#UKPHC19

Embodied Carbon & Natural Materials.

Anna Carton MSc, MCIAT, CEPH

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EMBODIED CARBON & NATURAL MATERIALS

Prepared by Jae Cotterell, Phil Neve and Anna Carton

ANNA CARTON MSc, MCIAT, CEPH

PASSIVHAUS HOMES & PH15 SYSTEM

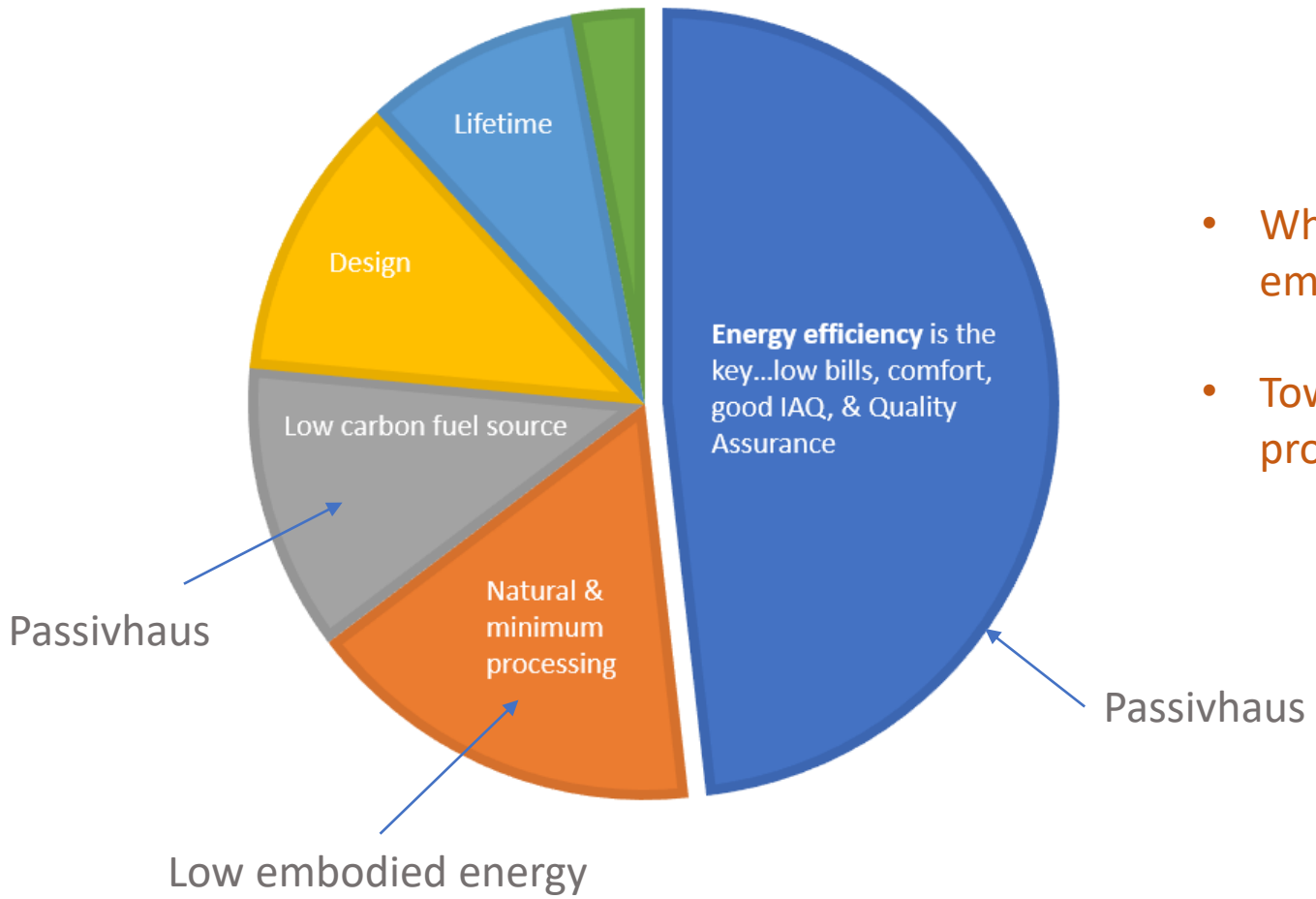
Winner Best Private House 2013 Passivhaus Trust UK Awards

Finalist for Ashden Award 2018

Shortlist for ASBP Awards 2019 (sustainable building products)

Member of 15-40 Architecture Collective

LOOKING AT A ‘WHOLE’ SOLUTION?



- What is ‘sustainable building’ in light of the climate emergency towards 2030 and 2050?
- Towards ‘ZERO CARBON’ – is this the right proportions of the pie?

Committee on Climate Change, Green Construction Board, RIBA Targets

RIBA 2030 Climate Challenge target metrics for domestic buildings

RIBA Sustainable Outcome Metrics	Current Benchmarks	2020 Targets	2025 Targets	2030 Targets	Notes
Operational Energy kWh/m²/y	146 kWh/m² /y (Ofgem benchmark)	< 105 kWh/m²/y	< 70 kWh/m²/y	< 0 to 35 kWh/m²/y	UKGBC Net Zero Framework 1. Fabric First 2. Efficient services, and low-carbon heat 3. Maximise onsite renewables 4. Minimum offsetting using UK schemes (CCC)
Embodied Carbon $kgCO_2e/m^2$	1000 $kgCO_2e/m^2$ (M4i benchmark)	< 600 $kgCO_2e/m^2$	< 450 $kgCO_2e/m^2$	< 300 $kgCO_2e/m^2$	RICS Whole Life Carbon (A-C) 1. Whole Life Carbon Analysis 2. Using circular economy Strategies 3. Minimum offsetting using UK schemes (CCC)
Portable Water Use Litres/person/day	125 l/p/day (Building Regulations England and Wales)	< 110 l/p/day	< 95 l/p/day	< 75 l/p/day	CIBSE Guide G

✓

?

UK ARCHITECTS DECLARE.

'Include life cycle costing, whole life carbon modelling and post occupancy evaluation as part of our basic scope of work, to reduce both embodied and operational resource use.'

'Accelerate the shift to low embodied carbon materials in all our work.'

Space heating demand

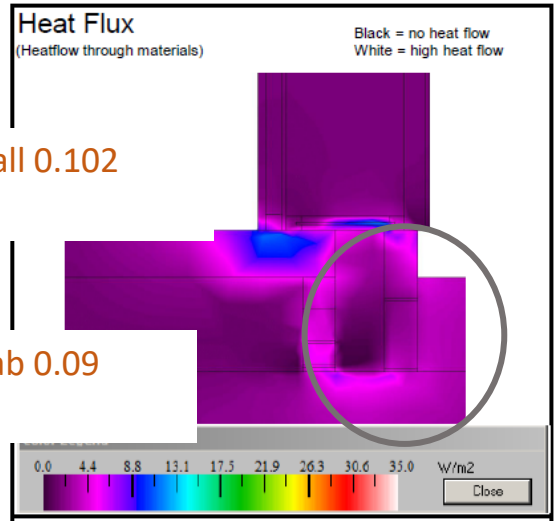
By latest 2025, space heating demand 15-20 kWh/m2/yr.

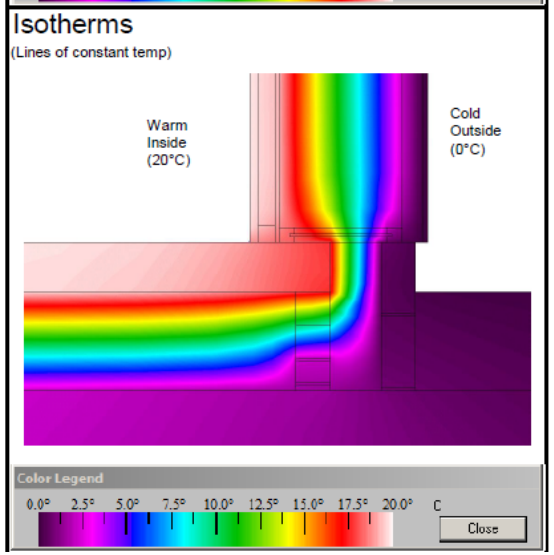
(Committee on Climate Change)

OPERATIONAL CARBON vs EMBODIED

U-value wall 0.102 W/m2K

U-value slab 0.09 W/m2K





Software:	Therm 6.3			Date:	04/11/2016
Job Name:	Tring TB Calcs			Job No:	2016 130
Tab name:	GroundFloor - Wall			Completed by:	LM
Descrip:	TBG-1 Ground floor to external wall junc			Checked by:	KP

Data colum	Row	Name	Ufactor name	Length mm	U factor	L2D W/Km
S	16	Wall	Internal	2000	0.0805	
T	16	Floor Casset	External	4000	0.0721	
U	16	L2D	Internal			0.4925

U - value calculation for data row	Wall	
Check surface resistances correct	y	
Checl total length correct	y	
Modelling U Value (W/m2K)		**0.081**

U - value calculation for data row	Floor Cassette				
Check surface resistance correct (zero under)	y				
Checl total length correct	y				
Floor Cassette Modelling U Value (W/m2K)					**0.072**
GROUND BEARING Ground Floor Calculation using ISO 13770, check values below					
areas m2	4	m2	perim m	1	m
wall thick	0	m	ground k	2.0	W/m2K
dg	27.82		B'	8	
FLOOR Modelling U Value (W/m2K)					**0.064**

Psi calculation		length mm	U-value/L2D W/m2K	heat flow W/mK	psi value W/mK
L2D				0.492	
Wall	Length time U value:	2050	0.0805	0.165	
Floor	Length time U value:	4000	0.0635	0.254	
				0.073	
psi Internal					**0.07** W/mK

Psi calculation		length mm	U-value/L2D W/m2K	heat flow W/mK	psi value W/mK
L2D				0.492	
Wall	Length time U value:	2500	0.0805	0.201	
Floor	Length time U value:	4522	0.0635	0.287	
				0.004	
psi External					**0.004** W/mK

Error in calculation:	From therm report - worst cell	7.3 %

OPERATIONAL CARBON

An excellent PH15 detail. psi value external of **0.004 W/mK**

*If below **0.01** (external) you can discount in PHPP.*

EMBODIED CARBON

Based on an 80sqm slab*:*

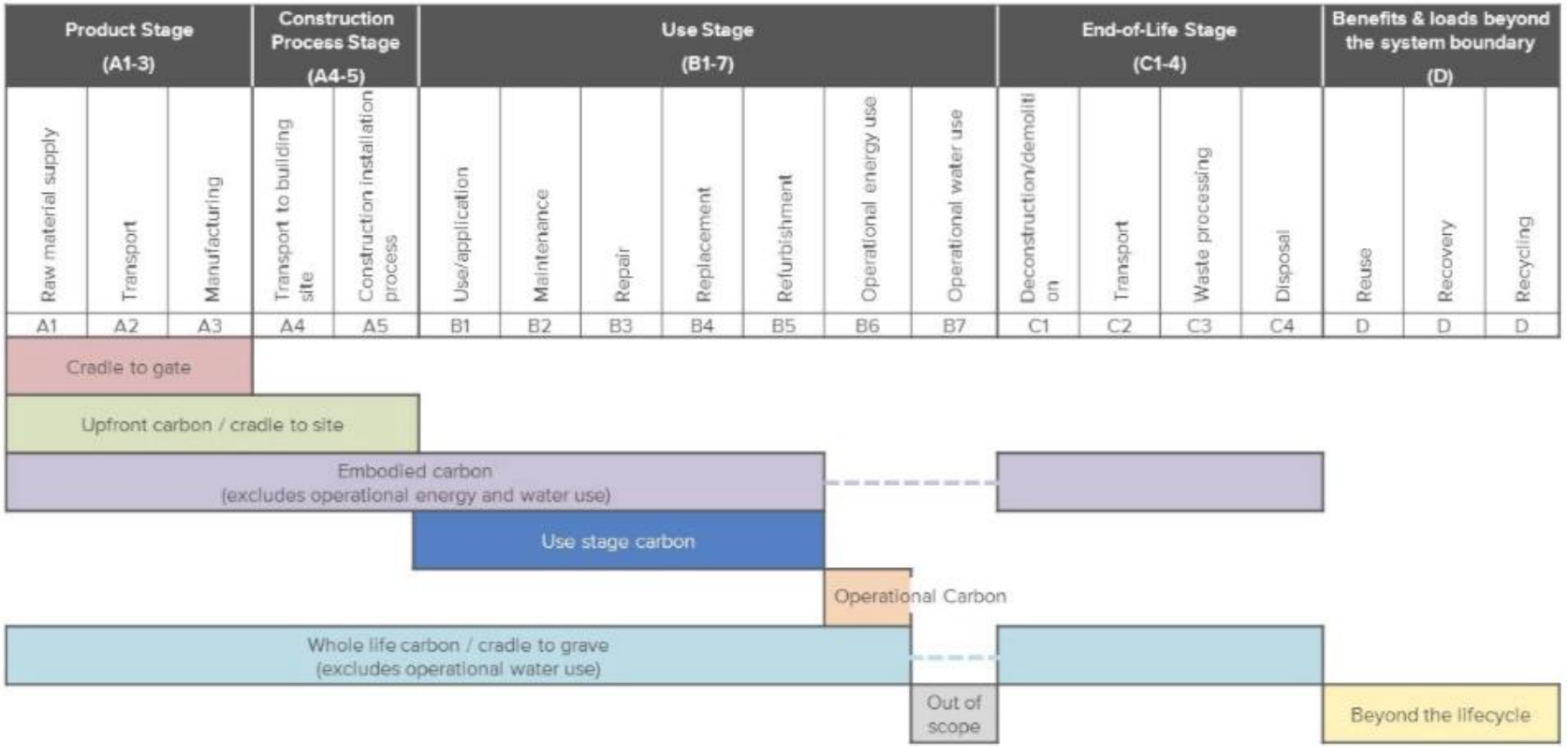
600mm trench fill footing, 150mm reinforced concrete slab, 160mm expanded polystyrene insulation

EMBODIED CARBON ??

(ONLY A1, A2, A3)

2030 Climate Change Committee targets

Cradle to Gate



E-C02 Climate Challenge Target: Embodied Carbon

Embodied Carbon $kgCO_2e/m^2$	1000 $kgCO_2e/m^2$ (M4i benchmark)	< 600 $kgCO_2e/m^2$	< 450 $kgCO_2e/m^2$	< 300 $kgCO_2e/m^2$

1000 kgCO2e/m²

300 kgCO2e/m²

XCO2 STUDY: Embodied Carbon

TRADITIONAL MASONRY

Walls: Cavity brick/block with 300mm mineral wool in cavity. 250mm intermediate joists with 100mm rockwool insulation, Roofing slate, timber joists with 300mm mineral wool insulation.

55.6 tCO2 total
25.5 above ground, 30 tonnes of slab/footings.

159KgCO2/m2

SIPS

Walls: 15mm OSB sterling boards, total 182mm Kingspan insulations, render finish. Roof with roofing slate, OSB boards and 172mm Kingspan insulations. Intermediate floor 250mm timber joists with 100mm Rockwool.

49.4 tCO2 total
19.4 above ground, 30 tonnes of slab/footings.

120 KgCO2/m2

LIGHTWEIGHT TIMBER

Walls: Cedar cladding, 18mm spruce boards with 275mm cellulose and timber studs, 10mm Fermacell boards. Intermediate floor, 115mm stud cavity with 18mm spruce boards, 100mm cellulose insulation and 10mm Fermacell board. EPDM rubber roof, 18mm spruce boards, timber I-joist 290mm with cellulose fully filled, 12.5 mm Fermacell board. Screw piles.

7.26 tCO2 total
1.26-0.76 tonnes for screw piles.

40 KgCO2/m2

NOTES: FOOTPRINT ANALYSIS FROM XCO2 Ltd. in accordance with ISO 14044 – only A1, A2, A3. Based on a two storey 160sqm house with thirty degree pitched roof with U-values of 0.14 W/m2K all elements. Exploring the material differences in carbon terms. Used ICE/CIBSE or product manufacturers declarations.

Kingspan ecological BUILDING SYSTEMS econekt MUNSTER JOINERY

ukpassivhaus conference 2019

RIBA/CCC TARGET 2030 300KgCO2e/m2 (A1-C4)

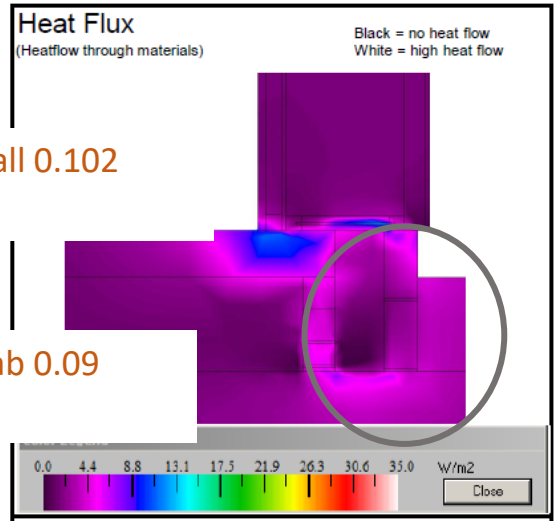
	MASONRY	SIPS	TIMBER FRAME
TOTAL (A1-A3) **incl. CONCRETE SLAB KgCo2e/m2**	X 348 (55,600kg total)	X 308 (49,400kg total)	✓ 231* (37,000 Kg total)
ABOVE GROUND ONLY (A1-A3) KgCo2e/m2	159 (mineral wool insulation)	120 (Oil based insulations)	40 (Cellulose insulations)

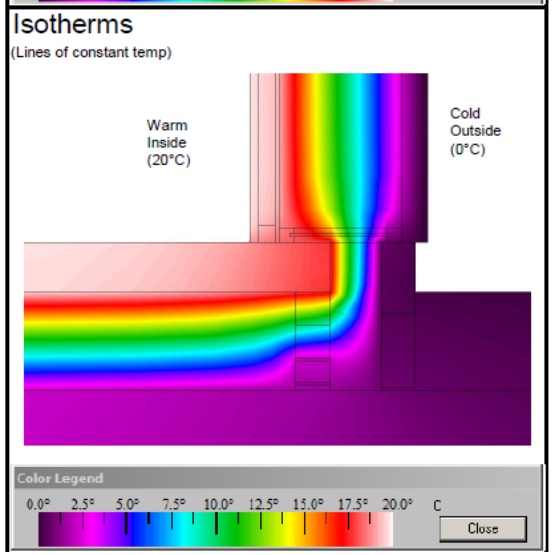
NOTES:

Embodied Energy Insulations x1 cellulose, x6 mineral wool,x30 oil based insulations.
Based on 160sqm GIA so a smaller house carbon might be 50% of these figures
*frame optimisation can increase embodied carbon by a factor of 2.

U-value wall 0.102 W/m2K

U-value slab 0.09 W/m2K





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				0.004	
psi External				**0.004**	W/mK

Error in calculation:	From therm report - worst cell	7.3 %

187 KgC02e/m2 X

Based on an 80sqm slab:

600mm trench fill footing, 150mm reinforced concrete slab, 160mm expanded polystyrene insulation

XCO2 Study

Lightweight Timber Frame = 80%

Masonry = 54%

(ONLY A1, A2, A3)

E-C02 Climate Challenge Target: Operational Energy

Operational Energy kWh/m²/y	146 kWh/m² /y (Ofgem benchmark)	< 105 kWh/m²/y	< 70 kWh/m²/y	< 0 to 35 kWh/m²/y

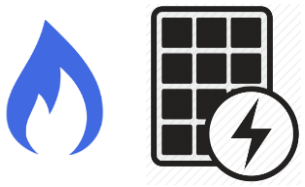
146 kWh/m²/y

35 kWh/m²/y

CERTIFIED PASSIVHAUS CLASSIC

- Detached, 2-storey, 4 bed house.
- TFA 184m² TFA
- 7 kWh/(m2.a)
- 5.5kW PV array
- Gas boiler for heating & hot water. Plan to swap to Air Source Heat Pump over time and will then be *Passivhaus Plus*.
- Overheating <1%
- PH15 Cost £114k net or approx. £582/m² of gross internal floor area

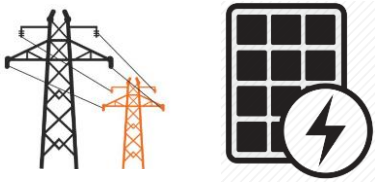
PH15 STUDY: Operational Energy



Gas boiler
+ 5.5kW PV array

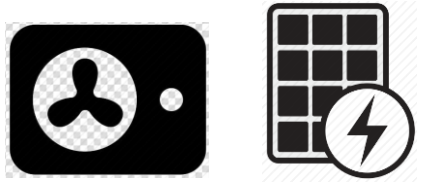
2200 kWh/yr. used in the house at 40% utilization.

40kWh/m2/y ex PV
30kWh/m2/y with PV



Electric (heating & hot water)
+ 5.5kW PV array

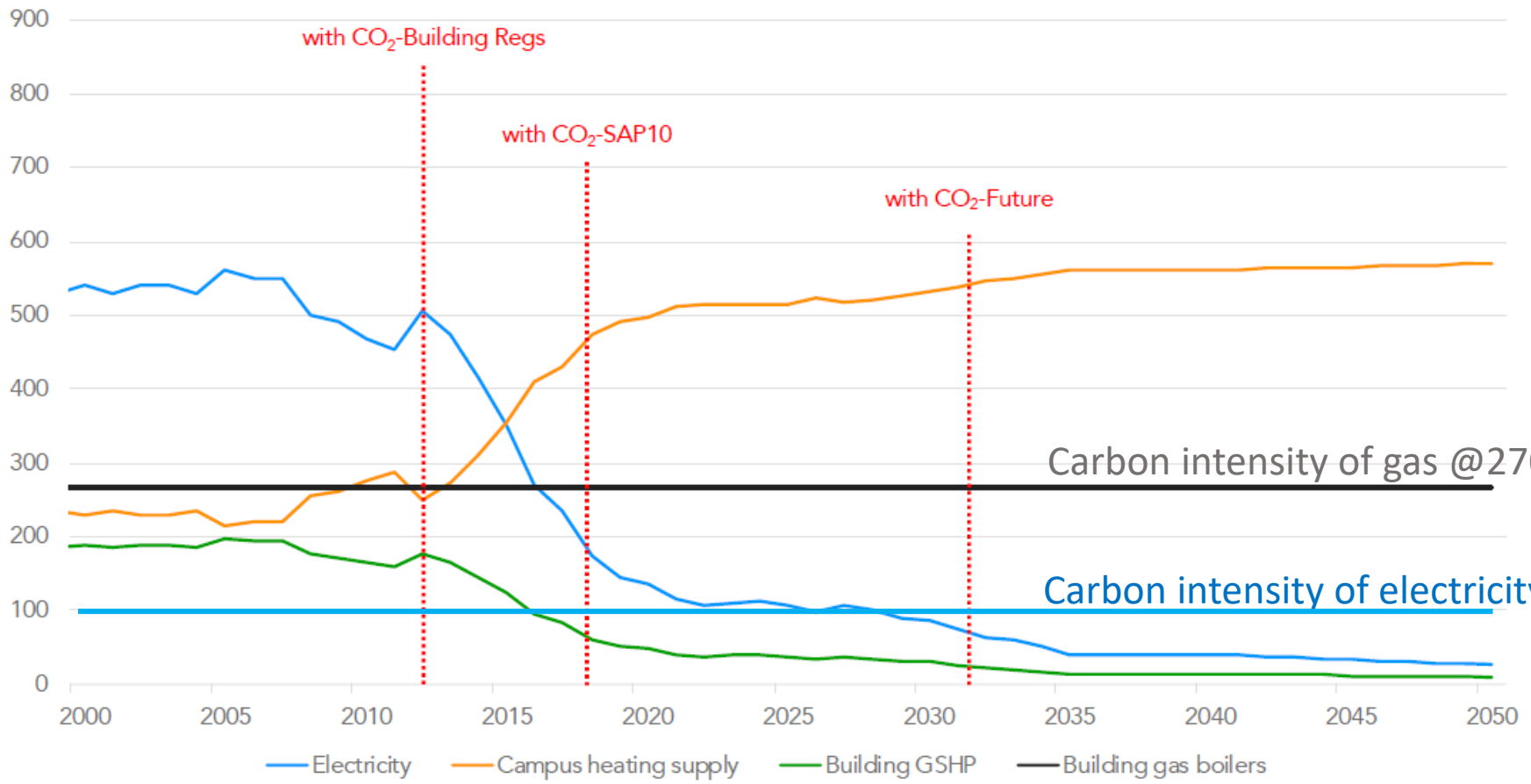
36kWh/m2/y ex PV
26kWh/m2/y with PV



Air Source Heat Pump
+ 5.5kW PV array

23kWh/m2/y ex PV
13kWh/m2/y with PV

Carbon content by fuel source

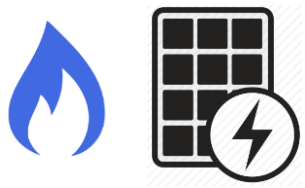


Carbon intensity of gas @270gCO2/kWh

Carbon intensity of electricity @100gCO2/kWh

Courtesy of ETUDE

PH15 STUDY: Operational Carbon over 60 years



Gas boiler + 5.5kW PV array

65tC02e over 60 years.

1.1 tC02e/yr

Air Source Heat Pump + 5.5kW PV array

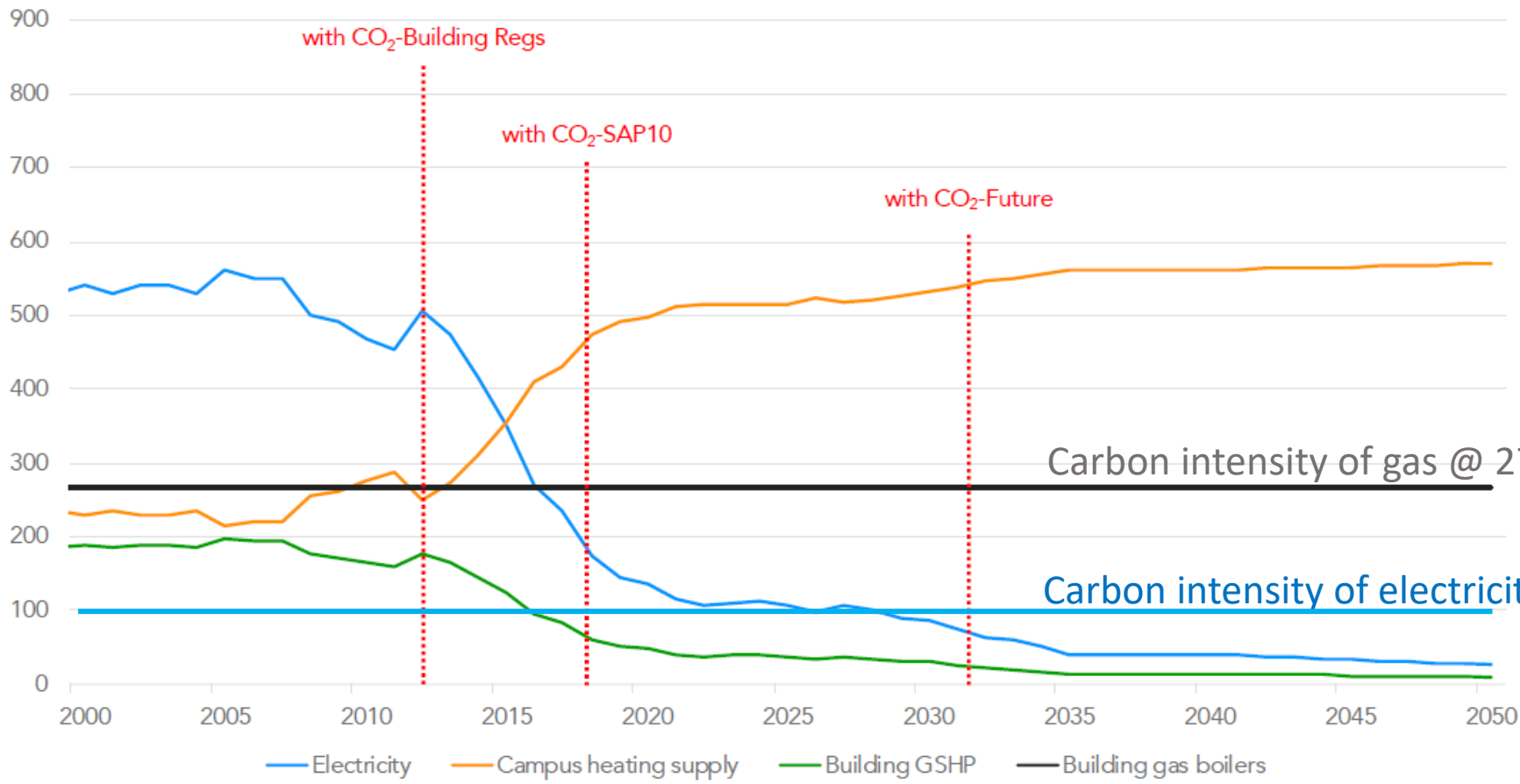
12tC02e over 60 years.

0.2 tCO2e/y

! EXTRA 53 TONNES if you use GAS. Equivalent to up to 53 years of operational use in version A

Note: figures do not account for any change in carbon intensity of PV or ASHP over 60 year period.

Carbon content by fuel source



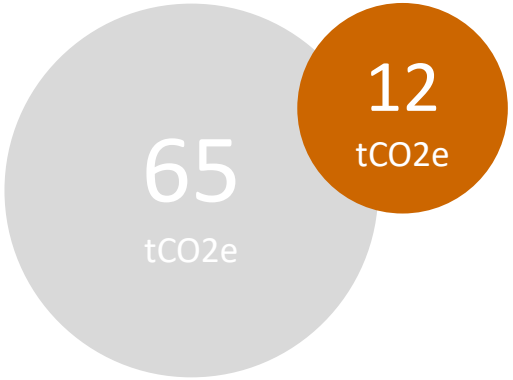
Carbon intensity of gas @ 270 gCO2/kWh

Carbon intensity of electricity @ 100 gCO2/kWh

Courtesy of ETUDE

OPERATIONAL vs EMBODIED

OPERATIONAL



EMBODIED

37
tCO2e

WITH CONCRETE SLAB
Maybe we need to find an alternative base?
Could you save 15 tonnes of carbon?

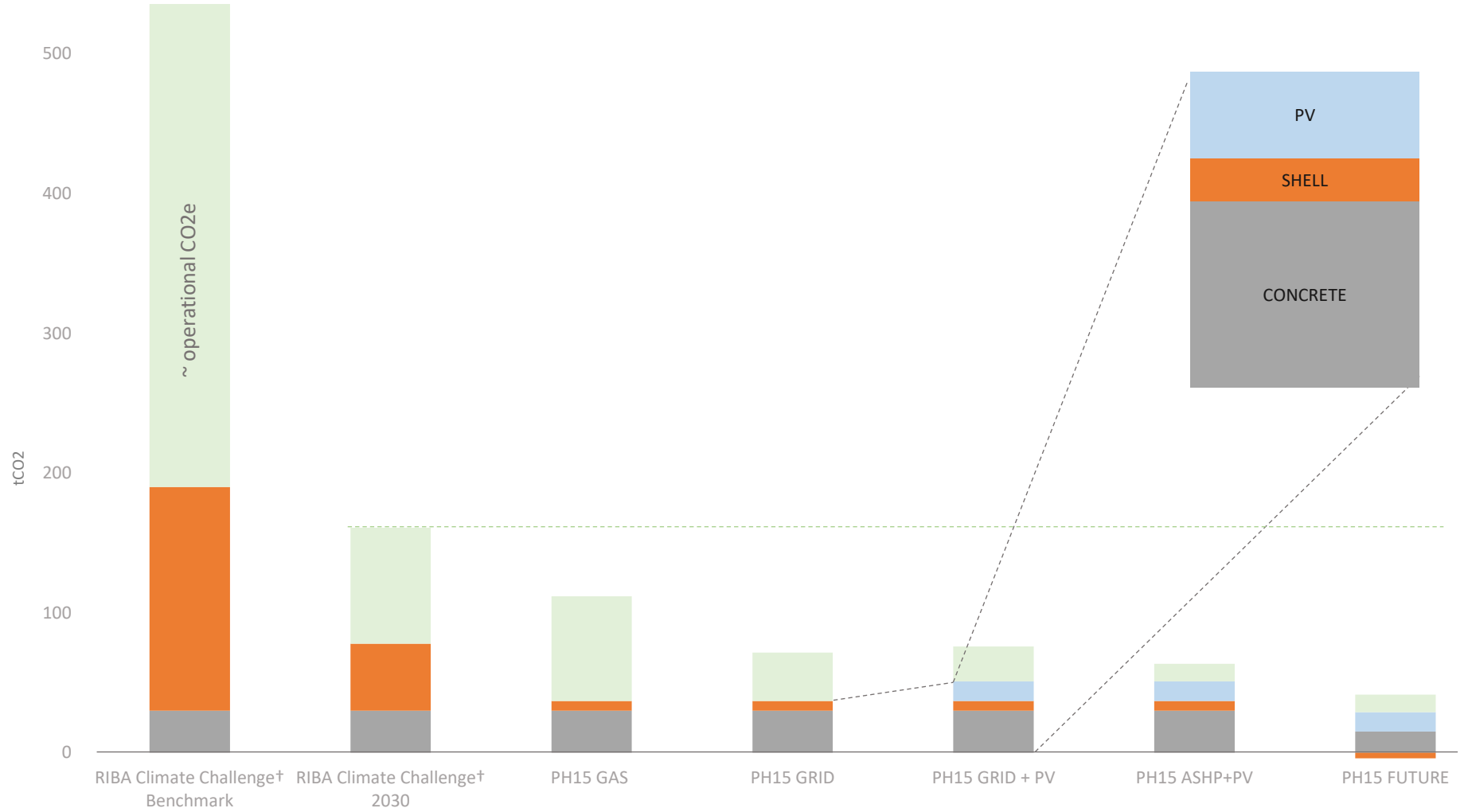
CARBON OFFSET not included. For use of TIMBER FRAME, CARBON STORAGE may be circa 11tCO2 per HOUSE (CCC, 2019)

NOTES:

Operational carbon – Using 1.0 tonnes carbon/year for two people, 0.5 tonnes/year. A more modest house (130sqm GIA) could be using 0.5 tonnes carbon/year for two people say 0.25 tonnes/year. 2050 target CO2e/person/year = 2 tCO2e/year. How do we allocate embodied cost?

Embodied carbon – Shell only, uses 37 tonnes. How do we allocate this? A more modest P15 might use 20 tonnes

SUMMARY: EMBODIED vs OPERATIONAL



Notes: Graph shows approximate values for 160m2 over 60years. All PH15 shell and concrete figures A1-A3 only. RIBA climate challenge figures are for total embodied CO2 from A-C. ASHP embodied CO2e not calculated. PH15 'FUTURE' estimates a 50% CO2 reduction for alternative ground works and includes CCC estimate for carbon storage/house.

Embodied - slab/foundations Embodied - above ground Embodied PV Operational

UK HOUSING FIT FOR THE FUTURE

From 2025 at the latest, ***no new homes should be connected to the gas grid****. They should instead be heated through low carbon sources, have ultra-high levels of energy efficiency alongside appropriate ventilation* ***and, where possible, be timber-framed****. A statutory requirement for reducing overheating risks in new builds is needed, alongside more ambitious water efficiency standards…*

Where properly planned and used, our homes can be low-carbon, more comfortable to live in, better for our health, and more affordable to run. The health cost to the NHS of conditions exacerbated by poor housing is currently estimated to be ***£1.4 – 2.0 billion per year in England alone.***

Improve focus on reducing the whole-life carbon impact of new homes, ***including embodied and sequestered carbon. Using wood in construction to displace high-carbon materials such as cement and steel is one of the most effective ways to use limited biomass resources to mitigate climate change.*** *New policies will be needed to support this. Increasing the number of new homes built in the UK each year* ***using timber frame construction systems from around 27,000-50,000 in recent years to 270,000 annually could triple the amount of carbon stored in UK homes to 3 MtCO2 every year.***

Low-regrets action (low cost, great benefit) should also be pursued to support the assessment and benchmarking of whole-life carbon in buildings.

In policy context of Government ambitions for about 1.5 million new houses by 2022

THOUGHTS TO PONDER towards 2030

1. Embodied CO2 - Timber frame can meet RIBA Climate Challenge 2030. Masonry and oil-based insulation appear to fail.

2. What is the whole life picture? Would PH15 total embodied carbon exceed operational carbon (over 60 years), when you consider other stages and materials/components?

3. A need for significant reforesting in UK (native woodland) and supply chain changes.

4. No gas after 2025, all electric, air source heat pumps and PV (depending on C02 intensity of grid).

5. Building design – Do we need less large houses (embodied not operational reasons). What are the impacts of form factor on *embodied energy* – must be substantial. How does optimizing the timber fraction impact on this as well?

6. Critical to reduce *embodied energy in manufacturing* significantly e.g. Steico I-joist factory in Poland (PH15 supply) shifting from 50:50 coal/biomass to 100% biomass from 2020.

7. The proposed 2030 targets will impact our choice of construction method & material selection *significantly*. A big challenge will be groundworks & concrete/steel use. Minimal (or no) oil-based insulations as well. *Business as usual' is not an option IF we take these targets seriously.*

PH15 TIMBER BASED CONSTRUCTION

ALLOWS OFFSITE METHODS
Including control of WASTE.

OFFSET of EMBODIED CARBON
Planting native woodland in UK &
STORED CARBON

PH15

QUESTIONS & FEEDBACK

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Project Data: COMPTON CERTIFIED PASSIVHAUS CLASSIC (PHPP 9.6 figures, PER sheet)

kWh/m2/yr.	GAS BOILER	ALL ELECTRIC	ASHP
SPACE HEATING	8.4	7.1	3.4
HOT WATER	16.6	14.4	6.6
APPLIANCES/LIGHTING ETC	12.8	12.8	12.8
AUX. PUMPS etc.	2.2	1.7	0.2
AT THE METER DEMAND	40	36	23
ADD PV ARRAY assuming 40% DIRECT OFFSET in DEMAND 5547kWh/yr. total generation 2219kWh/yr. used in the house direct (183m2 GIA) Say 10 kWh/m2/yr. conservative reduction in demand at meter	30	26	13

COMPTON CERTIFIED PASSIVHAUS CLASSIC

PV EMBODIED CARBON

MONOCRYSTELINE = 43gCO2/kWh generated/m2 panel (low levels of solar radiation).
Based on 30 years.
43 x 229kWh x 24m2 panel x 30 years = 7 tC02.
60 years (2 installs) assume max. 14tCO2.

TRIPLE GLAZED WINDOWS - Study from 2017

838 kWh/m2 (608 frame + 230 glass). Assume electric power @ 100g/kWh.
Scheme had relatively high glazed areas.
838 kWh x 35m2 window x 100 grams carbon = circa 3tCO2.
Would be less in a modestly glazed scheme.

STEEL I-SECTION

203 x 203 x 133mm is 25kg/m.
ICE V3 steel is 1.55 kgCO2e/kg.

If you put 2 no. 'goal posts' in using total 22m length of steel.
22m x 25kg = 550kg steel.
1.55 KgCO2e/kg x 550Kg = 850kgCO2. Typical 0.5-1 tonnes per scheme.