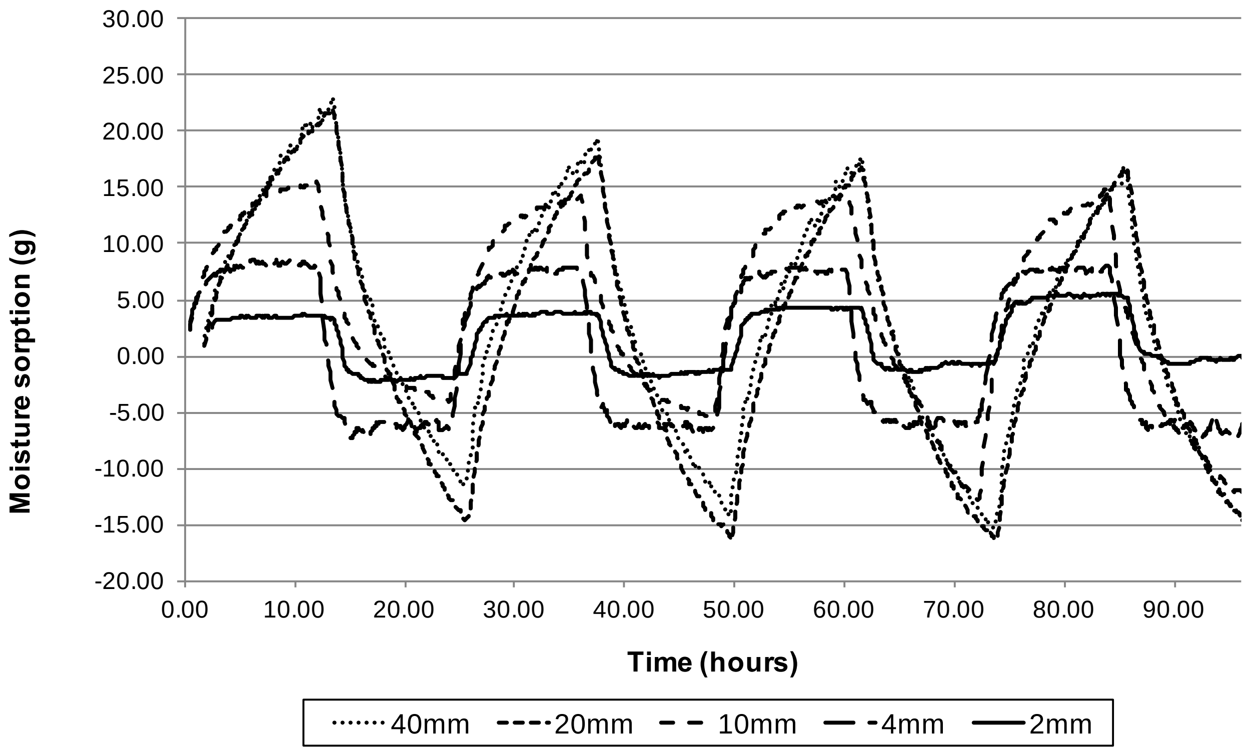
# Experimental penetration depth

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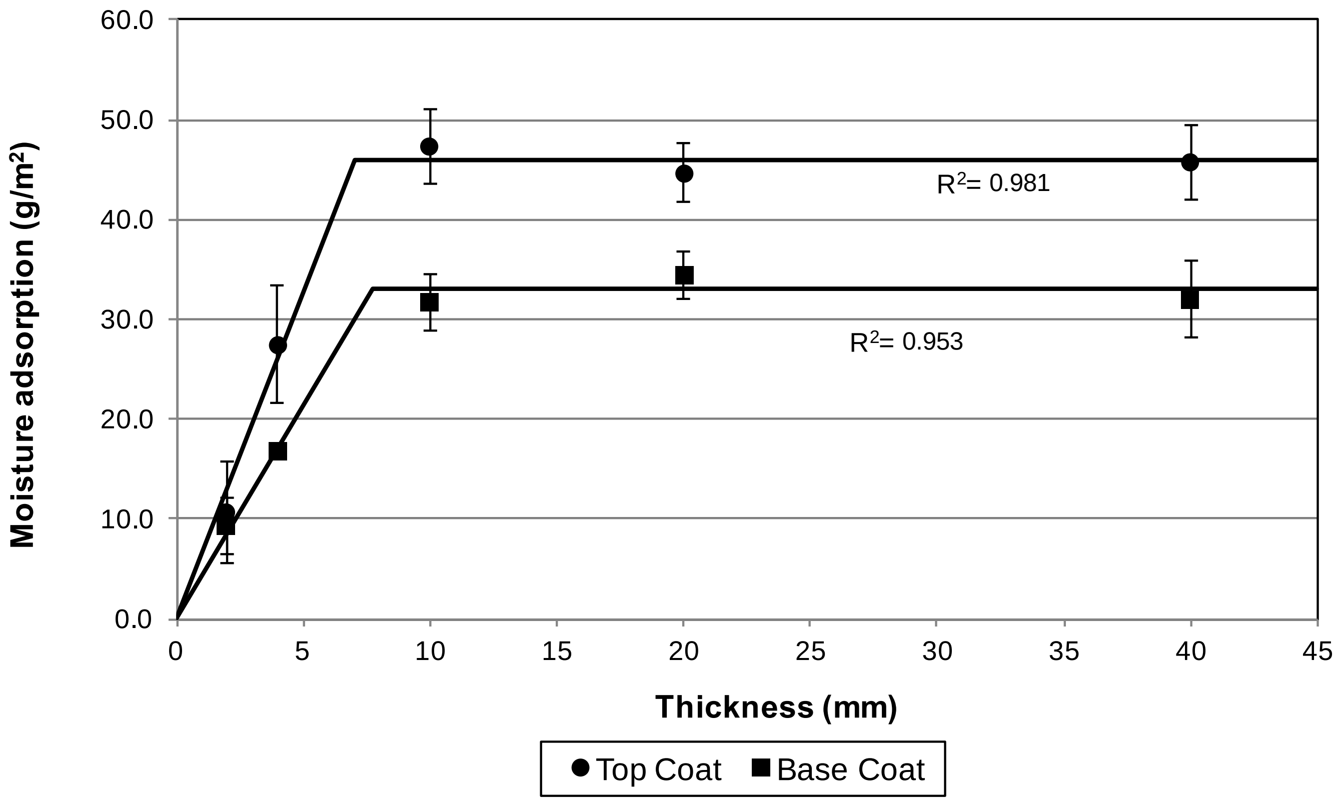
# Experimental penetration depth

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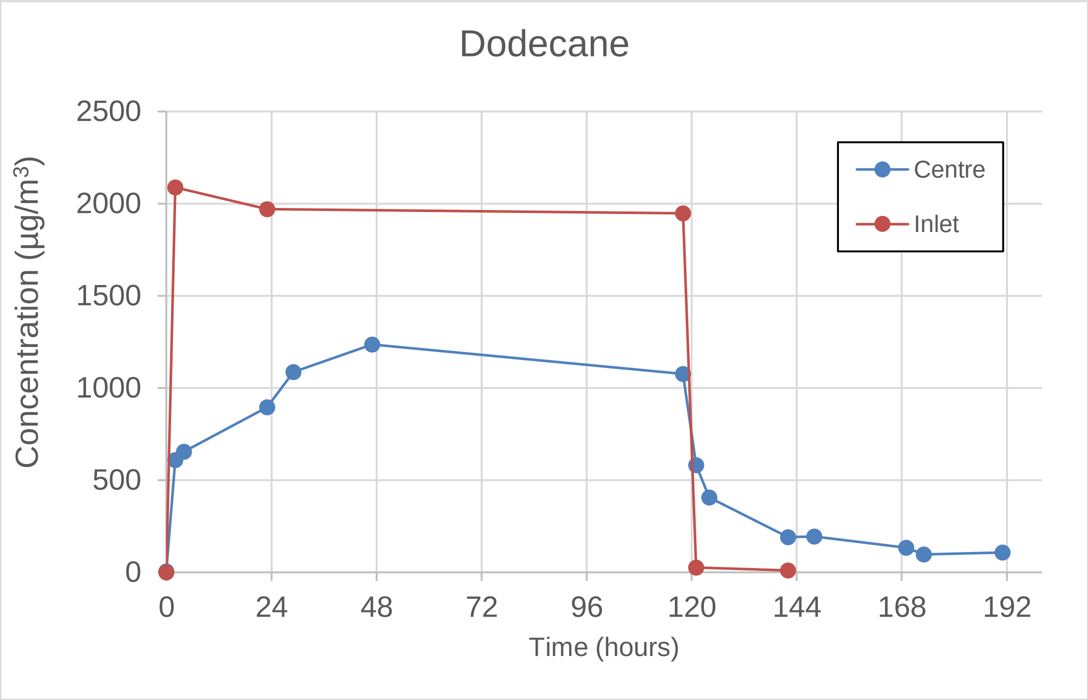
# VOC Adsorption/Desorption - Lab Results (E14/+2)

Curves differences after 24h adsorption

| | | µg/m³ | % |
|---|---|---|---|
| Toluene | Inlet-Centre | -12.75 | -1.4 |
| Limonene | Inlet-Centre | -99.25 | -16.7 |
| Dodecane | Inlet-Centre | -885.8 | -45.2 |



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# Bio-based insulation




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# ECO-SEE Materials: Insulation

Mineral wool

Hemp

Thermal flax

Hemp-lime (275 kg/m$^3$)

Cellulose flakes

Sheep's wool

Wood fibre

Hemp-lime (300 kg/m$^3$)



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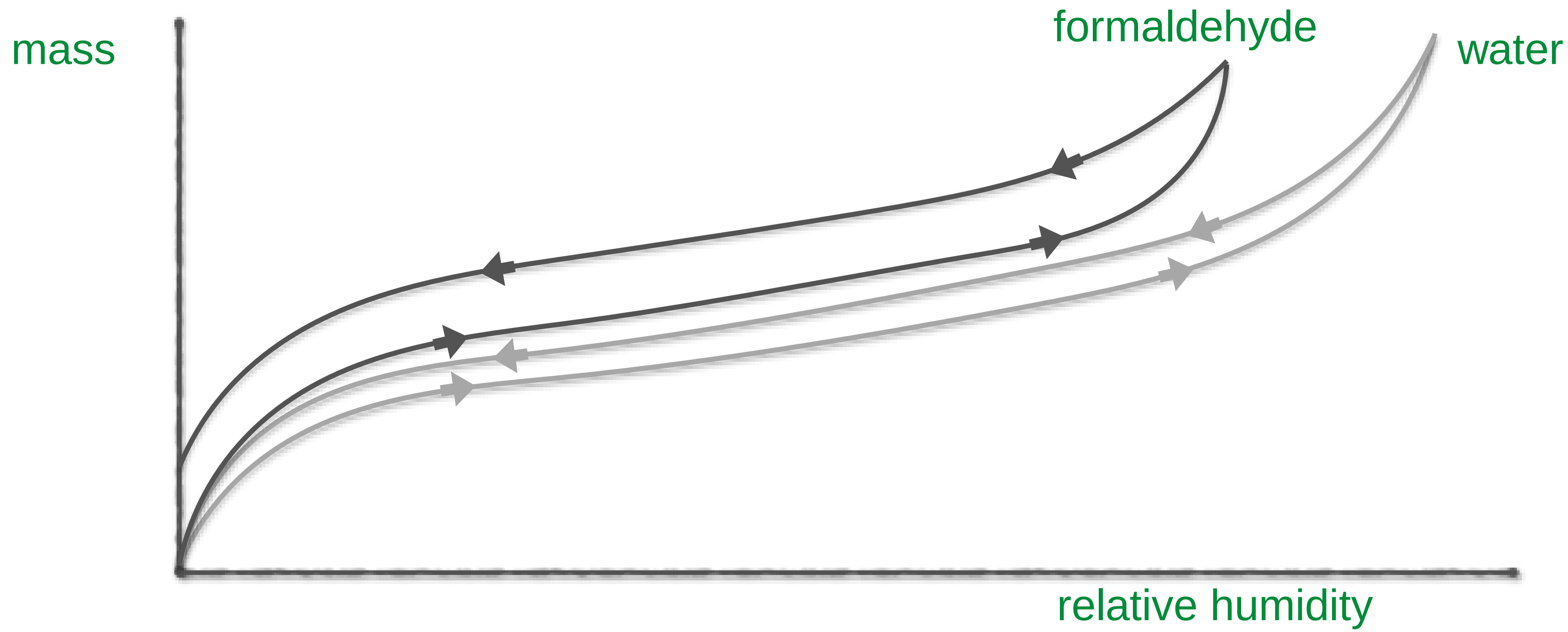
# VOC Capture



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# Over 100% improvement in VOC capture potential of sheep's wool insulation.




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# Photocatalytic coatings development



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- Development of doped photocatalytic nanoparticles. Commercial nanopowders and a silver-modified nanotitania developed by UAVR (produced via a green sol-gel procedure).

- Modified PC coatings were achieved a 50% higher photocatalytic activity under visible-light exposure than the most commonly used photocatalytic nanoparticles.

- Co-doped $TiO_2$ nano-particles were sol-gel coated onto alumina micro-particles for applying to flooring grade MDF boards. The coatings were based on a combination of $TiO_2$ particles, water, isopropyl alcohol (IPA) and commercial polyurethane/acrylate (PU/A) resin.


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Successful development at laboratory scale of two novel coatings, one P-C lime based and another polyurethane based for MDF panels.



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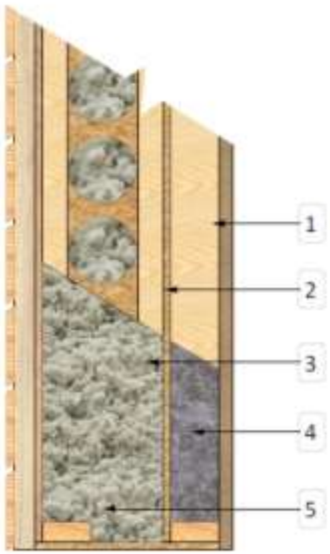
# Wall panel development




VERTICAL SECTION

1. ECO-SEE wall liner. There are three liner finishes; Photocatalytic Lime, Clay, Photocatalytic Timber Boards.
2. ECO-SEE external panel timber frame. The timber frame is made up of two sections; an outer chamber formed with timber I-Joists and an inner chamber. The two are seperated with an OSB diaphragm which controls water vapour movement into the colder outer chamber while still allowing the moisture buffering properties of the inner insulation to be coupled with the internal environment.
3. Outer layer of ECO-SEE insulation uses either factory installed hemp fibre or Nesocell cellulose, which is blown in on-site.
4. Inner layer of ECO-SEE insulation uses enhanced Sheep's Wool insulation. This inner blanket helps to buffer humidity and to degrade VOCs, which permeate through the vapour permeable internal liner.
5. External cladding provides weather protection to the external ECO-SEE panels. Cedar cladding is shown but a wide range of materials and finishes can be used.



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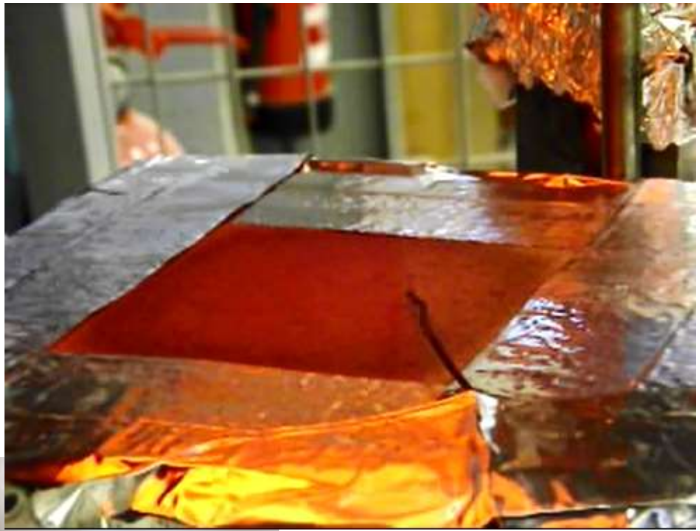



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# Demonstration



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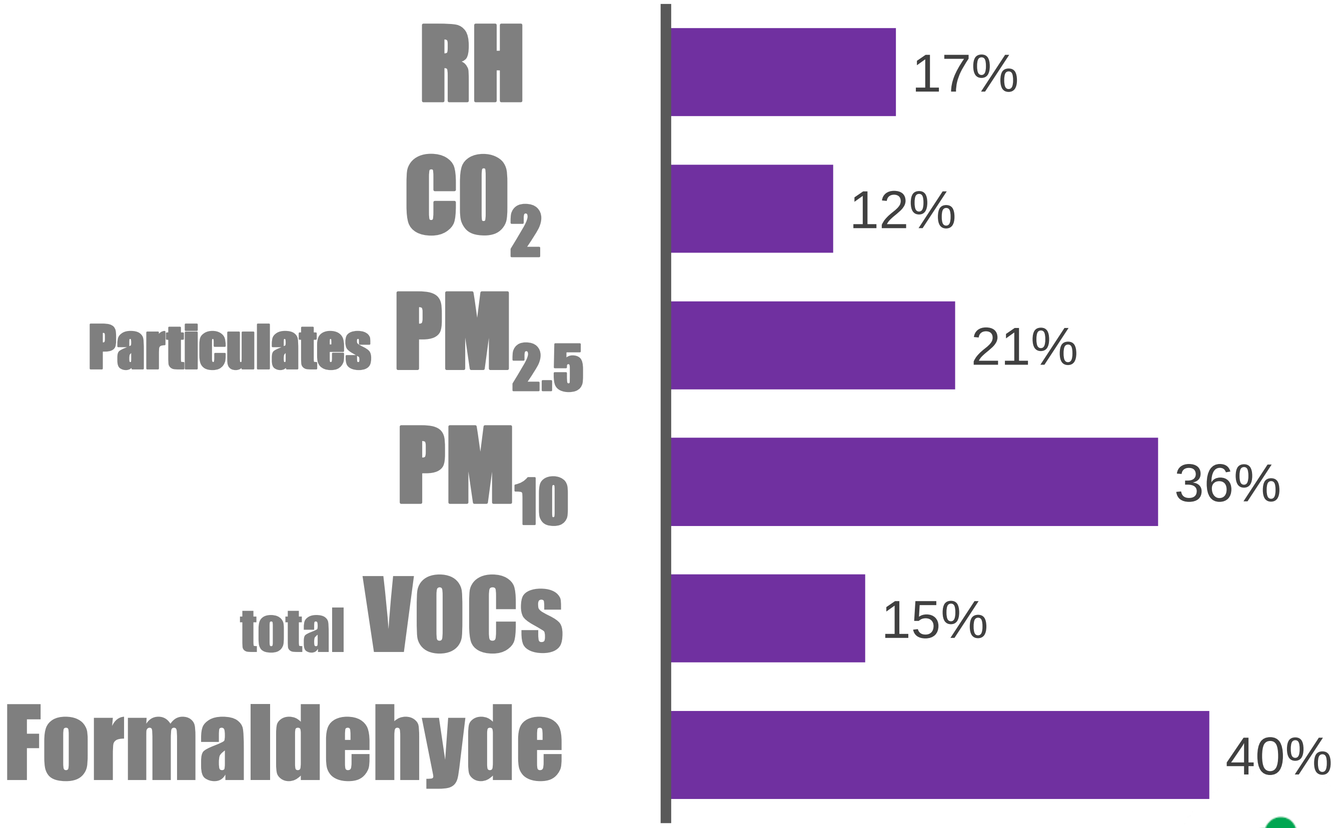
# Improvements using clay

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- In the UK the ECO-SEE cell had a higher level of thermal comfort than the Reference cell (lower variation of temperature).

- In Spain, the thermal comfort was better in the ECO-SEE cell during Autumn and Winter. However, in Spring and Summer, with warmer temperatures, the Reference cell was more comfortable.

- During routine IAQ sampling, the ECO-SEE cell showed lower levels of $CO_2$, particulate matter, TVOCs and formaldehyde.


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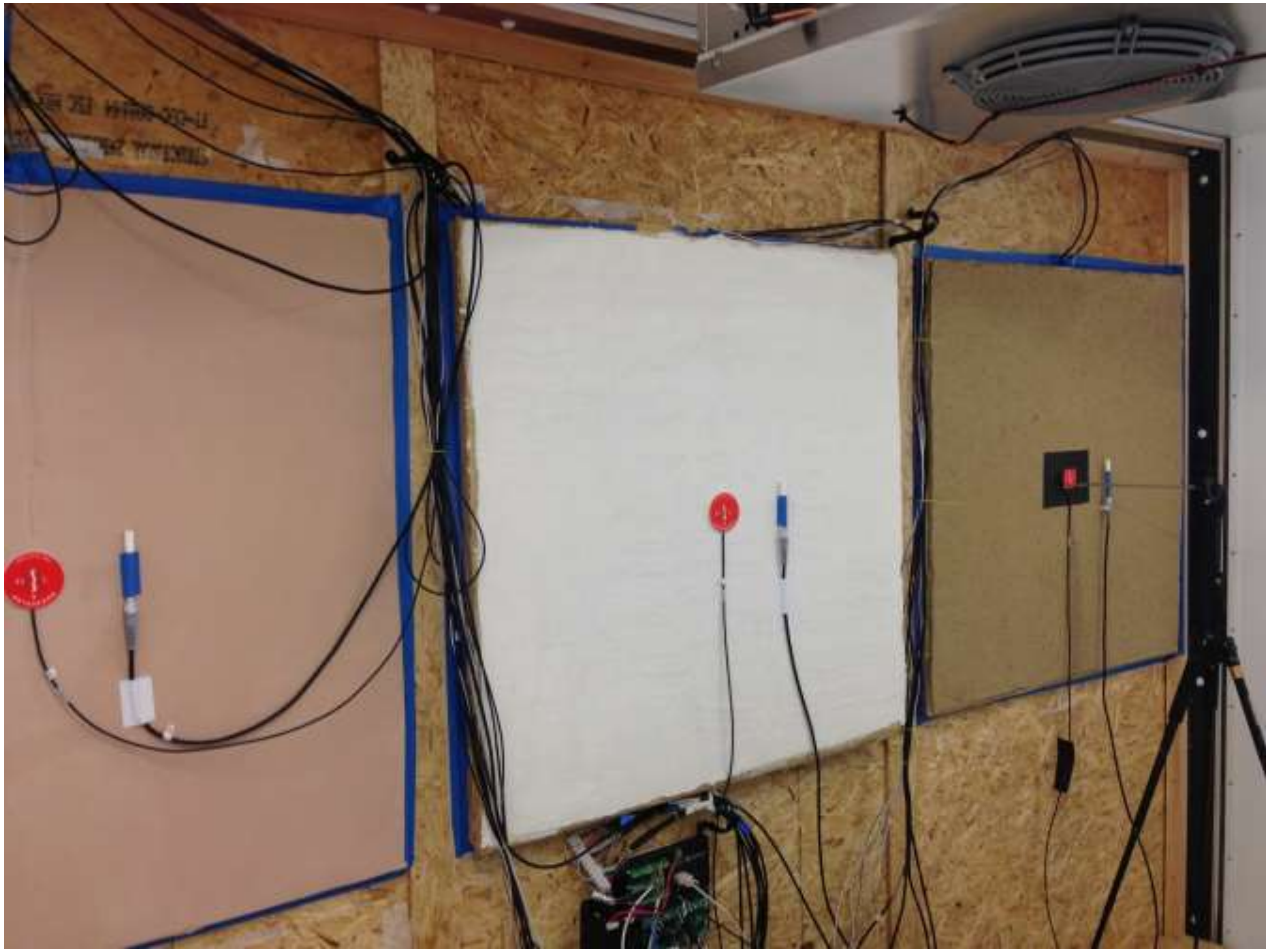



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Skanska HQ, Maple Cross



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Lübeck University, Germany

Envi-Park, Turin, Italy



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Seville:

- Heating demand of ECO-SEE panel was 25% lower than reference panel

Maple Cross:

- The air in the ECO-SEE and control rooms was similar in terms of temperature, humidity, airborne particulate matter, and air change rate.
- When a VOC challenge was presented, there was no conclusive effect of the ECO-SEE panels during spot measurements of the TVOC content.
- Differences seen in the passive TVOC content could be explained by different ventilation strategies used by users of the room (e.g. by having one door open for longer periods).



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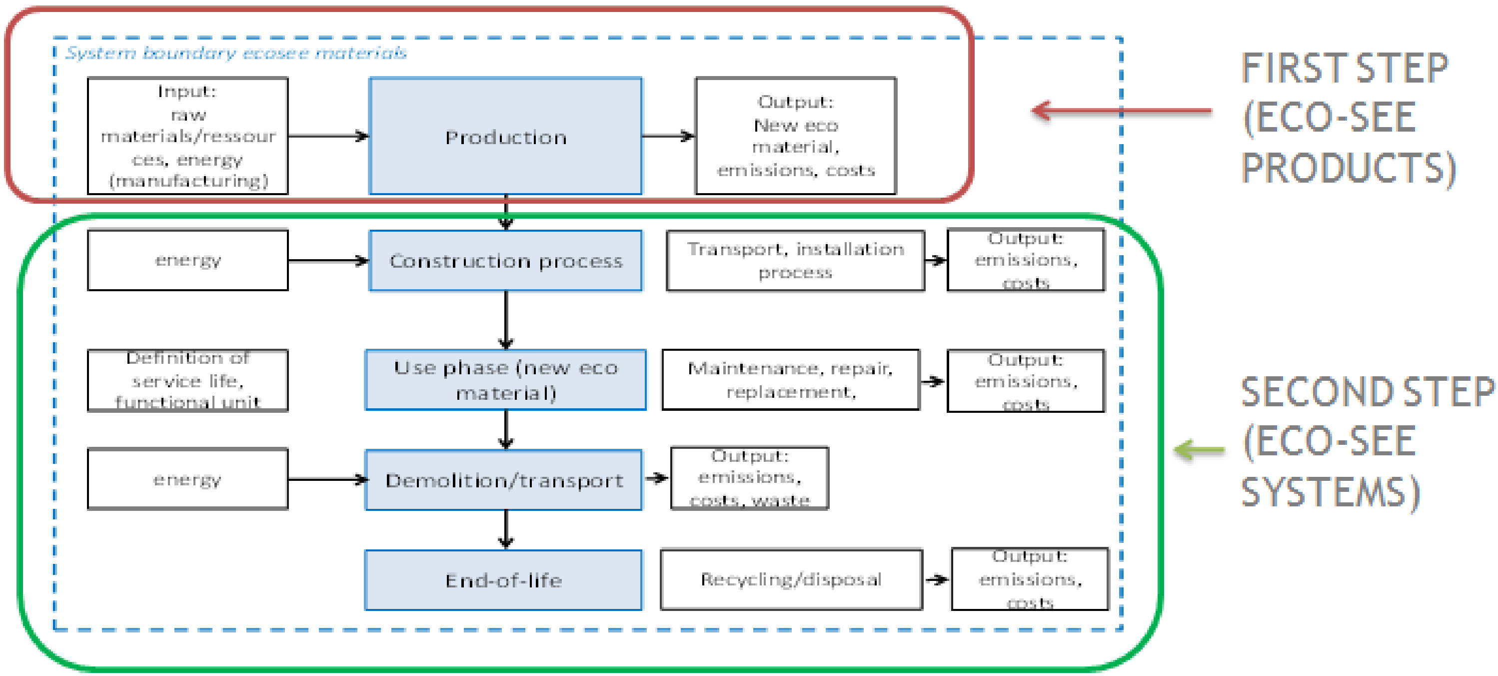
# LCA



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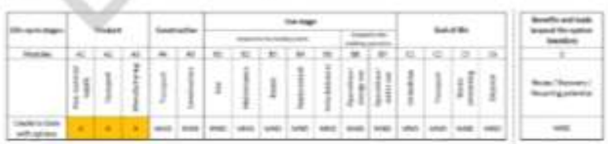
**Company specific information reported in EPD type document**

Note that other information is also present in an EPD but does not relate specifically to the company or product itself.

| Date: | 25th January 2017 |
|---|---|
| **Heading** | **Details** |
| **Product** | |
| Name: | CLAYTEC M3 clay plaster<br> |
| EPD type: | Cradle-to-gate (A1 to A3) |
| Company name: | CLAYTEC e.k. |
| Company address: | Nettetale Straße 113, 41751 Viersen-Boisheim, Germany |
| Company logo: | CLAYTEC® Baustoffe aus Lehm. |
| **Factory** | |
| Name: | Ramsbach – Baumbach site |
| Address: | Sälzerstraße 28, 56235 Ransbach-Baumbach, Germany |
| **Information modules** | |
| Modules selected: |  |
| **Construction product use and manufacture** | |
| Product description: | CLAYTEC M3 clay plaster is clay based, fine grained upper coat plaster which provides a 'ready to paint' smooth surface for internal walls. |
| Manufacturing process: | Clay powder is broken down. Then sand is sieved and the appropriate size fractions extracted. Predetermined quantities of material components are weighed out via computer assisted dosing, and the raw materials mixed. After mixing, the resulting product is packed for later distribution. |



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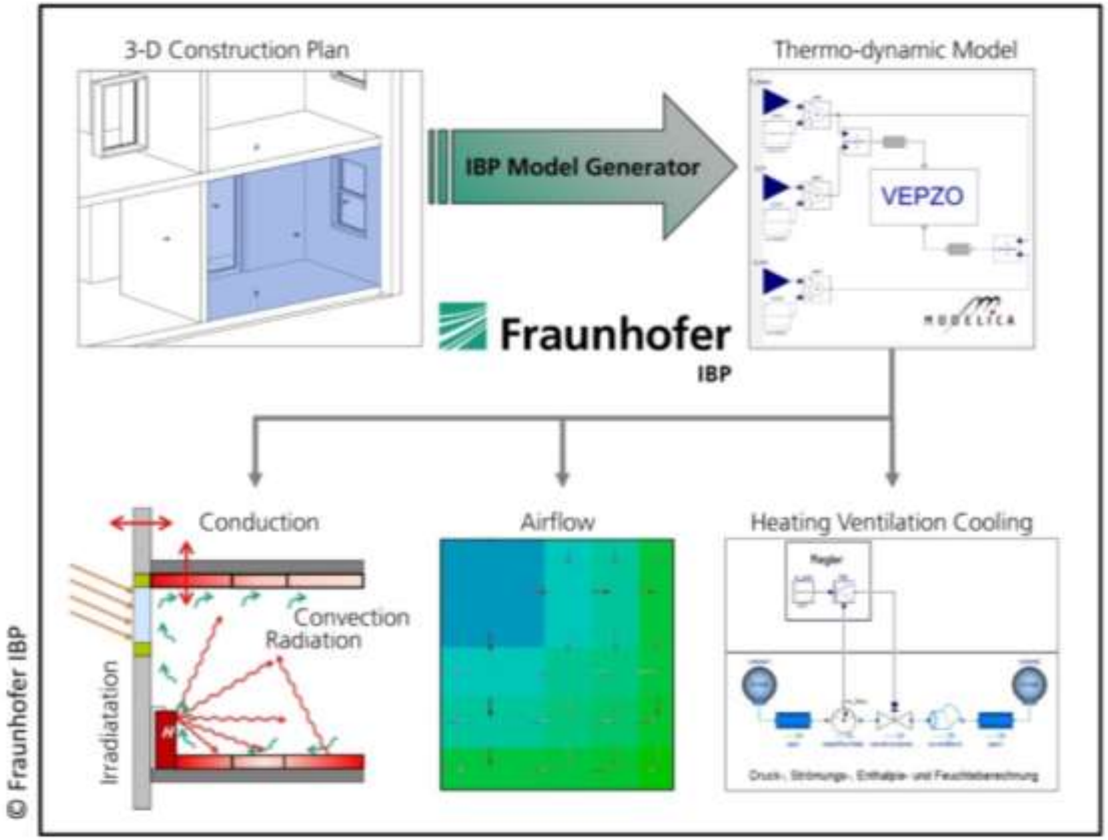
# Design tools




The IBP Model Generation Tool for automatic creation of Modelica simulation models from 3-D building or room designs



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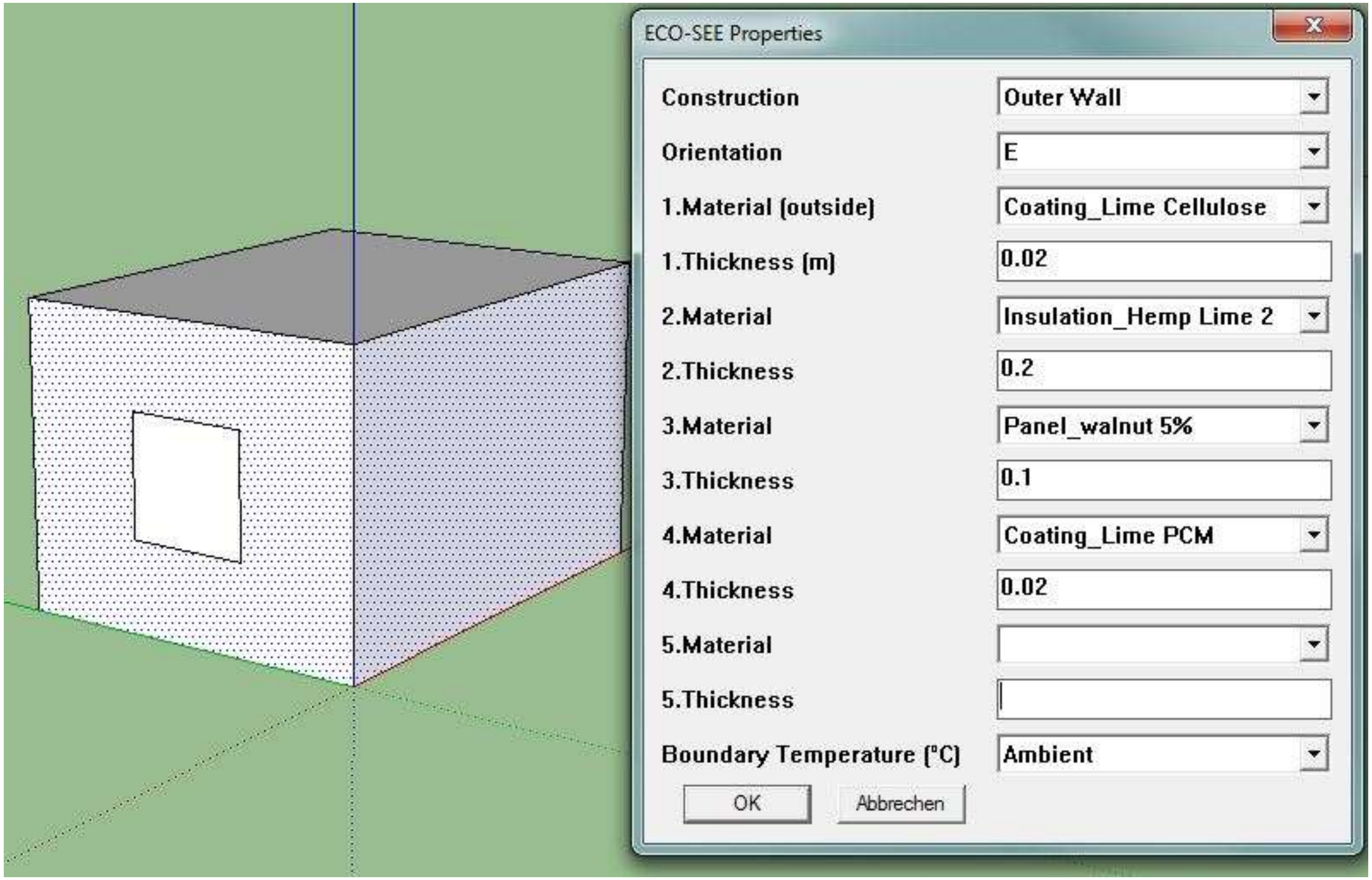


Input mask for properties of each component



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# Some ECO-SEE project outcomes:

- 60% improvement in thermal resistance of clay plasters.
- 80% improvement in moisture buffering performance of clay plasters.
- Over 100% improvement in VOC capture potential of sheep's wool insulation.
- Up to 50% reduction in energy performance of ECO-SEE test sites compared to standard timber framed and masonry construction.


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Thank You



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