Welcome

Natural buildings of the future
Research Festival 2020

CobBauge

Housekeeping

- Toilets
- Fire escapes (no test alarms are planned)
- Please be careful of any electrical wires that are used to power any displays in the foyer.
- Please only ask ‘burning questions’ at the end of each presentation, for questions that can wait please hold them for the Q&A at the end.

Running order

- Welcome
- The research problem and the completed 1st stage of CobBauge

2nd stage of CobBauge:

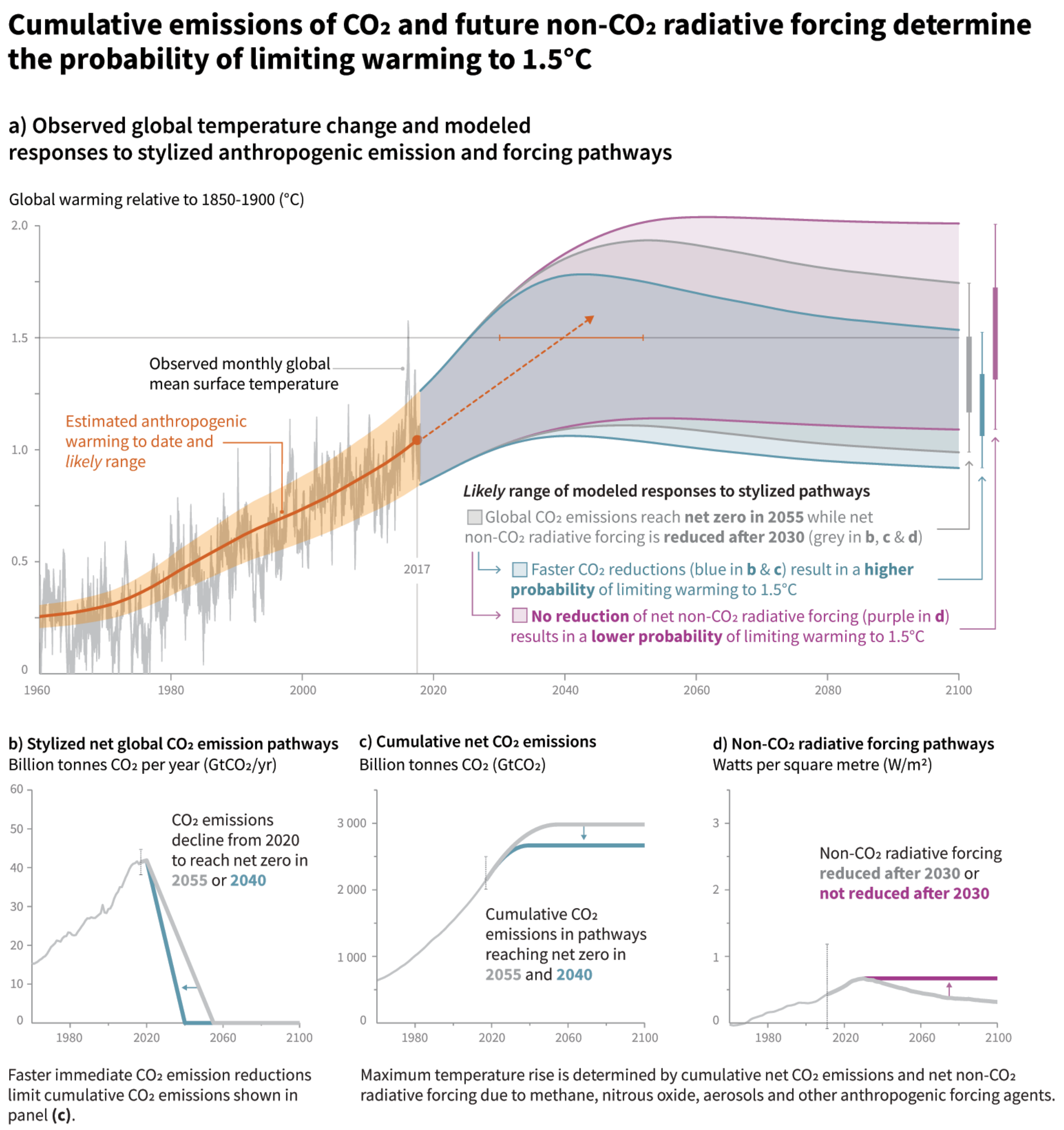
- Thermal and life cycle measurements
- CobBauge buildings; Prototypes, Pilots and beyond.

The big picture problem

Cement, other construction materials

and CO_2

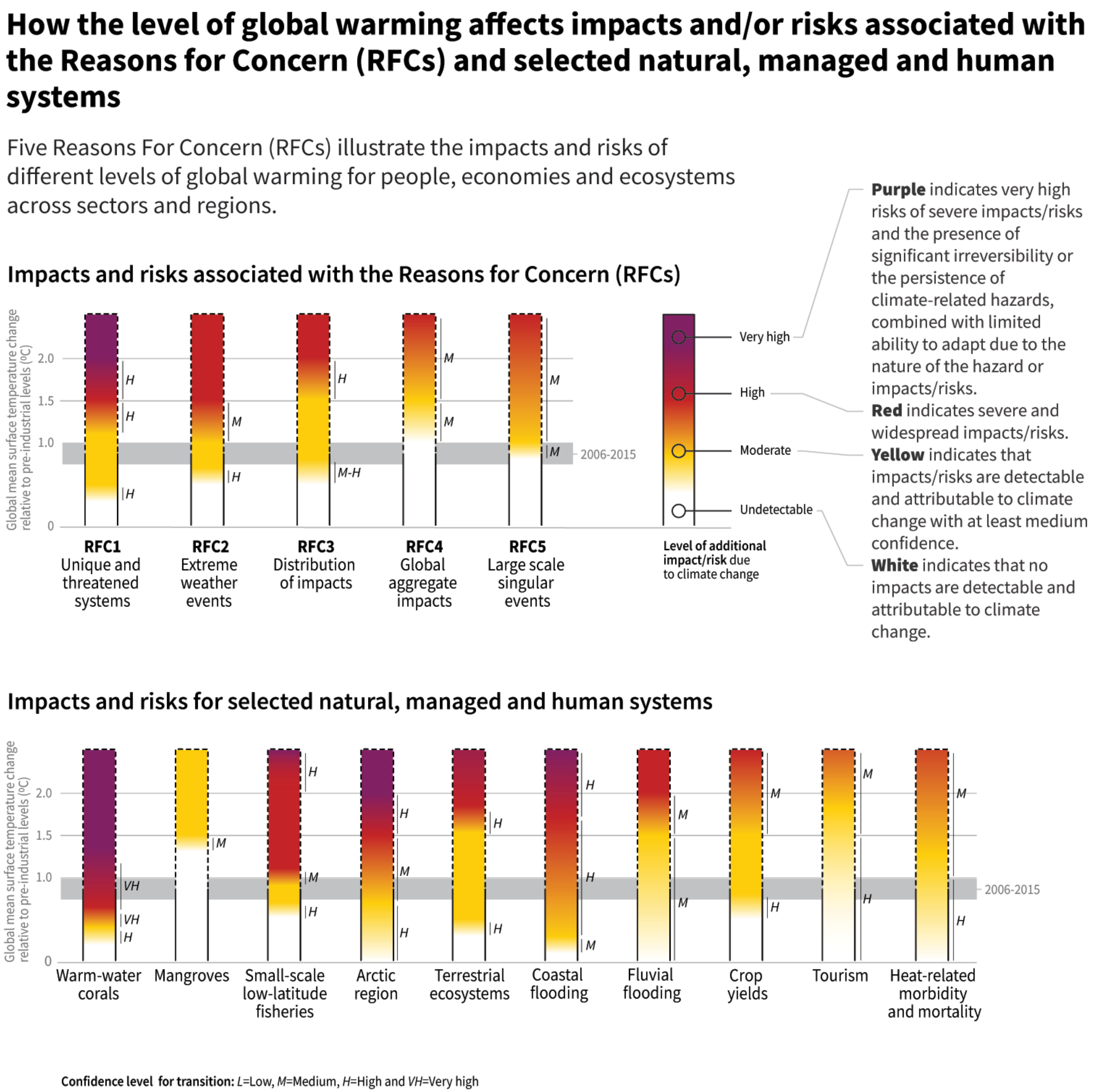
…or why we should build from CobBauge..



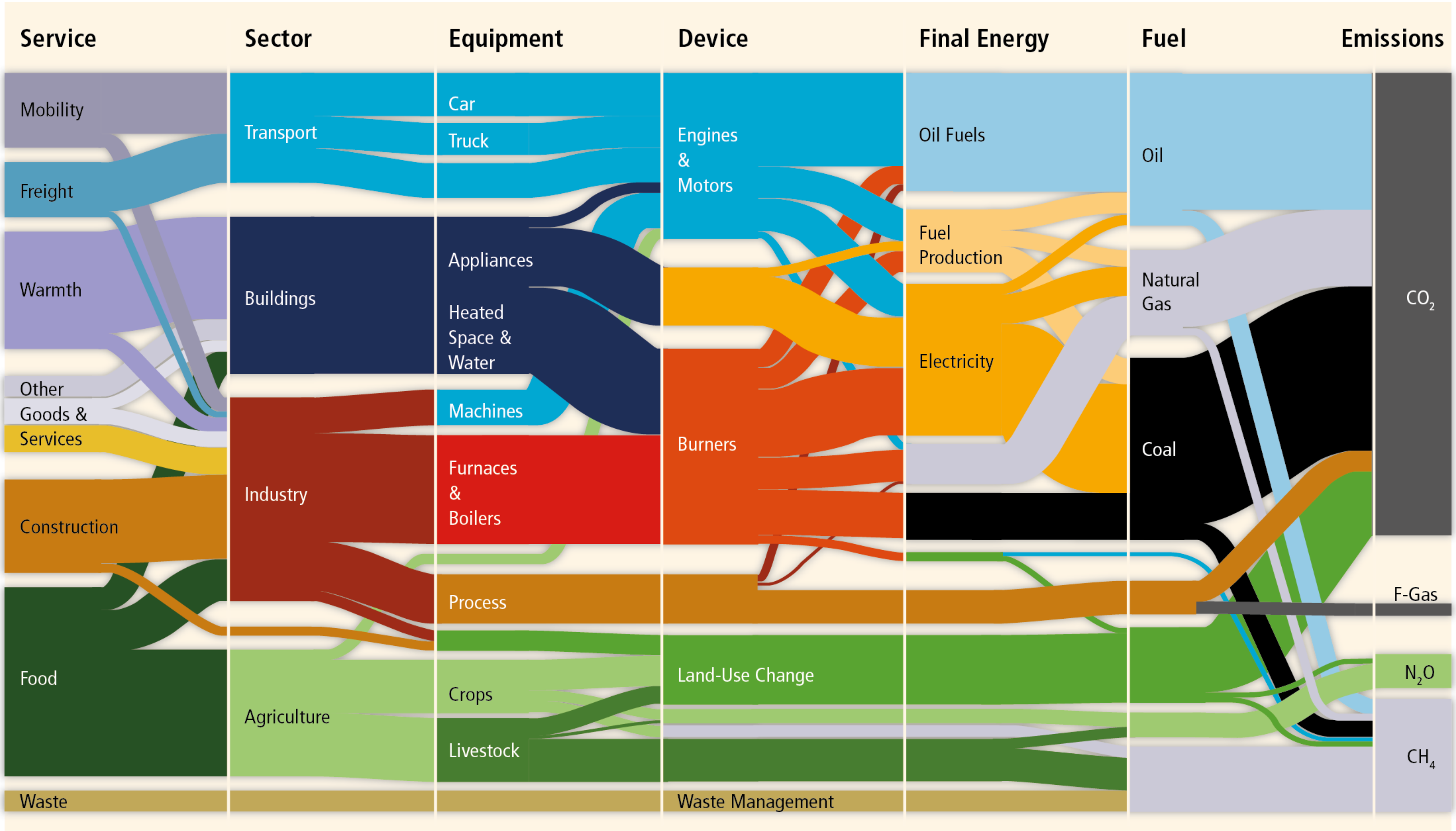
What is happening to global CO_2 ?

Source: IPCC SPM, 2018 Fig 1

What are the predicted impacts of global CO_2 ?

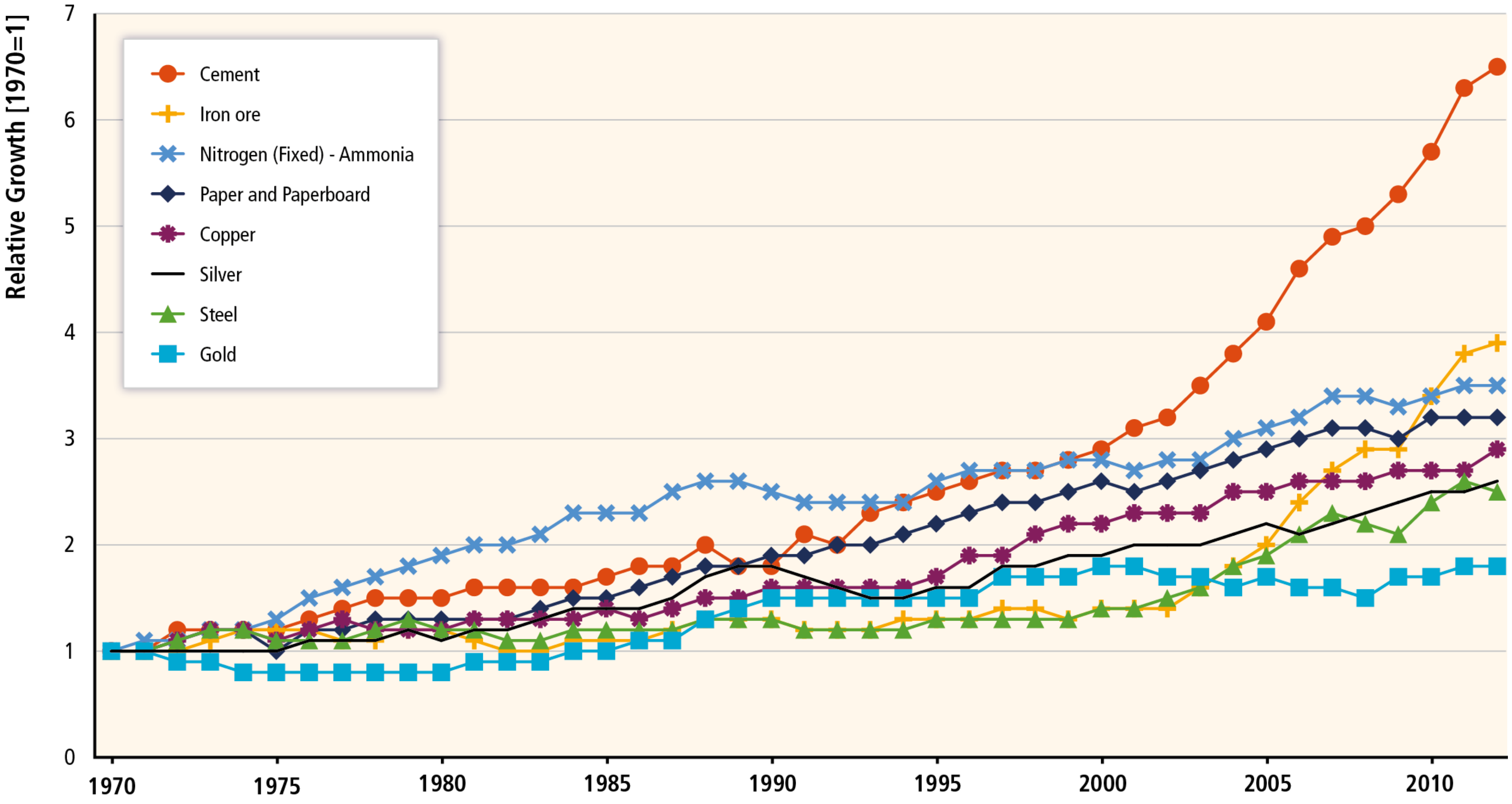


Source: IPCC SPM, 2018 Fig 2



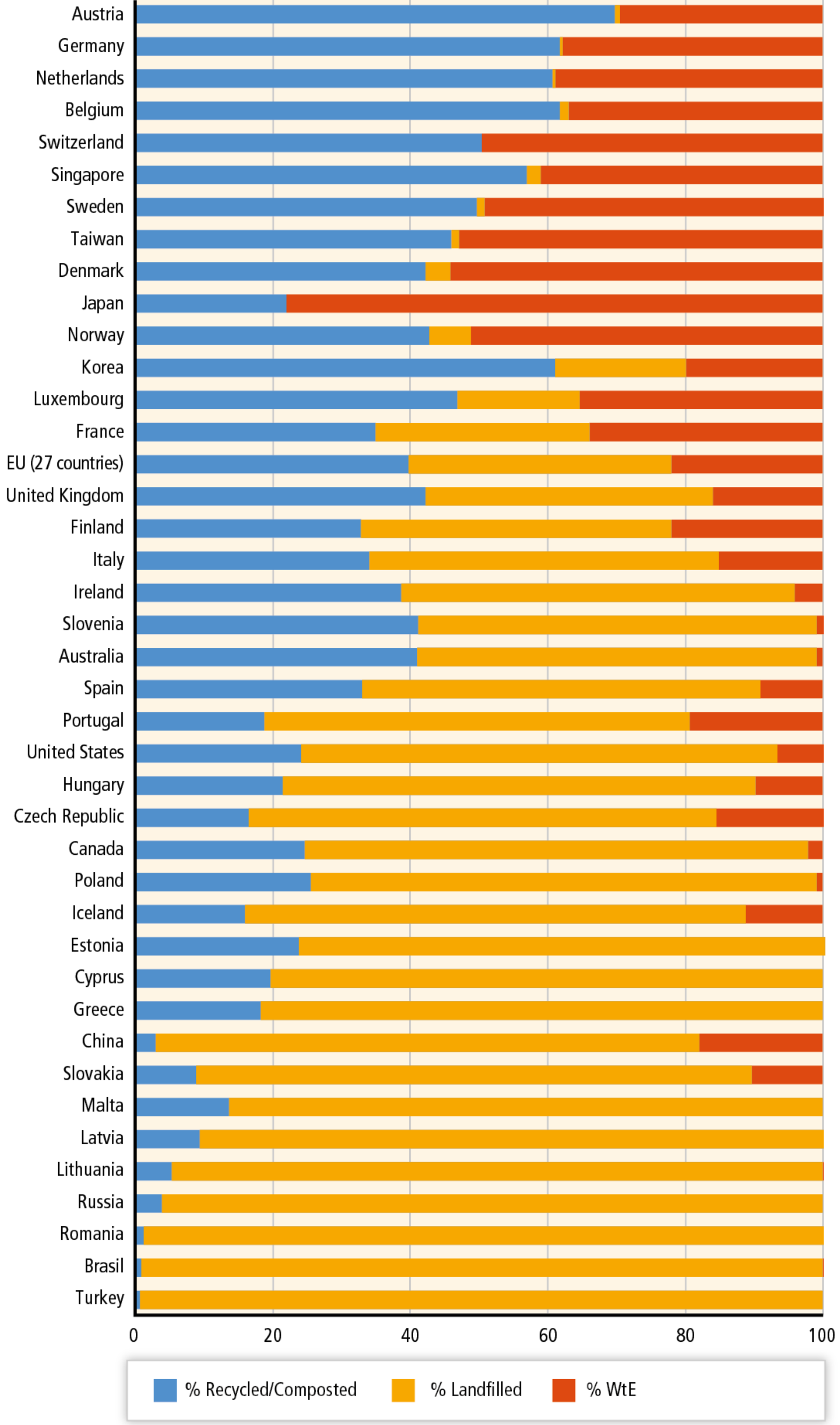
How much CO_2 from buildings?

Source: IPCC WG3 ARG5 Fig 10.1



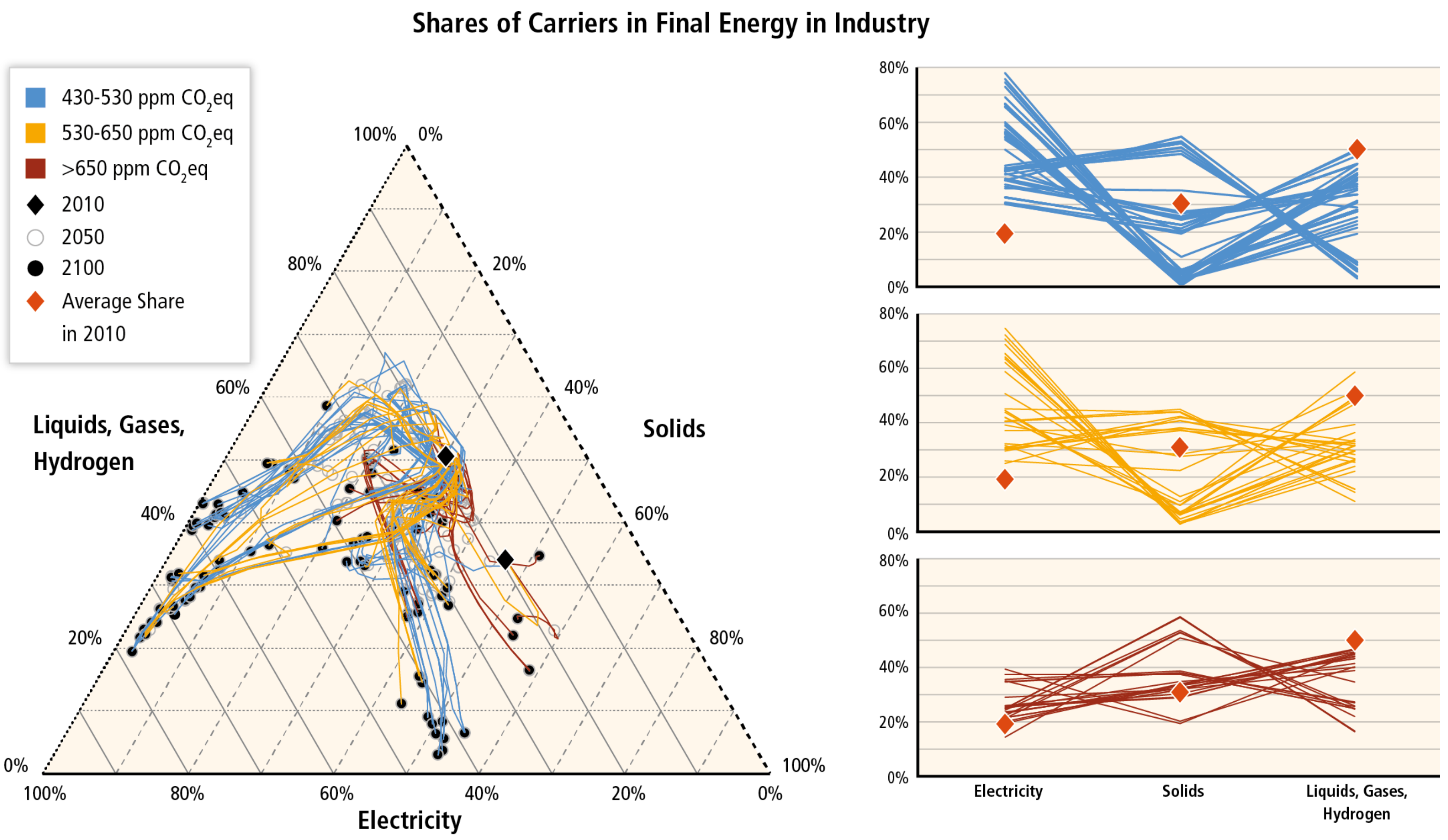
Growth of CO_2 attributed to cement?

Source: IPCC WG3 ARG5 Fig 10.3



The amount of waste to landfill

Source: IPCC WG3 ARG5
Fig 10.18



So you thought the previous graphs were indecipherable?

Source: IPCC WG3 ARG5 Fig 10.12

What to do?

Therefore…..

1. avoid the use of cement except where necessary

2. reduce waste to landfill

…or should build from a material made from very little CO_2 and sends very little waste to landfill …………..build with Cob..?

A vernacular material historically prevalent in the South West of the UK and Northern France.

Cob

- subsoil
- straw/fibre
- water

The Material

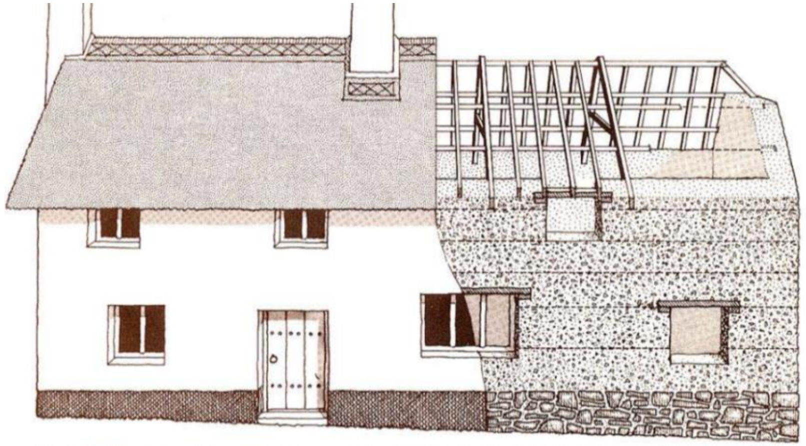
Cob

Layer of subsoil mixed with straw, laid upon a plinth in layers of approx 700mm high.

Allowed to dry before the next layer is laid and the windows and doors cut out afterwards.

ALWAYS needs '*gud 'at and boots*'

Traditional method of cob construction showing mixing, placing material on the wall, compaction by treading and paring back the wall face.



A typical 17th century cob house showing some constructional details. The wall is built off a stone plinth in several layers, or lifts, and lintels and roof timbers are supported on the cob, using timber pads or cross pieces where necessary.

Traditional Cob

Examples of traditional cob buildings



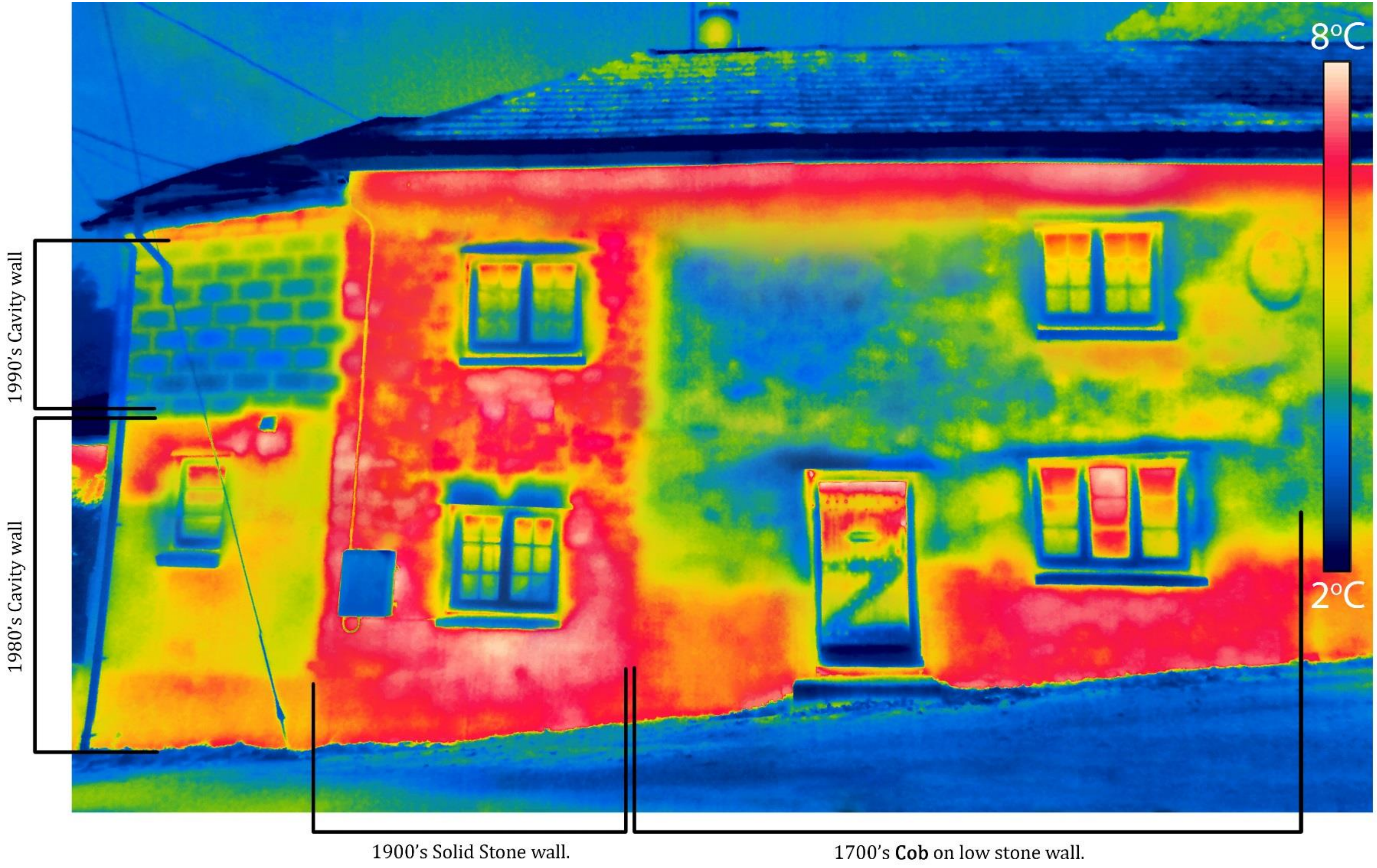
Vernacular UK cottage aesthetic

Modern Traditional Cob

Examples of modern traditional cob buildings

More modern aesthetic – people starting to push the boundaries.

Thermal properties of Cob



Things are looking good?

A further issue,

Cob doesn't have low enough thermal transmission value (or 'U' value) to conform to either UK or French Building Regulations.

The Project

The CobBauge project (a merging of the English and French words for the technique) will run until July 2023 and has received funding from the Interreg VA France (Channel) England Programme, co-financed by the European Regional Development Fund (ERDF).

The CobBauge project aims to improve the thermal performance of Cob whilst still maintaining its structural and moisture related properties.

Who are we? Project Partners

- Lead Partner – University of Plymouth
- Ecole Superieure D'ingenieur des Travaux de la Construction de Caen (ESITC)
- Syndicat Mixte du Parc naturel régional des Marais du Cotentin et du Bessin (PnrMCB)
- Earth Building UK and Ireland (EBUKI)
- Université Caen-Normandie (UCn), and
- Hudson Architects, Norfolk, UK (HA)

Recap on what we have done before…..CobBauge the 1st Phase;

Cob Mixes; thermal and structural

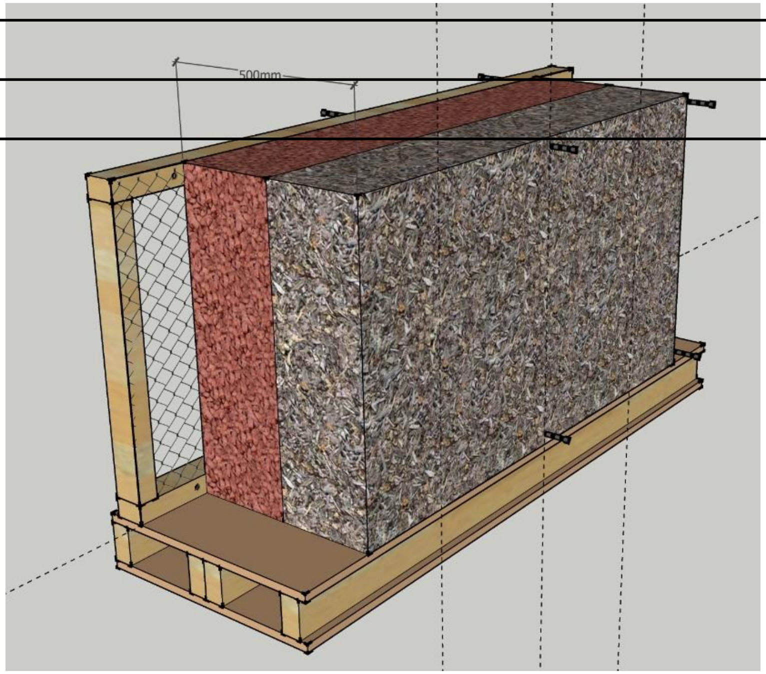
- 20 mixes of Cob that show ‘promise’
- 4 mixes, 2 French and 2 UK that are optimal
- 2 mixes selected for a potential stage 2 project.

This led to a series of design calculations that established the most efficient method of producing a Cob wall to satisfy the thermal regulations. A **thermal and a structural mix in one single system**.


HFM 446
Lambda
NETZSCH

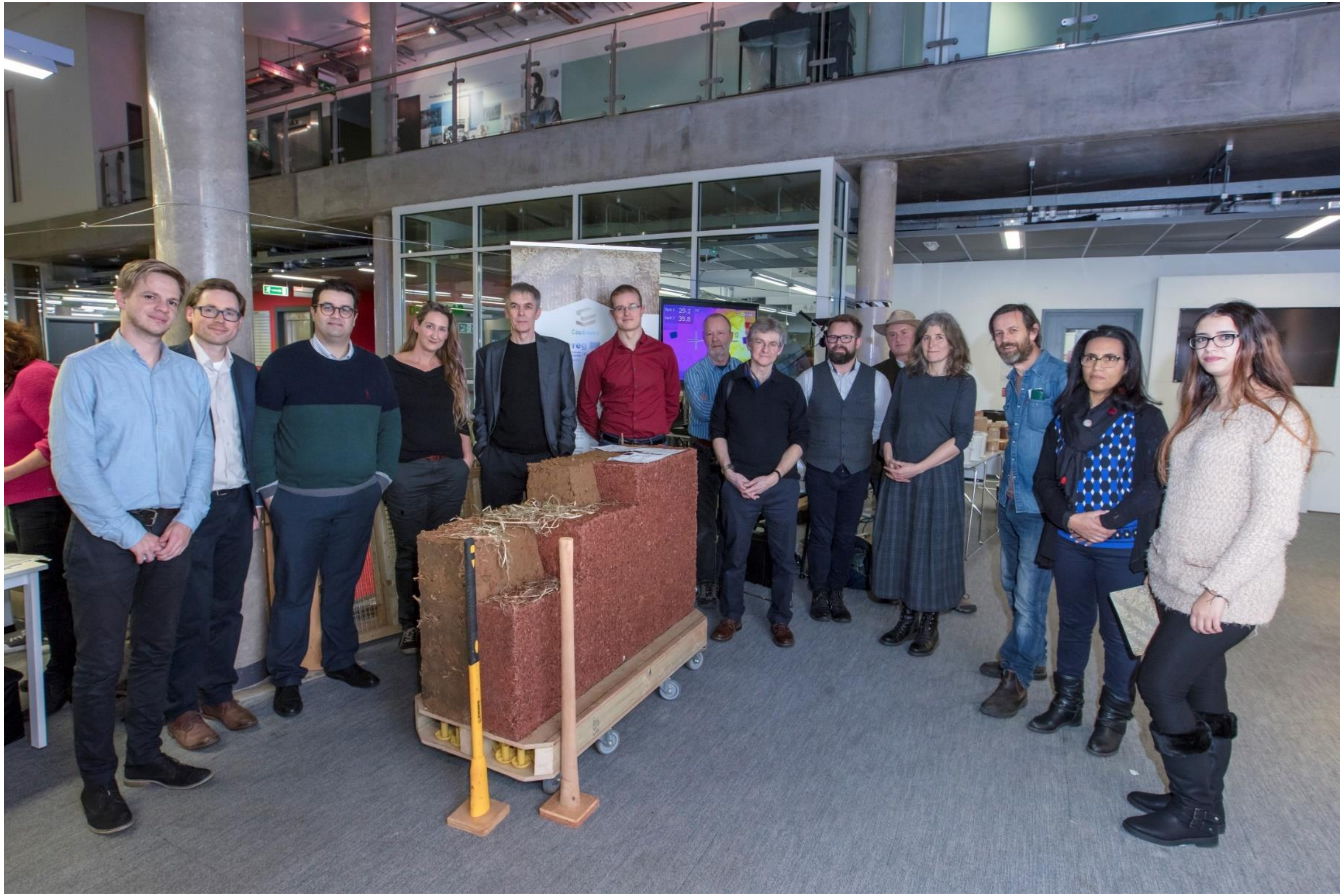
2-layer wall

Composite Cob + finishes	Density kg/m3	Thickness m	Cond. W/m.K	Resistance m2 K/W
Internal surface		n/a	n/a	0.12
Internal earthen plaster		0.03	0.44	0.07
Dense Cob UK6 2.5% Hemp straw	1423	0.250	0.44	0.57
Lightweight Cob UK3 50% Hemp shiv	340	0.300	0.11	2.73
Lime render		0.03	0.60	0.05
External Surface		n/a	n/a	0.06
Total Resistance				3.59
U-Value W/m2K				**0.28**



The CobBauge Wall

The CobBauge Wall and Partners



CobBauge the 2nd Phase;

Building, monitoring, networks and training

Building

Construction

- Why? The need to prove the new CobBauge technology
- Two buildings to be constructed, one in France and one in the UK.
- Both buildings need to be occupied to give valid comparisons with non-CobBauge buildings

Networks and training

Réseaux et formation

- Why networks and training? For any innovation to succeed it needs to be accepted by industry and have people who understand how to use the product.

- The initial network will be extended, more professionals and practitioners included including SMEs and local and national authorities.

- The two newly completed CobBauge buildings will be the centre point of training activities, both on-site and online materials.

Monitoring of the buildings

Surveillance (des mesures) des bâtiments des mesures

- Why monitor/measure? To provide evidence that the buildings perform as expected.
- Monitoring/measurements to be undertaken over at least two heating seasons
- Measurements taken of Energy, internal air quality and thermal performance.

Thank you …

Now for our 1st main presentation….

Thermal Testing

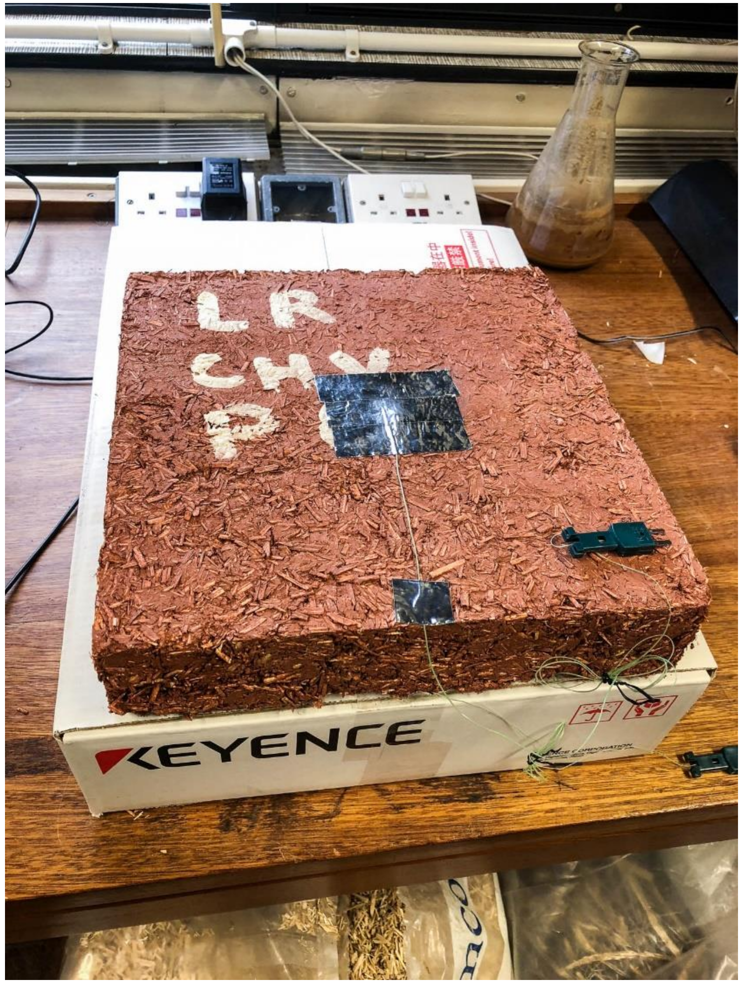
Building Regulations

U Values

Life Cycle Assessment

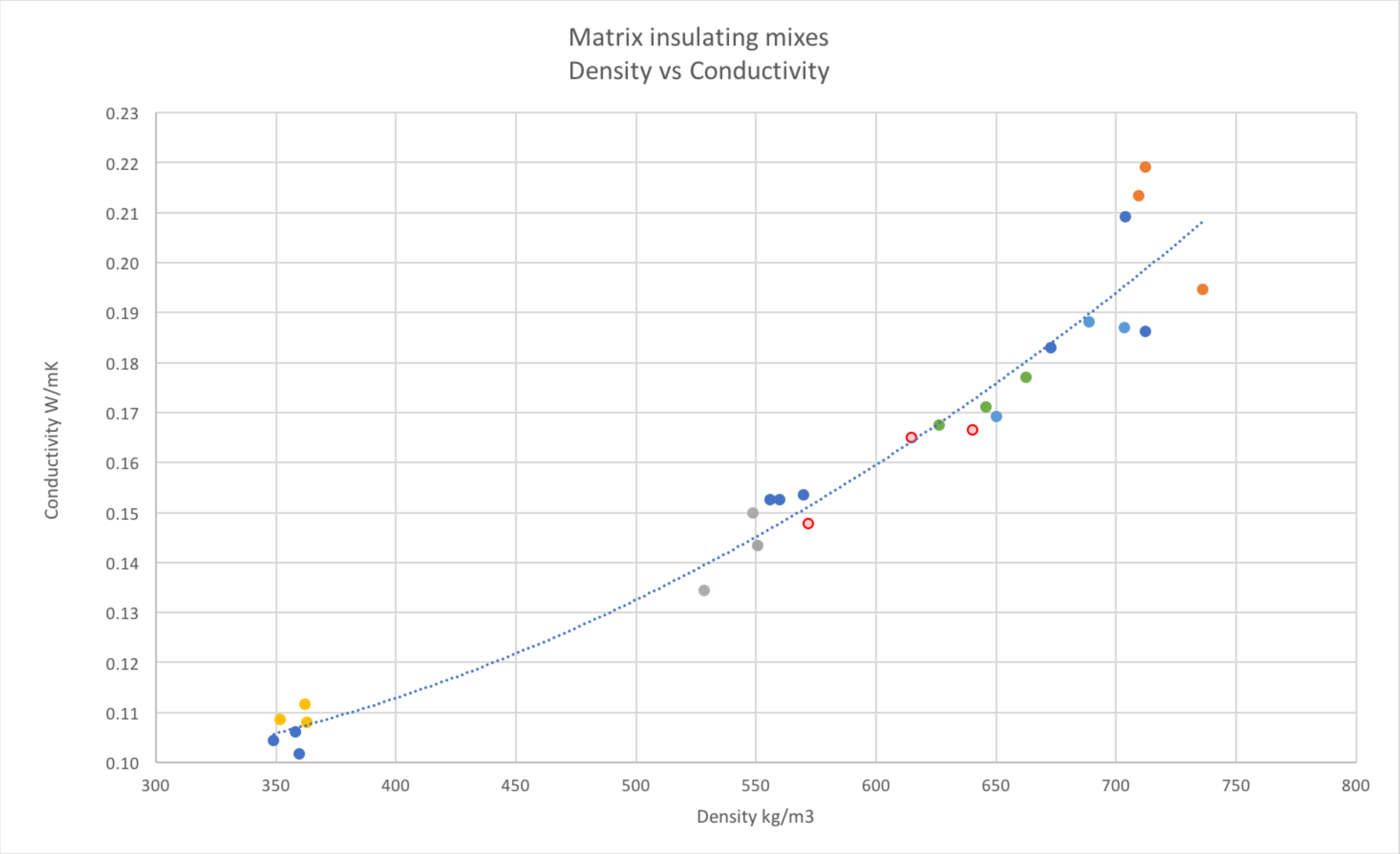
Thermal testing: Methodology

Interreg
France (Channel Manche) England



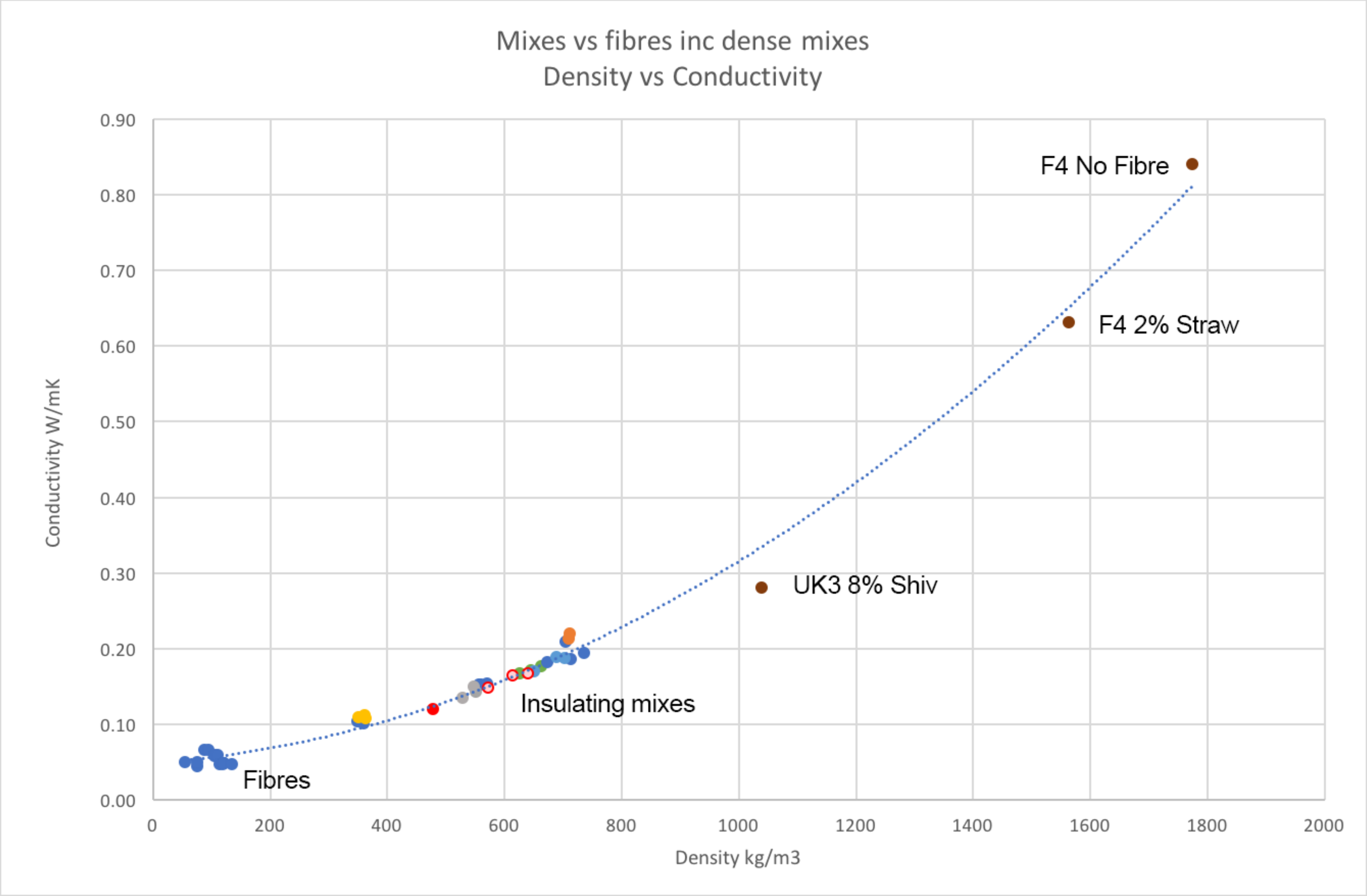
Thermal Testing Results

FR3 25% Reed W1	662.5	0.17688
FR3 25% Reed W2	626.4	0.16739
FR3 25% Reed W3	646.1	0.17106
FR3 25% Shiv W1	672.6	0.18297
FR3 25% Shiv W2	712.2	0.18624
FR3 25% Shiv W3	703.9	0.20921
UK3 25% Reed W1	703.7	0.18683
UK3 25% Reed W2	688.7	0.18802
UK3 25% Reed W3	650.3	0.16907
UK3 25% Shiv W1	736.1	0.19460
UK3 25% Shiv W2	709.7	0.21337
UK3 25% Shiv W3	712.5	0.21911
UK3 50% Shiv D1	358.3	0.10614
UK3 50% Shiv D2	359.9	0.10180
UK3 50% Shiv D3	349.1	0.10443
UK3 50% Shiv W1	351.9	0.10849
UK3 50% Shiv W2	363.0	0.10792
UK3 50% Shiv W3	362.2	0.11160
UK4 35% Reed W1	550.9	0.14330
UK4 35% Reed W2	549.0	0.14975
UK4 35% Reed W3	528.7	0.13431
UK4 25% Reed W1	572.1	0.14777
UK4 25% Reed W2	640.4	0.16653
UK4 25% Reed W3	615.0	0.16485
UK3 35% Shiv 1	555.7	0.15251
UK3 35% Shiv 2	559.7	0.15258
UK3 35% Shiv 3	569.7	0.15350

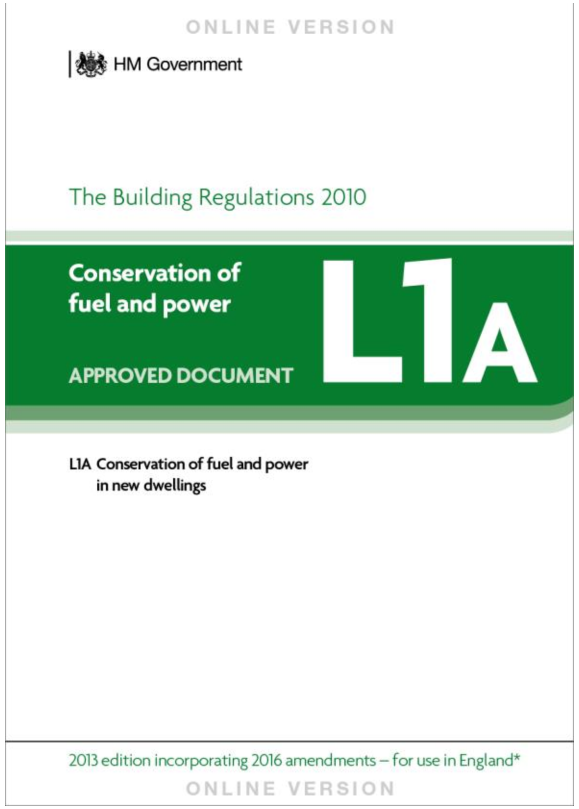


Thermal Testing Results

How do the insulating mixes fit into a broader set of results?



UK Building regulations: Part L1 A


ONLINE VERSION

HM Government

The Building Regulations 2010

Conservation of fuel and power

L1A

APPROVED DOCUMENT

L1A Conservation of fuel and power in new dwellings

2013 edition incorporating 2016 amendments – for use in England*

ONLINE VERSION

Table 2 Limiting fabric parameters

Roof	0.20 W/(m²·K)
Wall	0.30 W/(m²·K)
Floor	0.25 W/(m²·K)
Party wall	0.20 W/(m²·K)
Swimming pool basin[1]	0.25 W/(m²·K)
Windows, roof windows, glazed roof-lights[2], curtain walling and pedestrian doors	2.00 W/(m²·K)
Air permeability	10.0 m³/(h·m²) at 50 Pa

Therefore, cob cannot currently be specified without the addition of other insulating materials or mitigating measures.

The only recent cob building known to us used 150mm of expanded foam added to the walls to pass building regulations…

Cob and U Values

Traditional Cob	Density	Thickness m	Cond. W/m K	Resistance m2 K/W
Internal surface		n/a	n/a	0.12
Cob	1600	0.700	0.64	1.09
External Surface		n/a	n/a	0.06
Total Resistance				1.27
U-Value				**0.79**

Has to be .30

How thick would a traditional cob wall have to be to pass regulations?

Traditional Cob	Density	Thickness m	Cond. W/m K	Resistance m2 K/W
Internal surface		n/a	n/a	0.12
Cob	1600	2.00	0.64	3.13
External Surface		n/a	n/a	0.06
Total Resistance				3.30
U-Value				**0.30**

Two metres!

Cob and U Values

How light would a cob wall have to be to pass regulations?

Light Cob	Density kg/m3	Thickness m	Cond. W/m K	Resistance m2 K/W
Internal surface		n/a	n/a	0.12
Cob 25% fibre	673	0.600	0.183	3.28
External Surface		n/a	n/a	0.06
Total Resistance				3.46
U-Value				**0.29**

Less than half the density

Unfortunately, this lightweight cob wall could not support a second floor or a roof

Cob and U Values

The solution – A composite cob wall

Composit Cob	Density kg/m3	Thickness m	Cond. W/m.K	Resistance m2 K/W
Internal surface		n/a	n/a	0.12
Dense Cob UK6 5% Hemp straw	1600	0.300	0.45	0.67
Lightweight Cob UK3 50% Hemp shiv	340	0.300	0.11	2.73
External Surface		n/a	n/a	0.06
Total Resistance				3.57
U-Value W/m2K				**0.28**

Table 2 Limiting fabric parameters

Roof	0.20 W/(m²·K)
Wall	0.30 W/(m²·K)
Floor	[illegible]

Cob and U Values

Composit Cob	Density kg/m3	Thickness m	Cond. W/m.K	Resistance m2 K/W
Internal surface		n/a	n/a	0.12
Dense Cob UK6 5% Hemp straw	1600	0.300	0.45	0.67
Lightweight Cob UK3 50% Hemp shiv	340	0.300	0.11	2.73
External Surface		n/a	n/a	0.06
Total Resistance				3.57
U-Value W/m2K				**0.28**

What happens if we have an equivalent thickness of an average cob mix

Average Cob	Density	Thickness m	Cond. W/m K	Resistance m2 K/W
Internal surface		n/a	n/a	0.12
In The Middle	970	0.600	0.28	2.14
External Surface				0.06
Total Resistance				2.32
U-Value				**0.43**

The values for density and conductivity are exactly half way between the values for the two layers above, but the U value is nearly twice as bad

Cob and U Values

The CobBauge wall with finishes

Composite Cob + finishes	Density kg/m3	Thickness m	Cond. W/m.K	Resistance m2 K/W
Internal surface		n/a	n/a	0.12
Internal earthen plaster		0.03	0.44	0.07
Dense Cob UK6 2.5% Hemp straw	1423	0.250	0.44	0.57
Lightweight Cob UK3 50% Hemp shiv	340	0.300	0.11	2.73
Lime render		0.03	0.60	0.05
External Surface		n/a	n/a	0.06
Total Resistance				3.59
U-Value W/m2K				**0.28**

The same U value, standard finishes, and is now 556mm thick

Structural performance testing

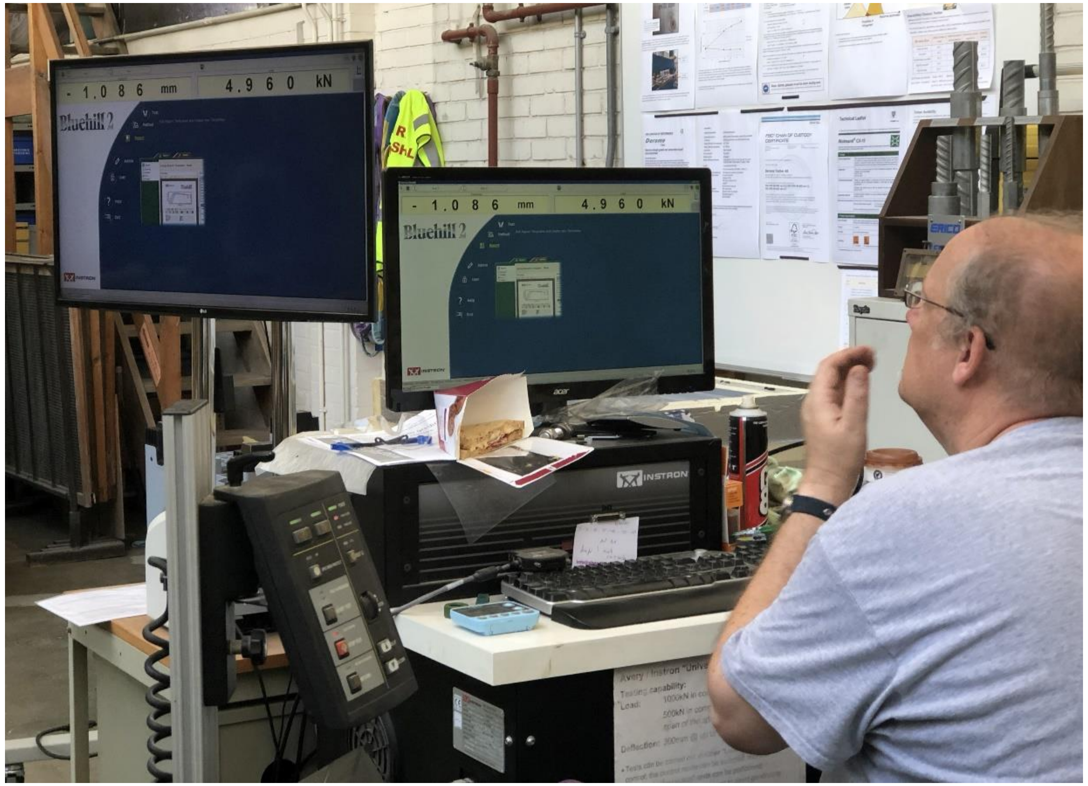
- Cylinders were produced from the high density mixes.

- Compressive strength measured.

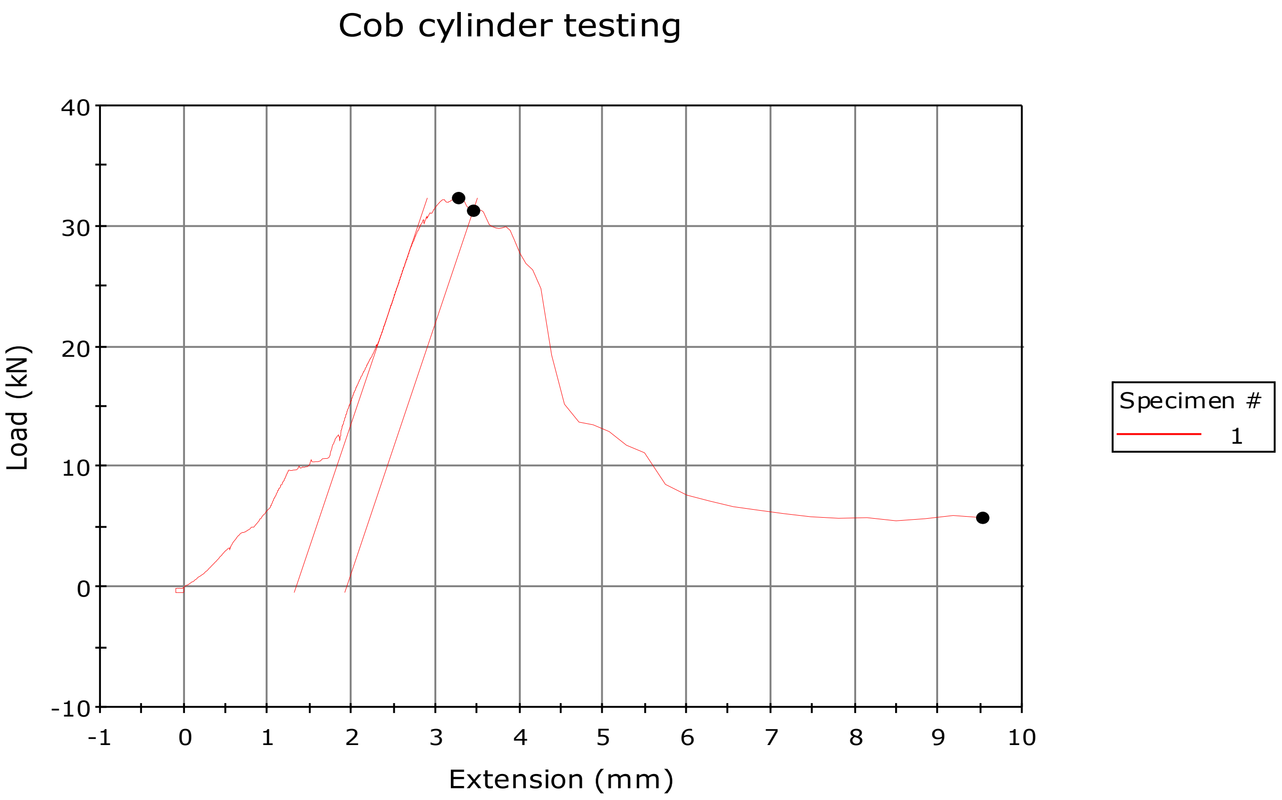
- Average measurement from samples with a density of 1700kg/m^3 (106.1lb/ft^3) were between 1.2 & 2.3MPa

Methodology

Methodology



Results



	CARES #	Modulus (MPa)	Offset Yield 0.2 % (kN)	Stress @ Offset Yield (N/mm^2)	Max Load (kN)	UTS (N/mm^2)	Extension at Break (mm)	Strain at Break (%)	User Strain (%)	Failure type
1	123	351.30	31.3	1.8	32.3	1.8	9.5	3.2	191.00	
Mean	123	351.30	31.3	1.8	32.3	1.8	9.5	3.2	191.00	
Coefficient of Variation	-----	-----	-----	-----	-----	-----	-----	-----	-----	
Standard Deviation	-----	-----	-----	-----	-----	-----	-----	-----	-----	

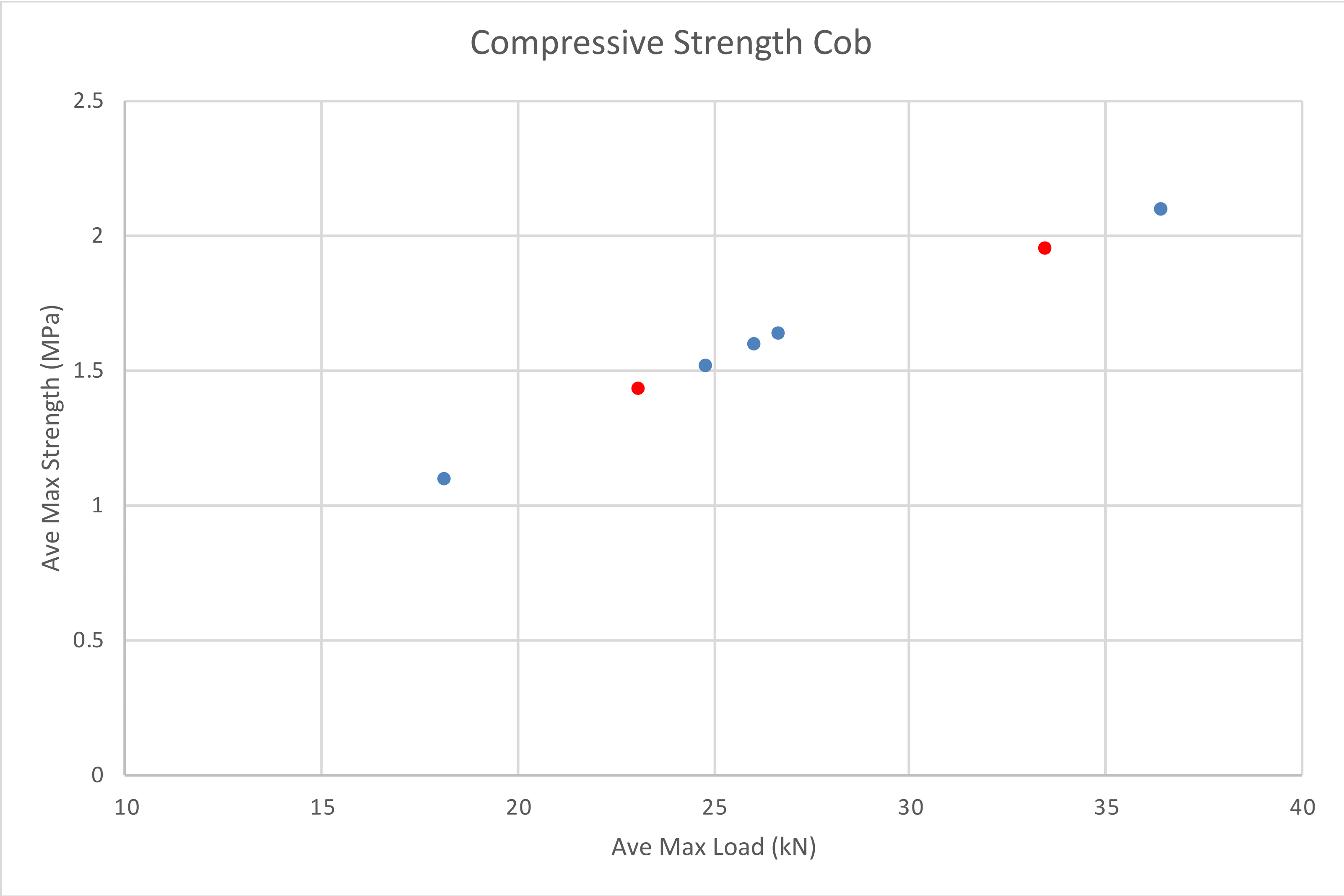
Results

Structural performance testing

- 50 Cylinders (10 per mix) were also tested at Cambridge by Dr Michael Ramage

	Compressive strength measurements cob soil fibre combinations				
Internal Mix No	Soil Type	Fibre &% by Volume	Ave Max Load (kN	Ave Max Strength (MPa)	
Mix 3	FR2	Hemp Straw, 2.5%	26.12	1.583	**Mix3**
Mix 4	FR2	Flax Straw, 2.5%	36.49	2.089	**Mix 4**
Mix 9	FR6	Flax Straw, 2.5%	26.77	1.627	**Mix 9**
Mix 10	FR6	Wheat Straw 2.5%	18.2	1.092	**Mix 10**
Mix 12	Fr6	Wheat Straw 5%	24.87	1.508	**Mix 12**

Results



- Average of 5 mixes (10 per mix) Cambridge results
- Average of 2 mixes
- (4 per mix)

  Plymouth results

Life Cycle Assessment – Embodied Energy

A BSRIA guide

Material Profile: Cement

Embodied Energy (EE) ICE-Database Statistics - MJ/Kg

Main Material	No. Records	Average EE	Standard Deviation	Minimum EE	Maximum EE	Comments on the Database Statistics:
Cement	**116**	**5.20**	**2.70**	**0.10**	**14.20**	There was a large sample of data.
Cement Mortar	11	1.54	0.91	0.10	3.49	
Unspecified	9	1.30	0.70	0.10	2.10	
Virgin	2	2.63	1.22	1.77	3.49	
Cement, Fibre Cement	1	4.60	4.60	4.60		
Virgin	1	4.60	4.60	4.60		
Cement, Fibre Cement	8	10.15	1.93	7.60	14.20	
Unspecified	8	10.15	1.93	7.60	14.20	
Cement, General	94	5.32	2.05	1.42	11.73	
Market Average	7	5.02	0.66	4.29	6.20	
Unspecified	65	5.46	2.27	1.42	11.73	
Virgin	22	4.88	1.07	3.00	6.50	
Cement, Soil-Cement	2	0.85	0.21	0.70	1.00	
Unspecified	2	0.85	0.21	0.70	1.00	

Selected Embodied Energy & Carbon Coefficients and Associated Data

Material	Embodied Energy - MJ/Kg	Embodied Carbon - Kg CO2e/Kg	Boundaries	Best EE Range - MJ/Kg		Specific Comments
				Low EE	High EE	
General (UK weighted average)	4.51	0.74	Cradle to Gate	(+/- 30%)		Weighted average of all cement consumed within the UK. This includes all factory made cements (CEM I, CEM II, CEM III, CEM IV) and further blending of fly ash and ground granulated blast furnace slag. This data has been estimated from the Mineral Products Association (MPA) factsheets (see Ref. 59). 23% cementitious additions on average.
Average CEM I Portland Cement, 94% Clinker	5.50	0.95				This is a standard cement with no cementitious additions (i.e. Fly ash or blast furnace slag). Composition 94% clinker, 5% gypsum, 1% minor additional constituents (mac's). This data has been estimated from the MPA factsheets (see Ref. 59).
6-20% Fly Ash (CEM II/A-V)	5.28 to 4.51	0.89 (@ 6%) to 0.76 (@ 20%)				Fly ash has a lower embodied carbon than blast furnace slag, however the upper threshold of fly ash content that can be used in a stable mixture is lower than for blast furnace slag. This data has been estimated from the MPA factsheets (see Ref. 59) and the ICE data for fly ash.
21-35% Fly Ash (CEM II/B-V)	4.45 to 3.68	0.75 to 0.62				
21-35% GGBS (CEM II/B-S)	4.77 to 4.21	0.77 to 0.65				GGBS = ground granulated blast furnace slag. Blast furnace slag has a higher embodied carbon than fly ash, however the upper threshold of blast furnace slag content is higher than for fly ash. This data has been estimated from the British Cement Association's factsheets (see Ref. 59) and the ICE data for GGBS.
36-65% GGBS (CEM III/A)	4.17 to 3.0	0.64 to 0.39				
66-80% GGBS (CEM III/B)	2.96 to 2.4	0.38 to 0.26				
Fibre Cement Panels - Uncoated	10.4	1.09 CO2 only		Estimated range +/- 30%		Few data points. Selected data modified from Ref. 107. An example application are facade panels.
Fibre Cement Panels - (Colour) Coated	15.3	1.28 CO2 only		Estimated range +/- 30%		

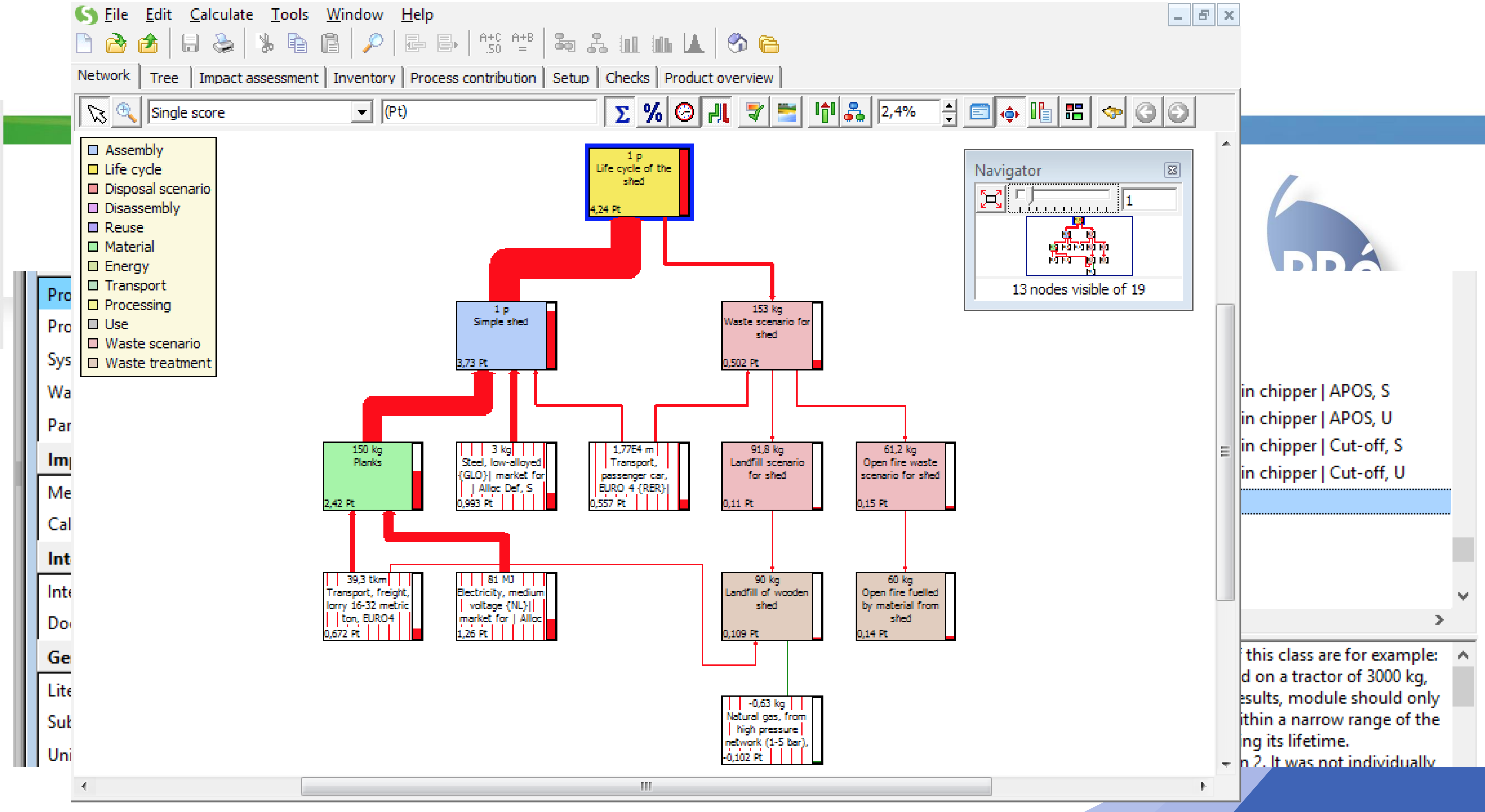
A joint venture of

UNIVERSITY OF BATH

BSRIA

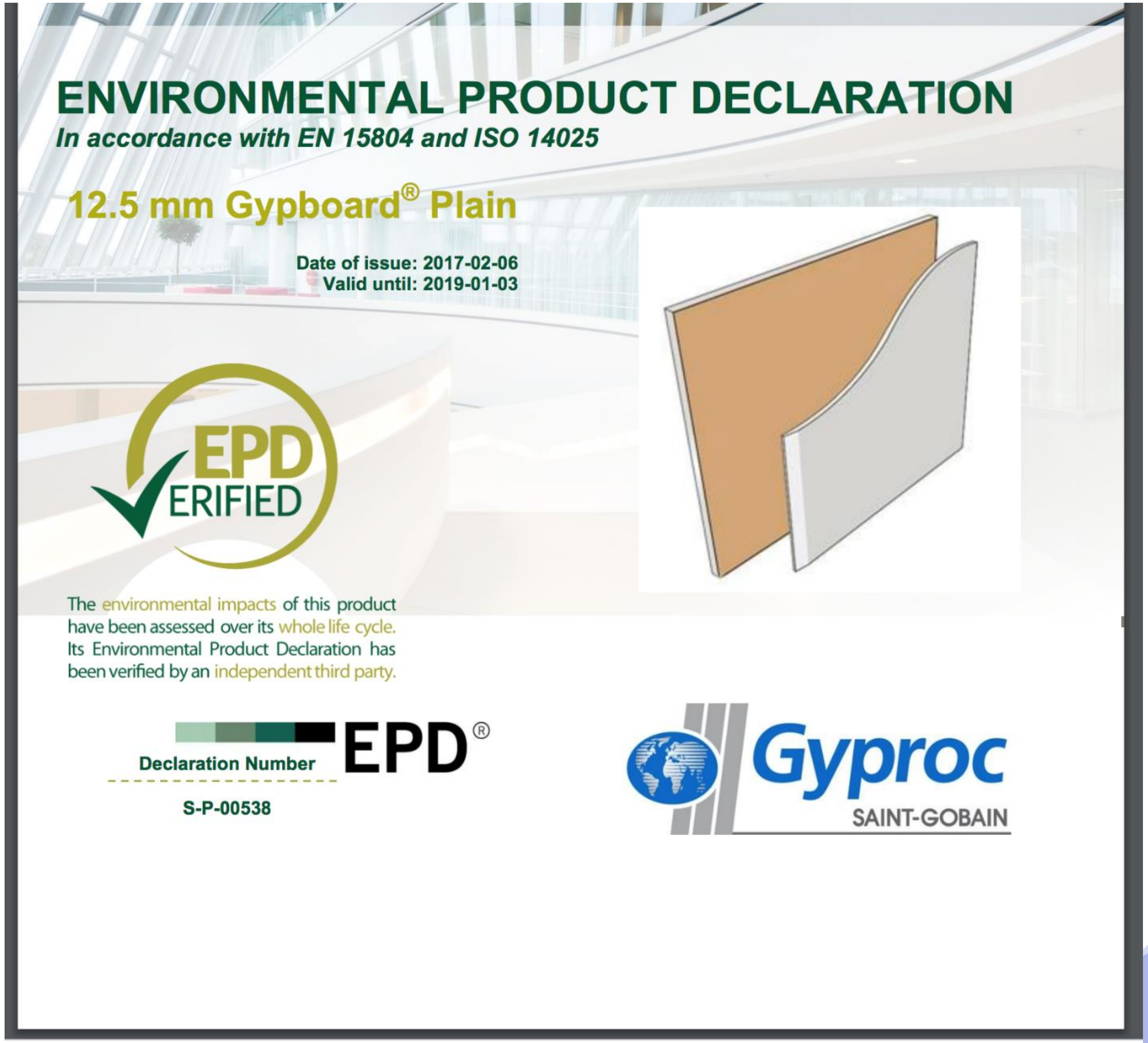
Comparing embodied energy

For typical wall	Density kg/m3	Thickness m	Weight per m2 kg	EE per m2 MJ/kg
Trad Cob	1700.000	0.500	850	95.47
Composit CobBauge	Density kg/m3	Thickness m	Weight per m2 kg	EE per m2 MJ/kg
Structural Cob	1600.000	0.250	400	51.12
CobBauge 50%	350.000	0.250	87.5	44.10
Total		0.500		95.22
Masonry Wall	Density kg/m3	Thickness m	Weight per m2 kg	EE per m2 MJ/kg
DenseBlock	2000.000	0.115	230	154.10
Foam	40.000	0.050	2	216.00
Cavity		0.050		
Aerated Block	700.000	0.115	80.5	281.75
Total		0.330		651.85

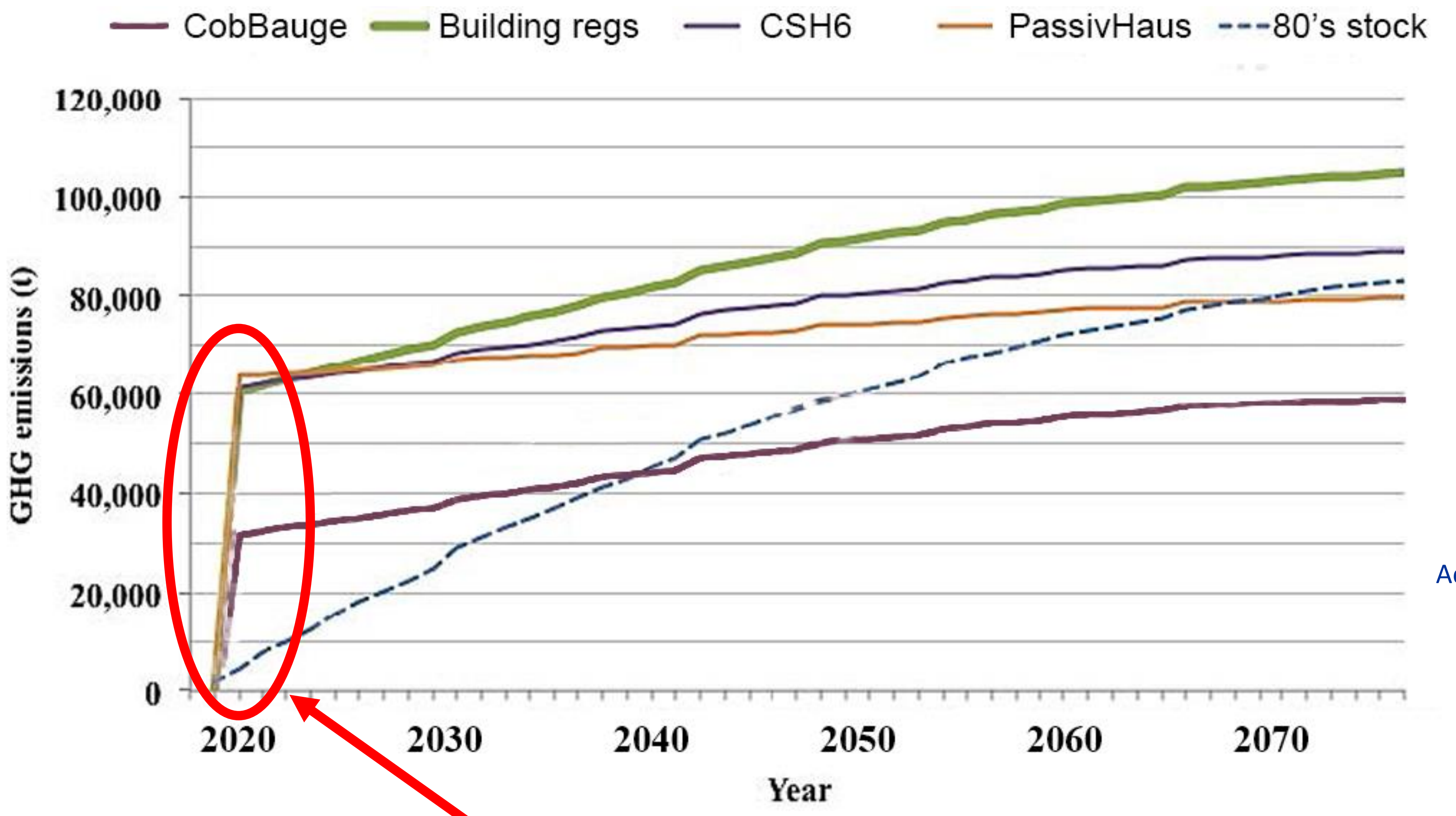

File Edit Calculate Tools Window Help
Network
Tree
Impact assessment
Inventory
Process contribution
Setup
Checks
Product overview
Single score
(Pt)
2,4%
Assembly
Life cycle
Disposal scenario
Disassembly
Reuse
Material
Energy
Transport
Processing
Use
Waste scenario
Waste treatment
Navigator
13 nodes visible of 19
1 p Life cycle of the shed 4,24 Pt
1 p Simple shed 3,73 Pt
153 kg Waste scenario for shed 0,502 Pt
150 kg Planks 2,42 Pt
3 kg Steel, low-alloyed {GLO}| market for | Alloc Def, S 0,993 Pt
1,77E4 m Transport, passenger car, EURO 4 {RER}| 0,557 Pt
91,8 kg Landfill scenario for shed 0,11 Pt
61,2 kg Open fire waste scenario for shed 0,15 Pt
39,3 tkm Transport, freight, lorry 16-32 metric ton, EURO4 0,672 Pt
81 MJ Electricity, medium voltage {NL}| market for | Alloc 1,26 Pt
90 kg Landfill of wooden shed 0,109 Pt
60 kg Open fire fuelled by material from shed 0,14 Pt
-0,63 kg Natural gas, from high pressure network (1-5 bar), -0,102 Pt
in chipper | APOS, S
in chipper | APOS, U
in chipper | Cut-off, S
in chipper | Cut-off, U
this class are for example:
d on a tractor of 3000 kg,
esults, module should only
ithin a narrow range of the
ng its lifetime.

Calculating LCA - SimaPro

Output:
European Product Declaration
for CobBauge



Life Cycle Assessment – Why is this important?



Adapted from Jukka Heinonen

This is happening now!

What next?

Prototype Buildings

Monitoring

Future work

CobBauge Phase 2 Objective

Source: Francois Strieff(2019)

To deliver CobBauge Dwellings

It's a question of scale.

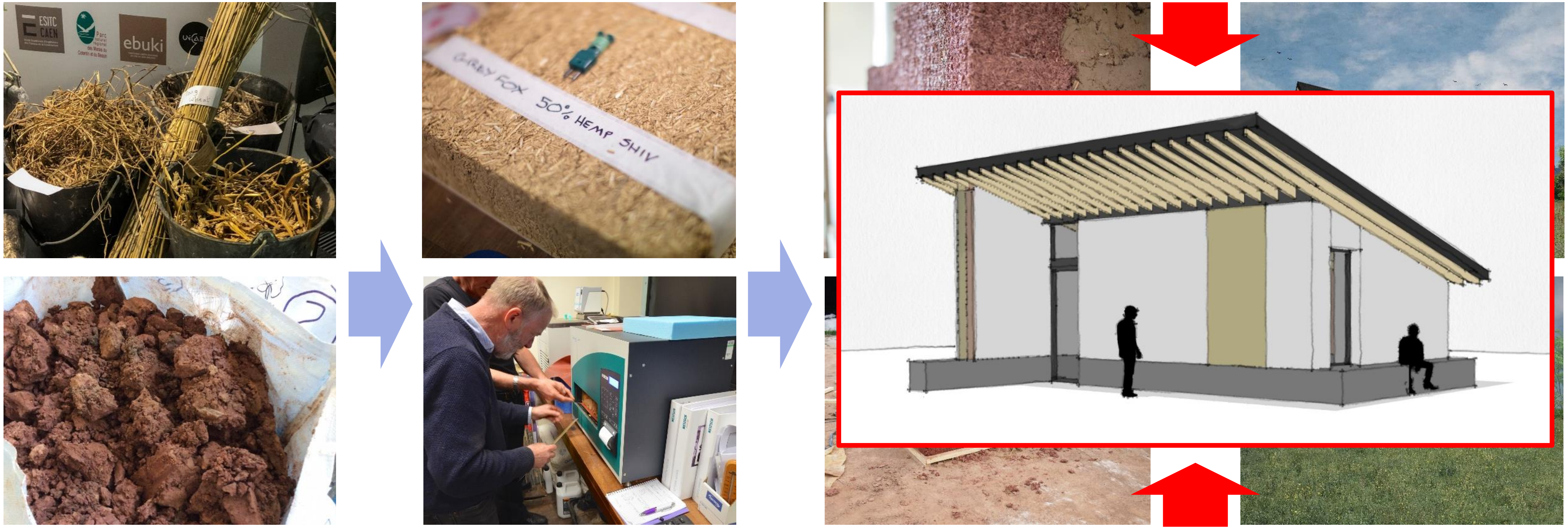





Source: Plymouth University (2019)

Making the jump from square samples and trial walls to somebodies home takes a leap of faith.

It's a question of scale.



Source: Plymouth University (2019)

An intermediary stage is to create small scale pilot buildings. To test ideas / scenarios / methods before using them on a habitable building.

CobBauge Prototype Buildings

- Important to bridge gap between trial wall / test samples and someone's home.
- Seeking to develop two prototype buildings. In France and UK
- Used as a driver to develop key details.
- Allows us to trial ideas / design variations / construction techniques

All images source: Francois Strieff (2019)

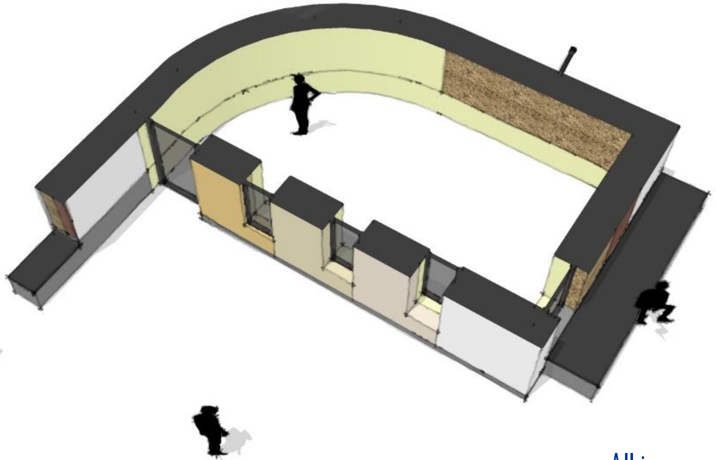
CobBauge Prototype Buildings

- French building under construction

All images source: Francois Strieff (2019)

CobBauge Prototype Buildings

- Seeking funding through preparation of a business case
- UK building aiming to enter planning process shortly
- Anticipated site start summer 2020.



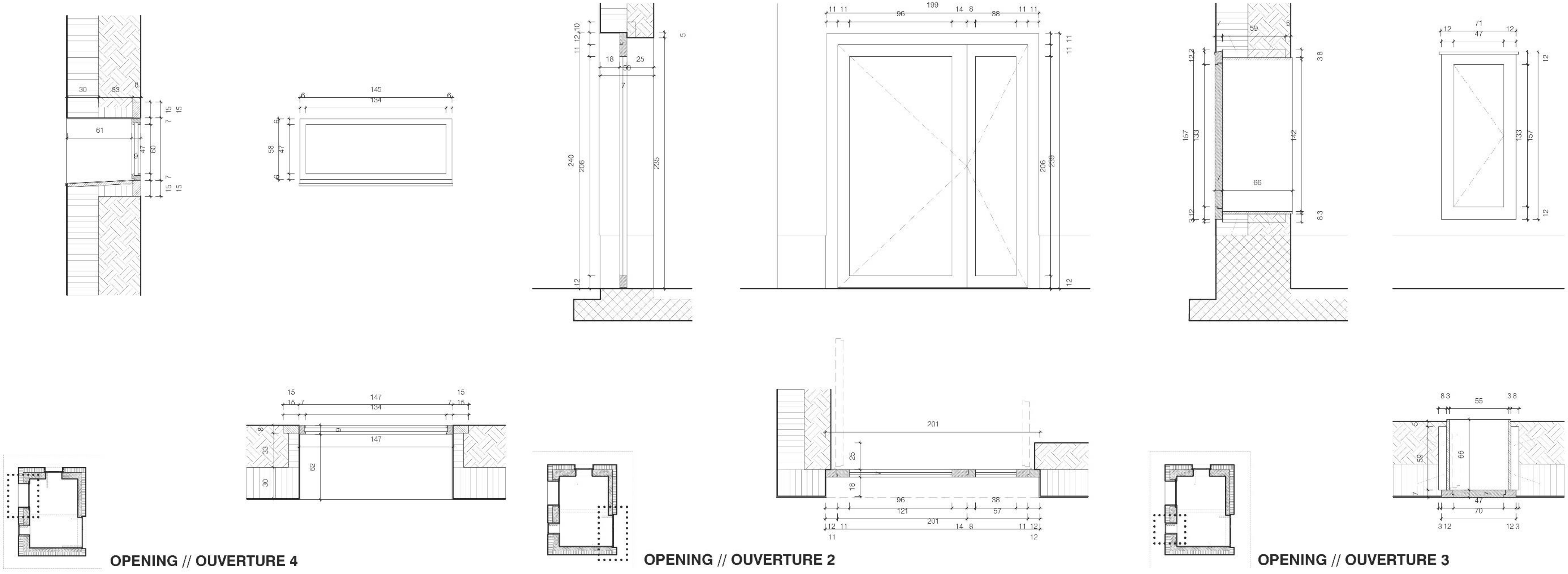
All images source: Fox Ecological Architects (2019)

- Experimenting with a curved wall.
- Using the curve to lead people into the room.

What we need to achieve

- The use of formwork saves time on the building site
- Site organization to optimize the implementation of construction
- Refine tools to help make the work effective.
- Building details to meet a demand for modern aesthetics and the requirements of regulatory performances

All images source: Francois Strieff (2019)



All images source: Francois Strieff (2019)

- How to create windows/doors on external face, internal face or in the middle of the wall
- How to avoid thermal bridging

CobBauge Pilot Houses

- Once experimentation has been completed on the prototype buildings two pilot residential dwellings shall be constructed.
- One in France and one in the UK

All images source: Francois Strieff (2019)

Building Monitoring

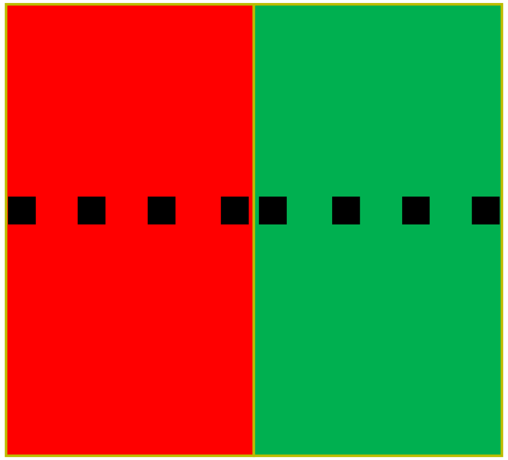
Pilot and prototypes need to ***demonstrate performance.***

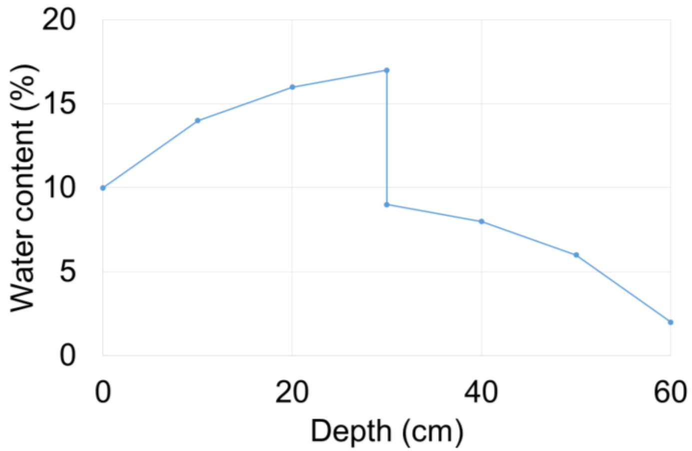
- Mid building construction monitoring
- Post building construction monitoring

Building Monitoring

Mid construction:

- Time-lapse video
- Analysis of processes and procedures
- Material moisture content and drying evolution in both layers
- Material shrinkage and compaction





All images source: ESITC (2019)

Building Monitoring

Post construction:

- Thermal imaging
- Measure the thermal conductivity in situ
- Air tightness testing
- Air quality
- Mean radiant temperature
- Energy use

All images source: Matthew Fox (2019)

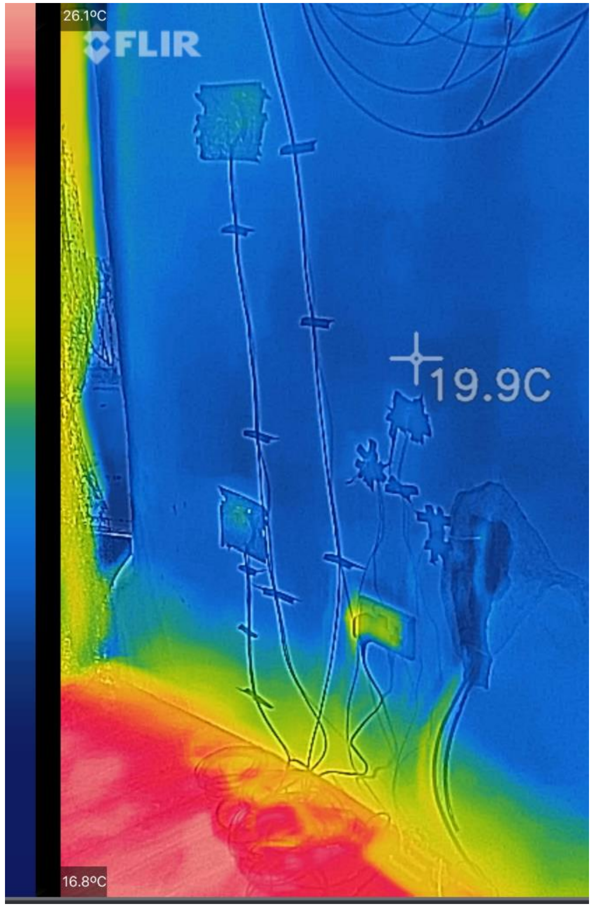
Early in-situ monitoring

In-situ monitoring of existing Cob buildings

In-situ measured (over 4 weeks)

We found:

- Traditional cob delivers U-values around **0.9W/m²K (R6)** for a 600mm thick wall.



Source: Plymouth University (2019)

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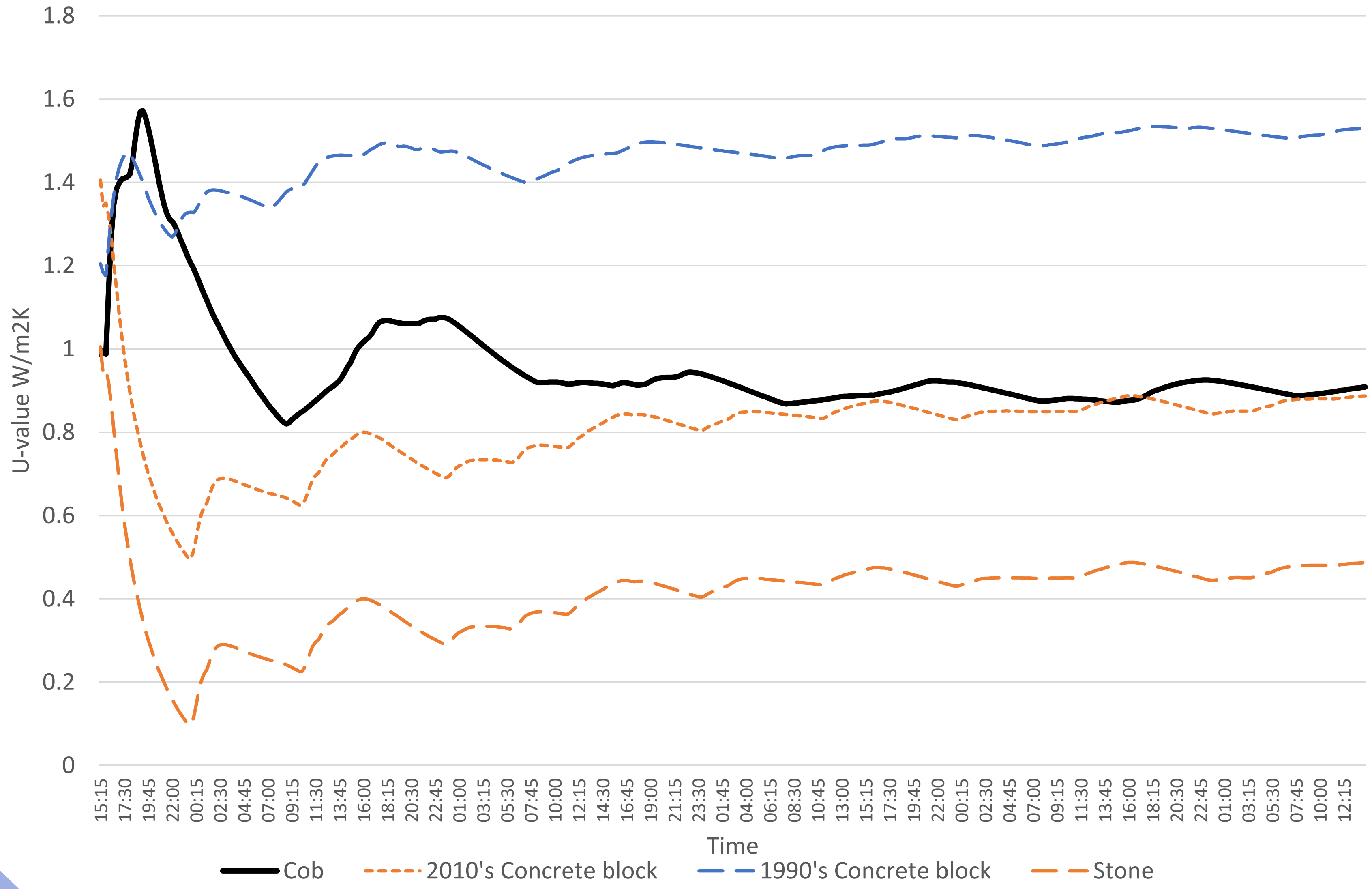
Early in-situ monitoring

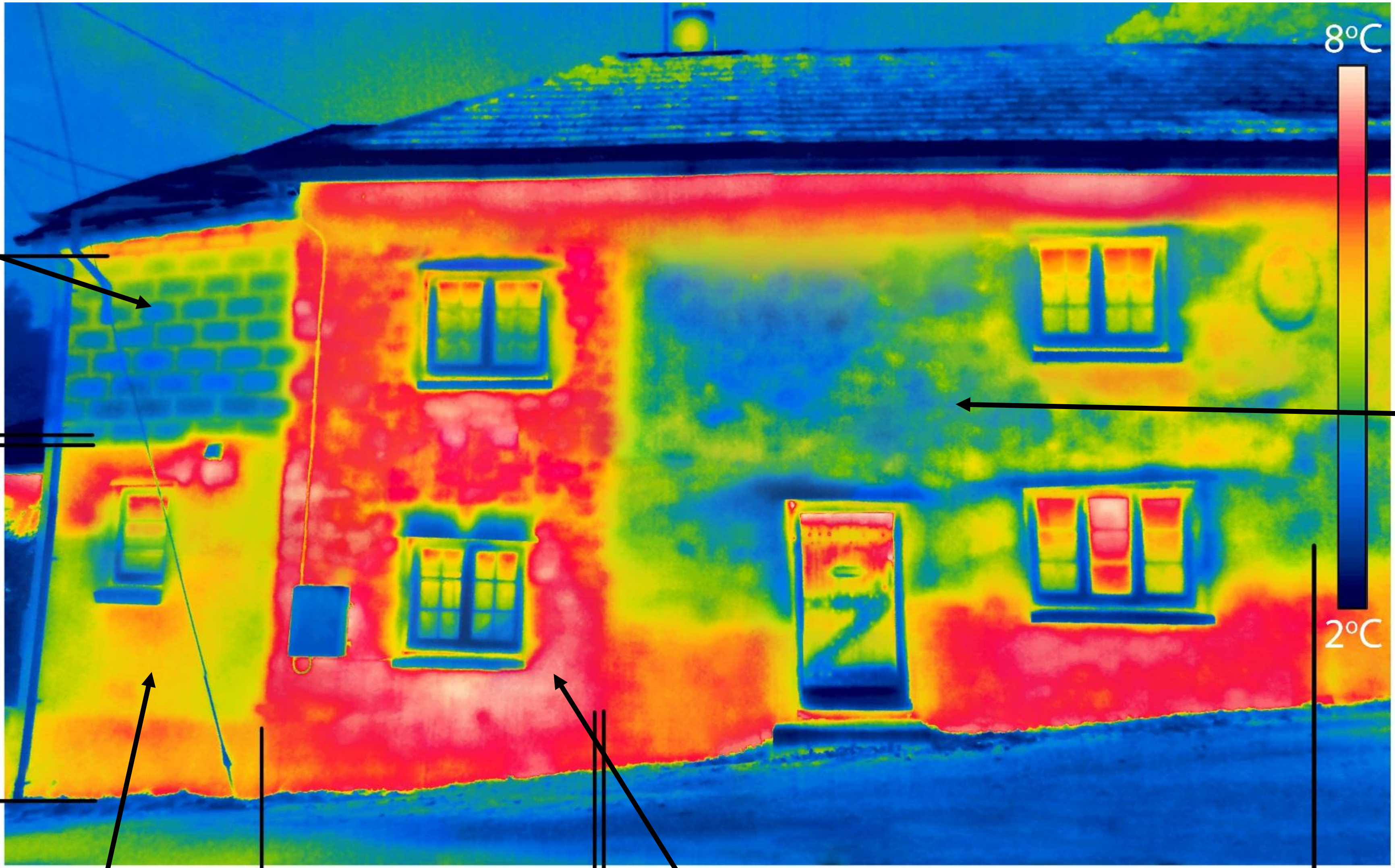


Source: Plymouth University (2019)

Approx.
0.9W/m2K (R6)

1990's Cavity wall

1980's Cavity wall



Approx.
0.9W/m2K (R6)

1900's Solid Stone wall.

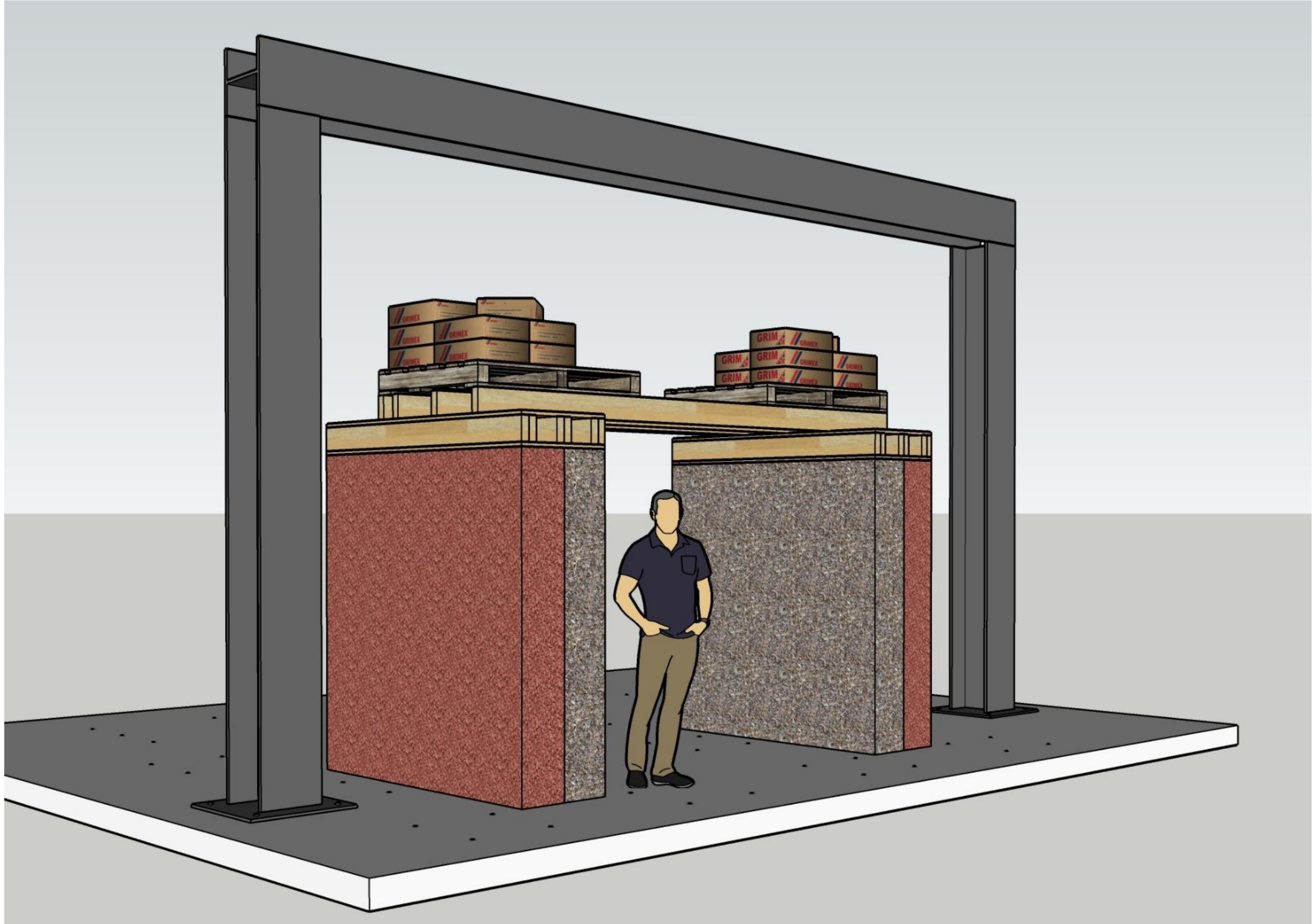
1700's **Cob** on low stone wall.

Approx.
1.1W/m2K (R5)

Approx.
1.5W/m2K (R4)

Source: Matthew Fox (2018)

Future work: Full size test walls



Other future work objectives

- Training builders how to construct using CobBauge
- Measuring the embodied energy of CobBauge
- Determining the cost of constructing using CobBauge
- Developing a network. Links with training and dissemination.

All images source: EBUKI (2019)

We're a winning team!

Source: Plymouth University (2019)

Contact us for further information:

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Parc naturel régional des Marais du Cotentin et du Bessin
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HUDSON Architects

Thank you