DT175 BSc (Hons) Architectural Technology

TDS_T6_ Final Thesis Presentation

An investigation of three different wall types in the residential sector based on thermal performance, operational and embodied energy

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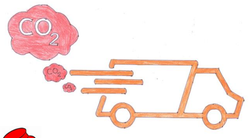
Objectives

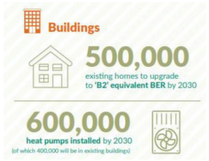
- To research the impact Ireland's construction industry has on the environment
- Identify a suitable case study building and using Revit explore the building in more detail
- Investigate three types of high-performing wall systems that are available and assess their potential to provide energy-efficient housing solutions
- Test and compare the embodied energy, operational energy and thermal performance of the chosen wall types
- Analyse and compare results to the governments housing and climate action plan



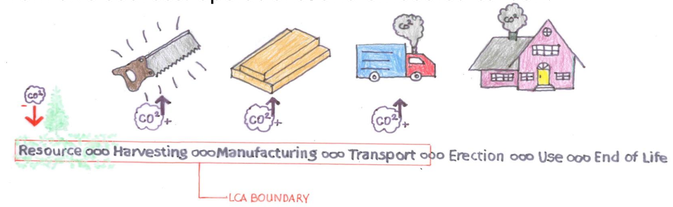
Aims

- The aim of this research is to determine the carbon emissions associated with three different construction methods while also assessing their thermal properties.
- My aim is also to assess the carbon impact of Irelands new housing plan which states that an average of 33,000 new homes is needed every year from 2021 to 2030.

Motivation



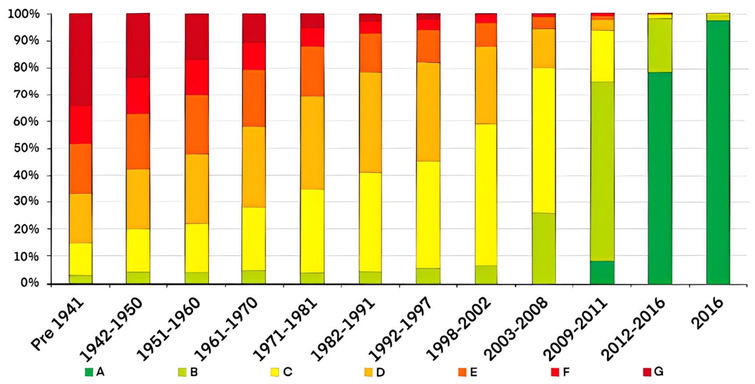
- As the world faces the challenges of climate change and the need for sustainable development, it is crucial to identify and implement sustainable and energy-efficient solutions in the construction sector.
- The Climate Action Act of 2021 obligates Ireland to a target of a national reduction of 51% (GHG) emissions by 2030, This aims to cut the building sector's GHG emissions by 44-56%. 37% of Ireland's yearly GHG emissions are caused by the built environment and come from two sources: operational and embodied carbon.



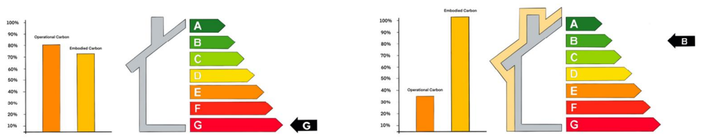
	2018 Baseline (MtCO2eq.)[1]	Sectoral Emission Ceilings for each 5 year carbon budget period (MtCO2eq.)		Emissions in final year of 2021-2025 carbon budget period (MtCO2eq)	Reduction in Emissions in final year of 2021-2025 carbon budget period compared to 2018 Baseline	Emissions in final year of 2026-2030 carbon budget period (MtCO2eq)	Reduction in Emissions final year of 2026-2030 carbon budget period compared to 2018 Baseline
Sector	*2018*	*2021-2025**	*2026-2030*	*2025**	*2025*	*2030*	*2030*
Electricity	10	40	20	6	~40%	3	~75%
Transport	12	54	37	10	~20%	6	~50%
Build Environment-Residential	7	29	23	5	~20%	4	~40%
Build Environment-Commercial	2	7	5	1	~20%	1	~45%
Industry	7	30	24	6	~20%	4	~35%
Agriculture	23	106	96	20	~10%	17.25	~25%
LULUCF[2]	5	XXX	XXX	XXX	XXX	XXX	XXX
Other (F-Gases, Waste & Petroleum refining)	2	9	8	2	~25%	1	~50%
Total[3]	**68**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**	**XXX**
Legally binding Carbon Budgets and 2030 Emission Reduction Targets[4]	-	295	200	-	-	34	51%
Annual unallocated Emission Savings in 2030	-	-	5.25[5]	-	-	-	–
Unallocated Savings 2026-2030[6]			26				

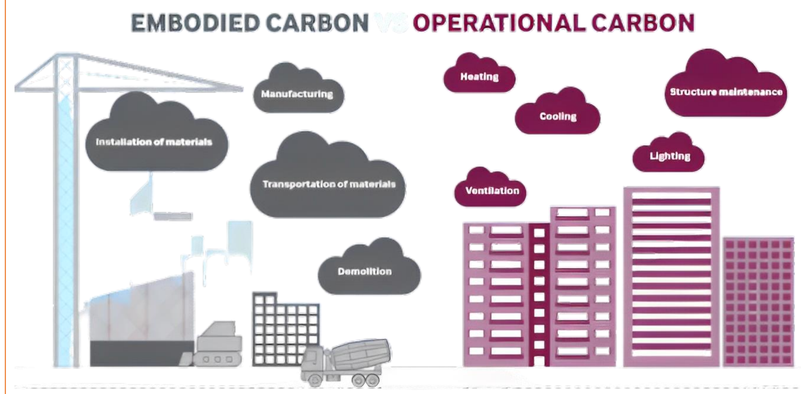
Sectoral Emission Ceilings as approved by Government on 28 July 2022

Ireland's Housing For Action Plan



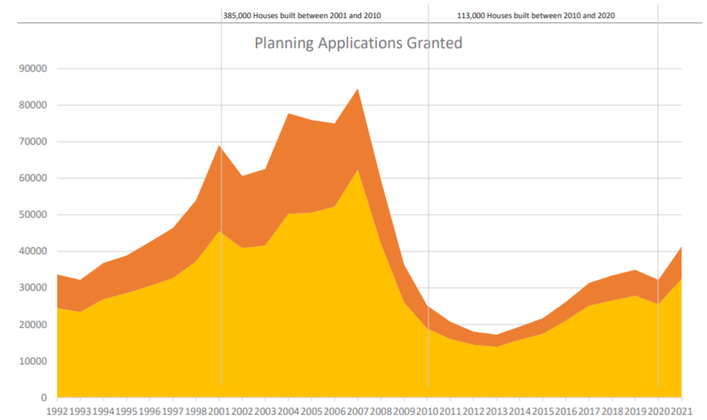
BER by Period of Construction



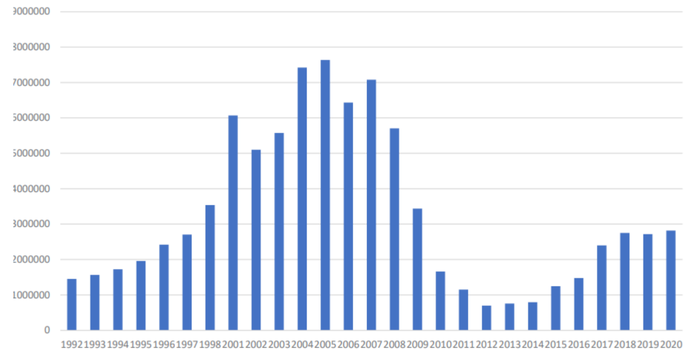


Embodied – The carbon footprint of construction materials

Operational – The building energy consumption when in use



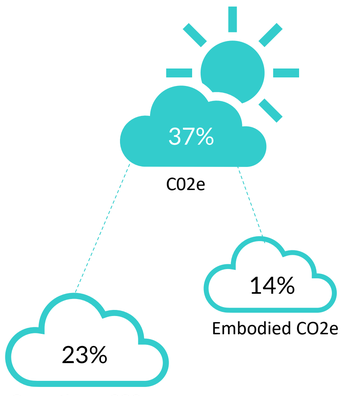
Granted Planning Applications 1992 - 2021

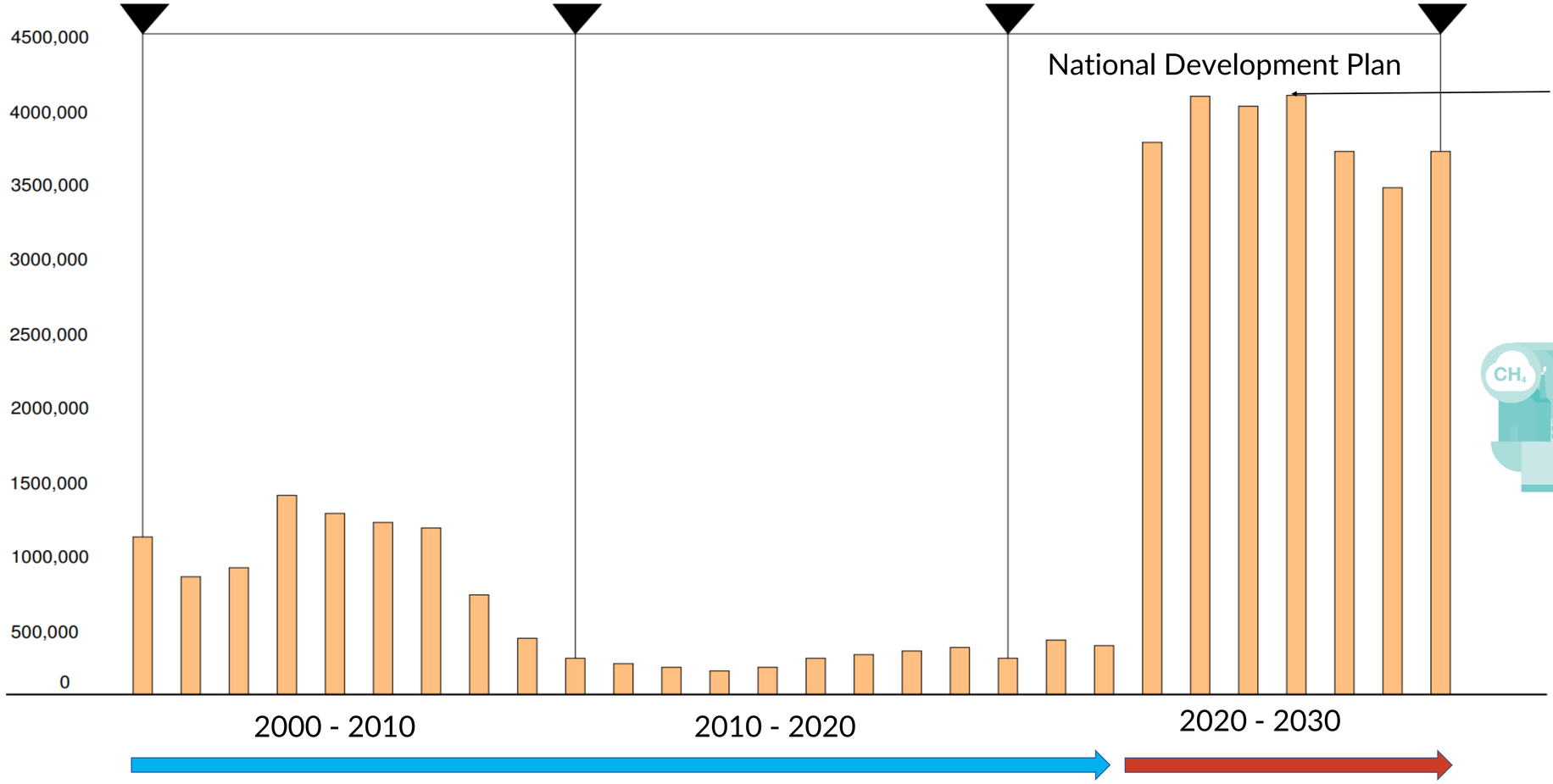


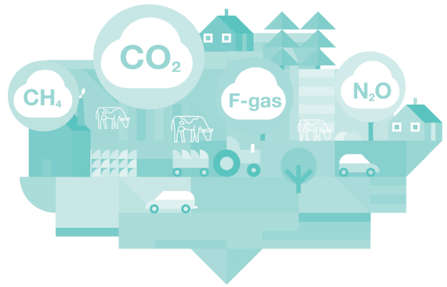
CO2 of Irish Dwellings 1992 - 2021

An investigation of three different wall types in the residential sector based on thermal performance, operational and embodied energy

According to the built environment report, 23MtCO2e per year are linked to the construction and operation of buildings in Ireland. This amounts to 37% of all national emissions.

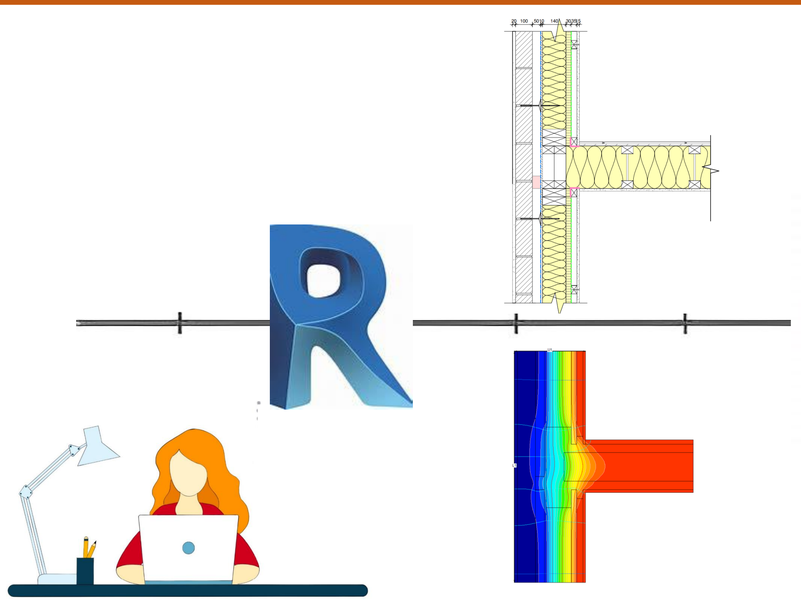


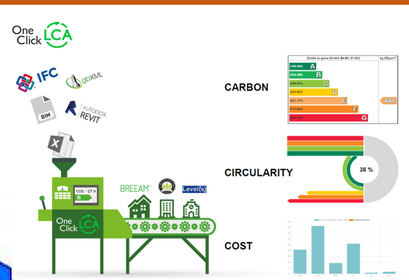


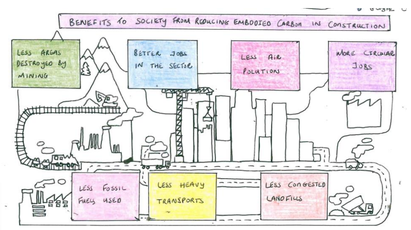


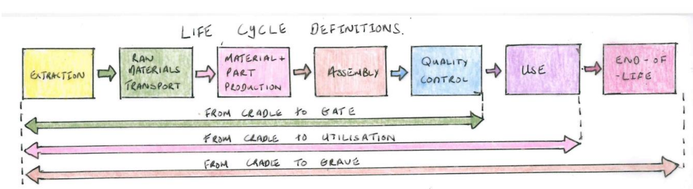
Projected Carbon Levels if the Government is successful in delivering 33,000 new homes every year

METHODOLOGY





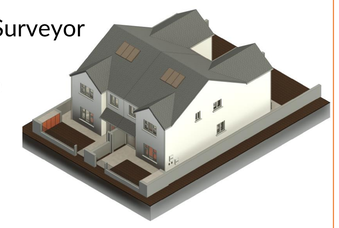


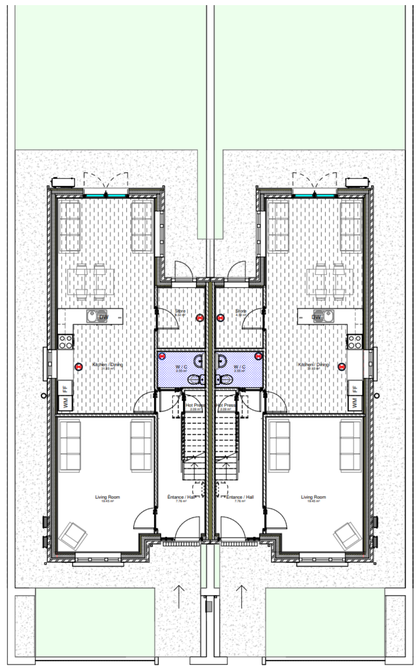


CASE STUDY BUILDING

Project Overview

- **Location:** Cois Urlann, Downings North, Prosperous, Co. Kildare.
- **Builder:** Kelby Developments Ltd
- **Architect:** CROSS Architect and Building Surveyor
- **House Type:** 4 Bed Semi Detached House
- **Ventilation:** MHRV system
- **Heating:** Air to water heat pump



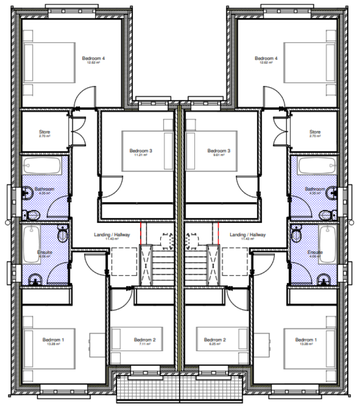


Ground Floor Plan

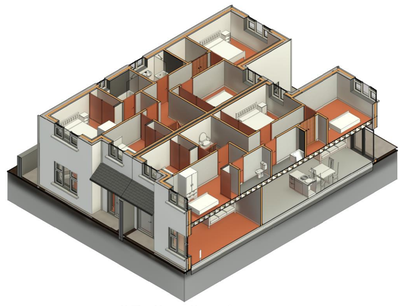
HOUSE TYPE B		
2 STOREY/ 4 BEDROOM / 7 PERSON		KCC / D.O.E. MIN. REQUIREMENT
FLOOR AREA	143.4 m²	110.0 m² / 110.0 m²
LIVING ROOM	19.7 m²	- / 15.0 m²
KITCHEN / DINING	32.1 m²	
AGG. LIVING AREA	51.8 m²	- / 40.0 m²
BEDROOM 01	13.5 m²	- / 13.0 m²
BEDROOM 02	7.3 m²	- / 7.1m²
BEDROOM 03	11.5 m²	- / 11.4 m²
BEDROOM 04	12.5 m²	- / 11.4 m²
AGG. BEDROOM AREA	44.8 m²	- / 43.0 m²
INTERNAL STORE	7.0 m²	
EXTERNAL STORE	3.0 m²	
TOTAL STORAGE	10.0 m²	6.0 m² / 10 m²
NOTE: ADDITIONAL STORAGE AVAILABLE IN ATTIC NOT USED IN THIS CALCULATION		

Room Area Schedule

3D



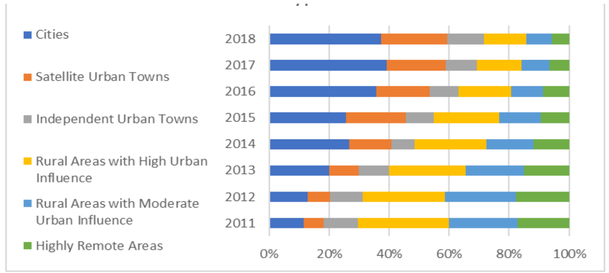
First Floor Plan



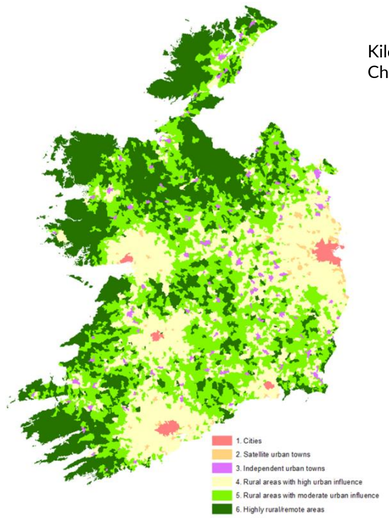
3D Cut Sections

Why Prosperous?

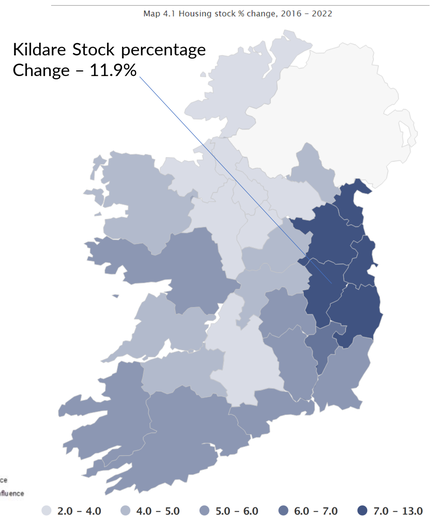
- Located 45 minutes from Dublin, Prosperous is located in area of high urban influence. Other than cities this area type is the highest growing sector for housing with 13,198 dwellings being completed from 2011 – 2018 according the Central Statistics Office.
- Access to resources: Prosperous is a growing town with a range of resources including building materials suppliers, construction companies, and energy consultants which ultimately reduce the operational carbon of transport.



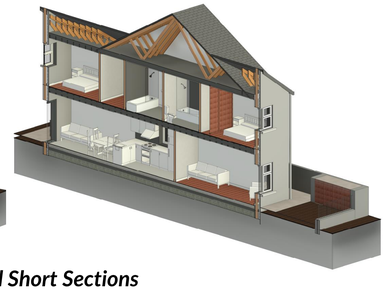
Percentage of New Dwelling Completions by Area Type



Map of Ireland and Area Types



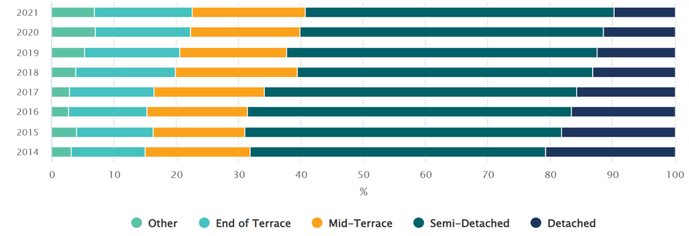
Housing Stock % Change 2016 - 2022



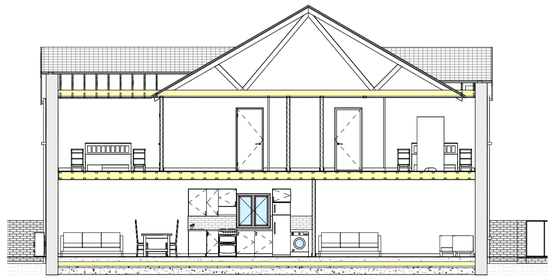
3D Long and Short Sections

Why Semi–Detached?

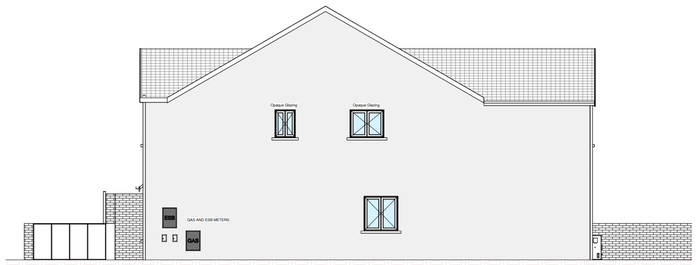
- When building scheme developments or housing estates semi-detached has been the most popular choice according to the central statistics office from 2016- 2021.
- Energy efficiency potential: Semi-detached houses have the potential to be more energy-efficient than detached houses due to their shared wall, which can help to reduce heat loss and energy consumption. This makes them a good choice for testing different wall types and assessing their thermal performance.



New Scheme Dwellings By BER Type ,2014 - 2021



Section A-A

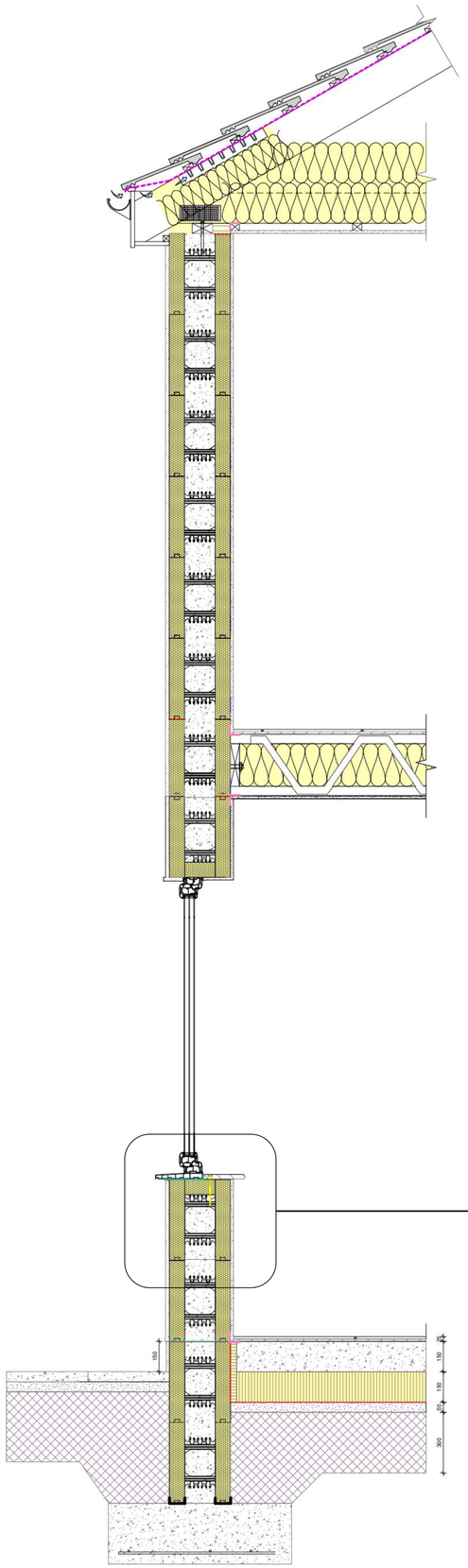


East Elevation

South Elevation

North Elevation

INSULATED CONCRETE FORMWORK



ICF Wall Section

WHY I.C.F?

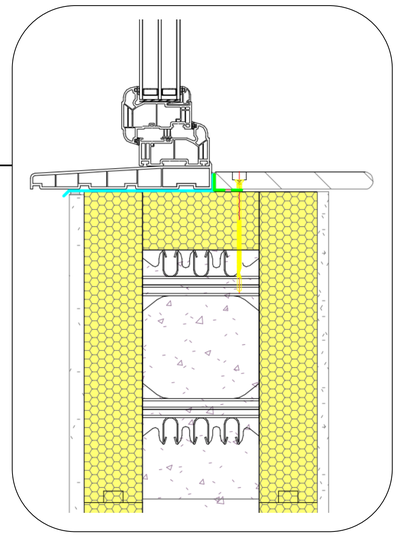
- According to Statista, over 80% of firms in the Irish construction industry experienced skill shortages in the past 12 months which limited the number of projects that could be completed.
- Using ICF construction requires little skill and nullifies the use of block and brick layers which results in shorter build time and saving on labour costs.

WALL CONSTRUCTION:

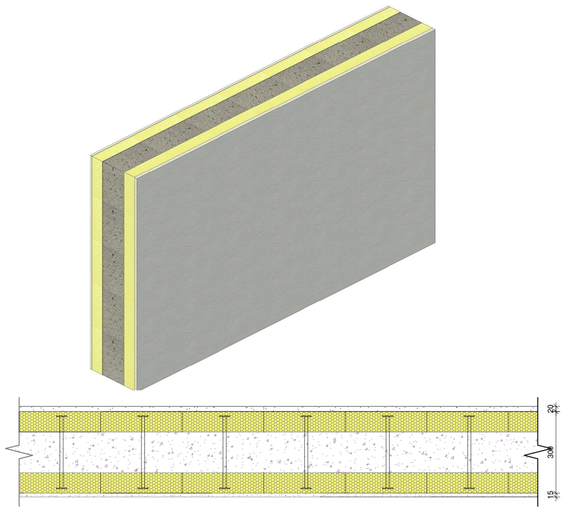
- 18mm external monocouche render finish to be applied to
- mesh reinforced base ON Amvic or E.A. Insulated Concrete Formwork with 2 layers of 75mm thick EPS insulation with polypropylene web ties on
- 12.5mm Gypsum plasterboard mechanically fixed to ICF with
- 2mm final coat of Gyproc Finish Plaster applied over and skimmed over

WALL BUILD-UP AND CONDUCTIVITY

Material	Thickness (Millimetres)	Conductivity (W/mK)
Render	18	0.44
Neopor EPS	75	0.3
Poured Concrete	150	0.5
Neopor EPS	75	0.3
Plasterboard	15	0.25



Window Cill Detail



Wall Jamb Detail and 3D section

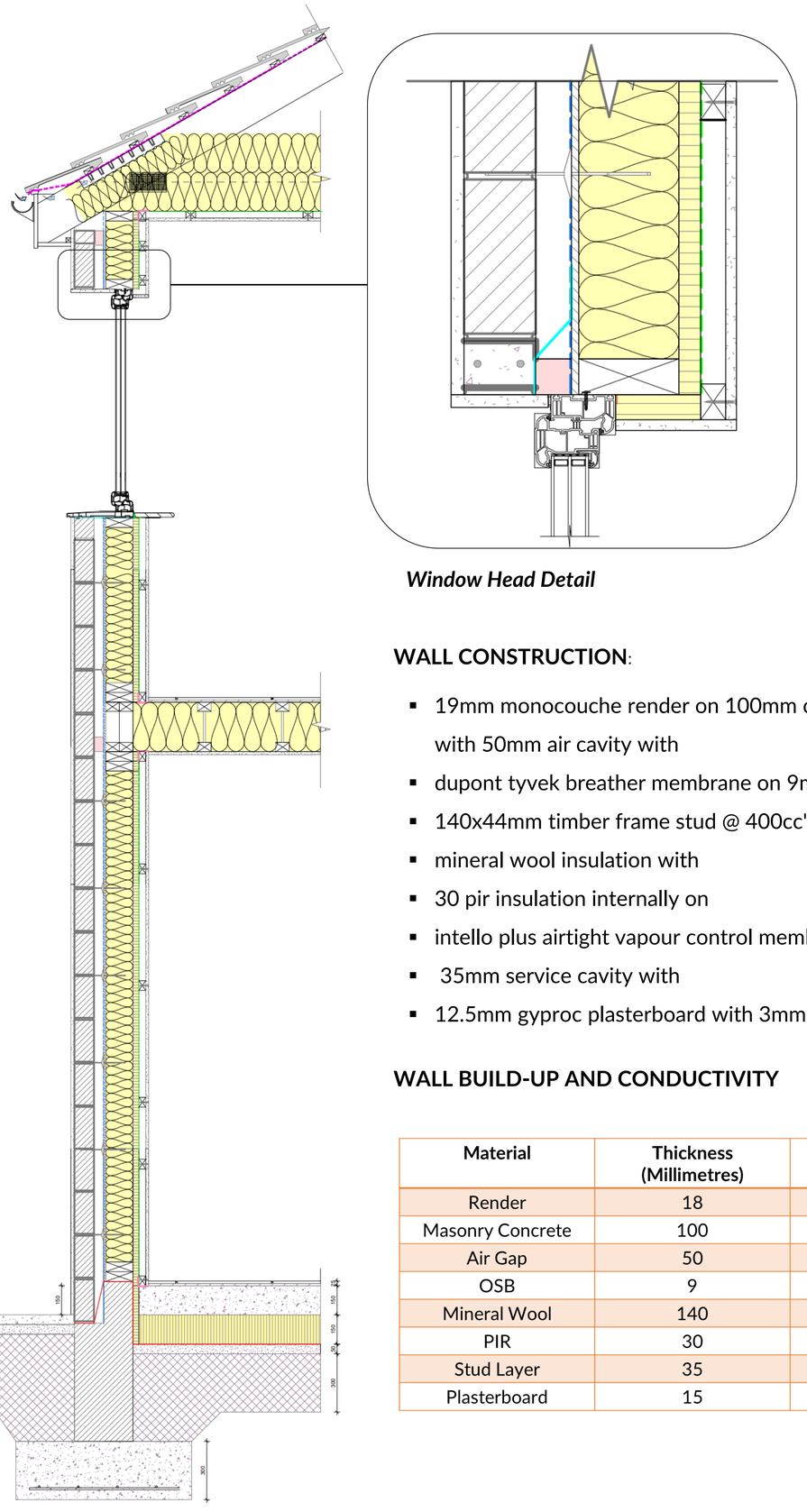
Roof U-Value = 0.12 Wm^2K

Wall U-Value = 0.18 Wm^2K

Window U-Value = 1.2 Wm^2K

Floor U-Value = 0.15 Wm^2K

TIMBER FRAME CONSTRUCTION



Window Head Detail

WHY TIMBER FRAME?

- According to a report by the Timber Frame Manufacturers Association (TFMA) in Ireland, the market share for timber frame construction in the residential sector was around 22% in 2019.
- The report also noted that the use of timber frame construction in Ireland has been growing steadily over the past decade, with an average annual growth rate of around 7%.

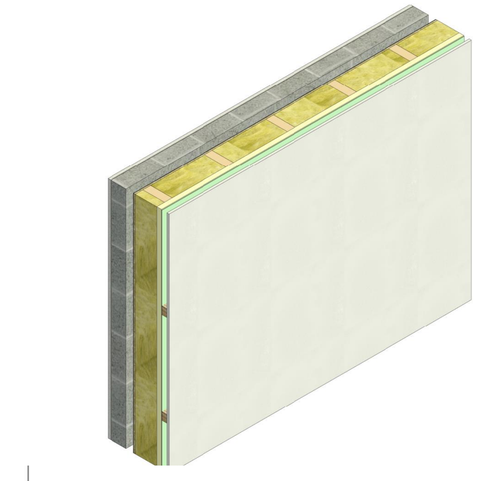
WALL CONSTRUCTION:

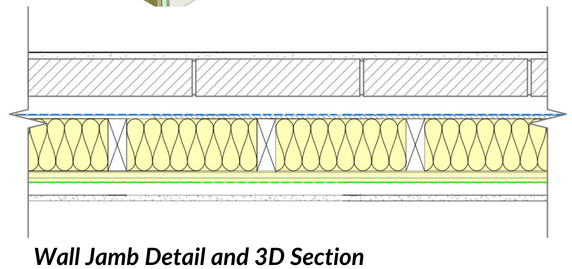
- 19mm monocouche render on 100mm concrete blockwork wall with 50mm air cavity with
- dupont tyvek breather membrane on 9mm osb board with
- 140x44mm timber frame stud @ 400cc's fillled with
- mineral wool insulation with
- 30 pir insulation internally on
- intello plus airtight vapour control membrane with
- 35mm service cavity with
- 12.5mm gyproc plasterboard with 3mm skim finish

WALL BUILD-UP AND CONDUCTIVITY

Material	Thickness (Millimetres)	Conductivity (W/mK)
Render	18	0.44
Masonry Concrete	100	0.55
Air Gap	50	0.298
OSB	9	0.13
Mineral Wool	140	0.035
PIR	30	0.022
Stud Layer	35	0.298
Plasterboard	15	0.25

Timber Frame Wall Section





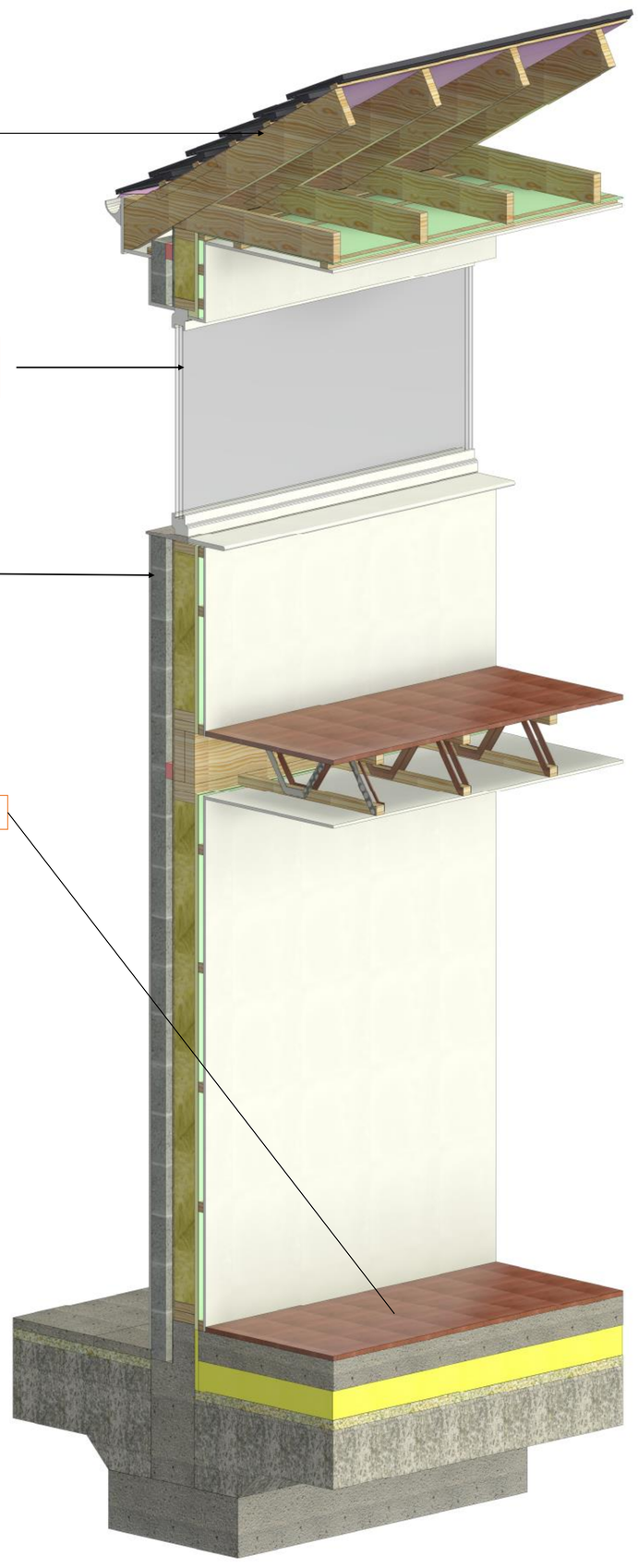
Wall Jamb Detail and 3D Section

Roof U-Value = 0.12 Wm²K

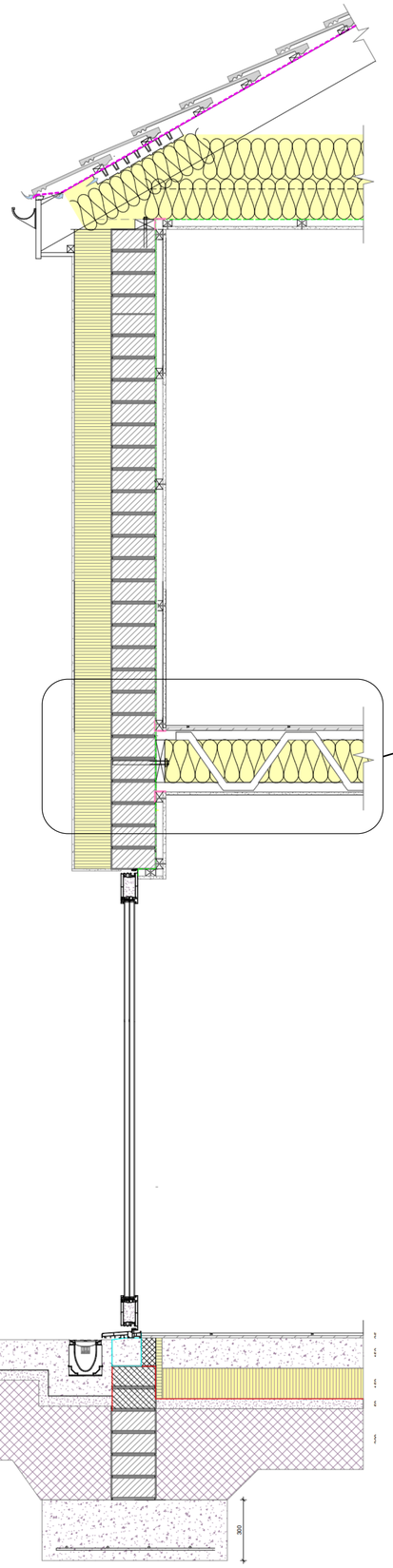
Window U-Value = 1.2 Wm²K

Wall U-Value = 0.16 Wm²K

Floor U-Value = 0.15 Wm²K



EXTERNALLY INSULATED MASONRY CONSTRUCTION



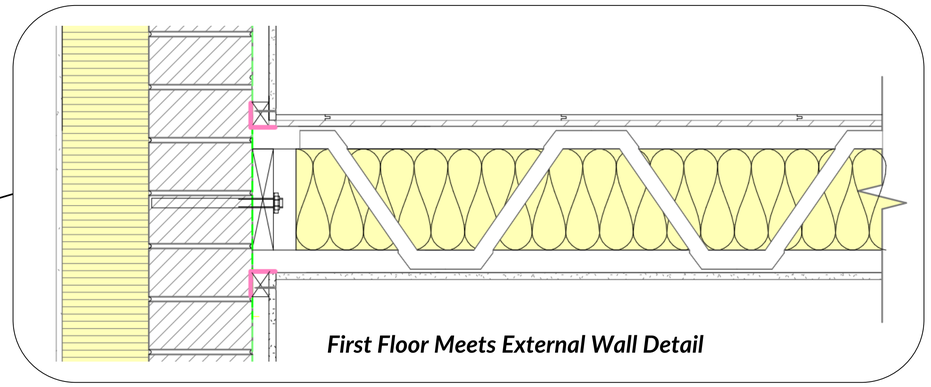
Masonry Wall Section

WHY EXTERNALLY INSULATE?

- External insulation systems can be easily applied to a masonry wall leaving less chance of mistakes and a reduction in building time.
- An airtight home and external insulation system can significantly reduce energy consumption and costs which can help to reduce fuel poverty and make housing more affordable for those on low incomes.

WALL CONSTRUCTION:

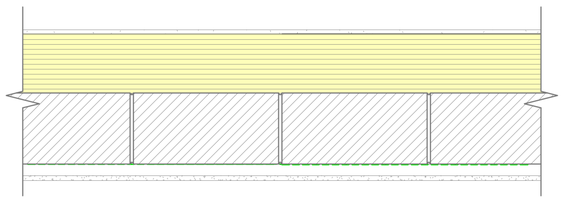
- 180mm kore external eps700 silver insulation adhered to
- 215mm solid concrete block wall with external render system consisting of a high polymer base coat, reinforcing mesh, silicone primer and silicone render on
- intello plus airtight vapour control membrane with 35mm service cavity with
- 12.5mm gyproc plasterboard with 3mm skim finish



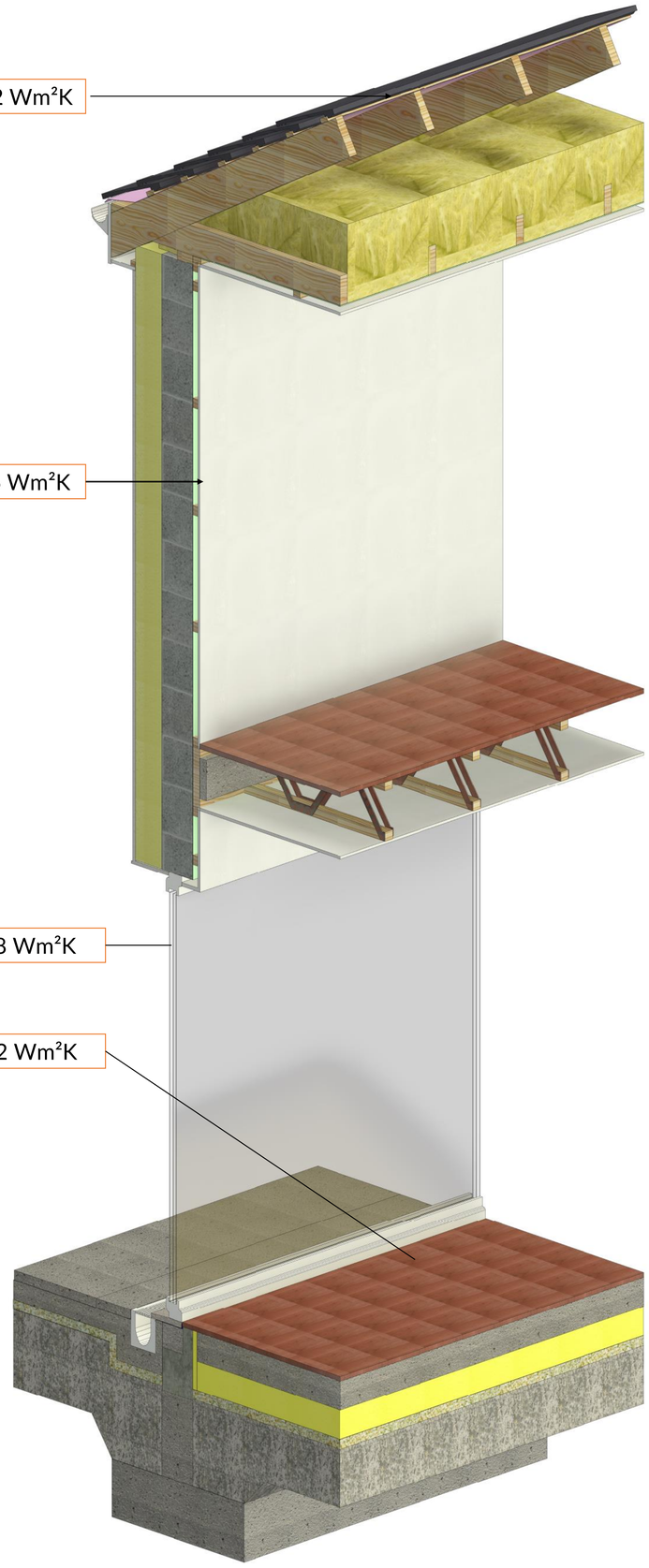
First Floor Meets External Wall Detail

WALL BUILD-UP AND CONDUCTIVITY

Material	Thickness (Millimetres)	Conductivity (W/mK)
Render	18	0.44
Kore EPS 700 SIlver	180	0.031
Masonry Concrete	215	0.55
Stud Layer	35	0.298
Plasterboard	15	0.25

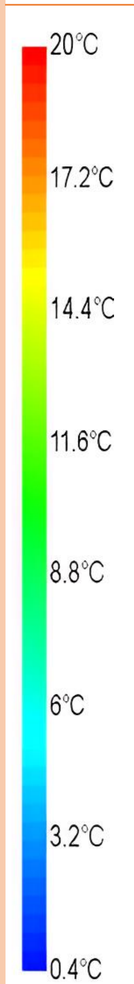


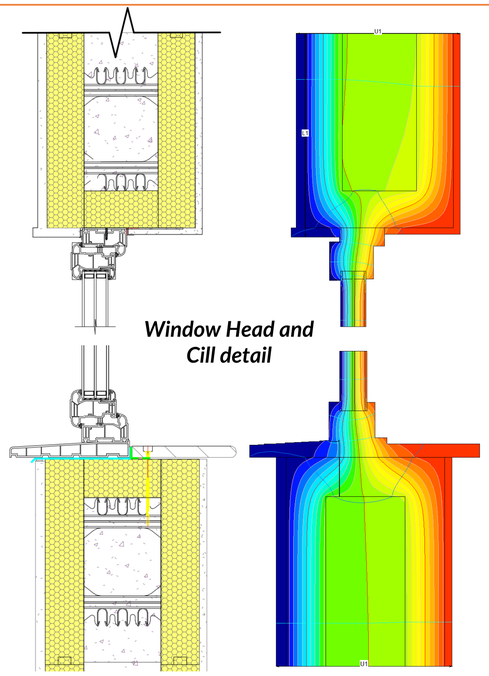
Wall Jamb Detail and 3D Section



THERMAL BRIDGE ASSESSMENT USING TRISCO2D

I.C.F Construction





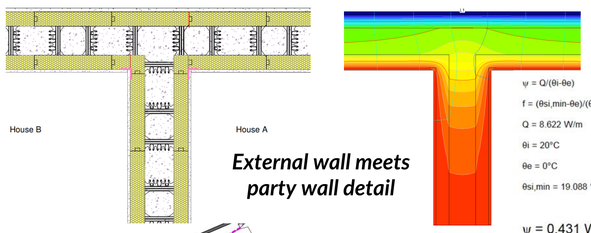
ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 5.675 W/m
θi = 20°C
θe = 0°C
θsi,min = 15.487 °C
U1 = 0.164 W/(m².K)
L1 = 0.4374 m

ψ = 0.212 W/(m.K)
f = 0.774

Window Head and Cill detail

ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 4.736 W/m
θi = 20°C
θe = 0°C
θsi,min = 16.365 °C
U1 = 0.180 W/(m².K)
L1 = 0.333 m

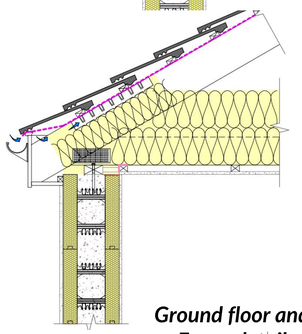
ψ = 0.177 W/(m.K)
f = 0.818



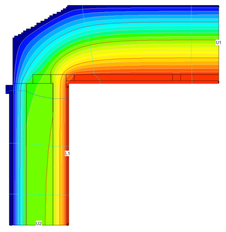
External wall meets party wall detail

ψ = Q/(θi-θe)
f = (θsi,min-θe)/(θi-θe)
Q = 8.622 W/m
θi = 20°C
θe = 0°C
θsi,min = 19.088 °C

ψ = 0.431 W/(m.K)
f = 0.954

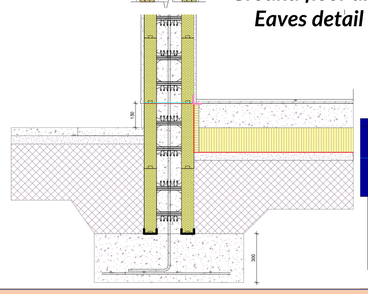


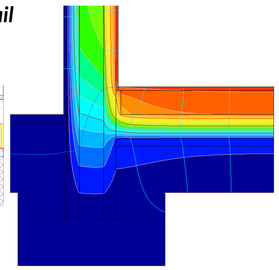
Ground floor and Eaves detail



ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 4.878 W/m
θi = 20°C
θe = 0°C
θsi,min = 19.276 °C
U1 = 0.087 W/(m².K)
L1 = 0.789999 m

ψ = 0.175 W/(m.K)
f = 0.964

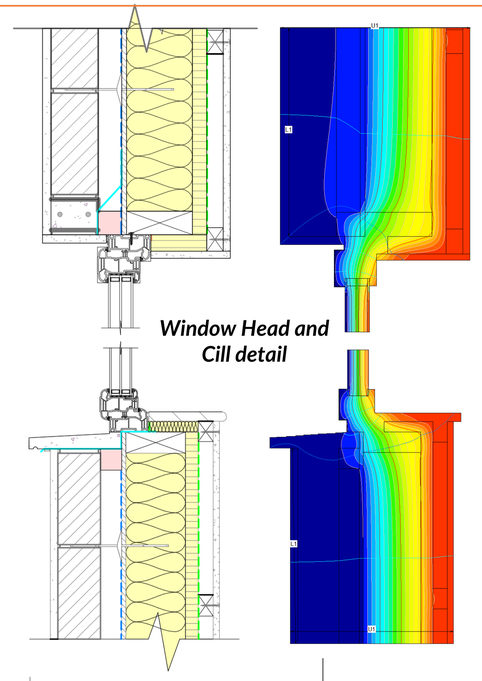




ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 7.052 W/m
θi = 20°C
θe = 0°C
θsi,min = 18.857 °C
U1 = 0.179 W/(m².K)
L1 = 1.9 m

ψ = 0.013 W/(m.K)
f = 0.943

Timber Frame Construction



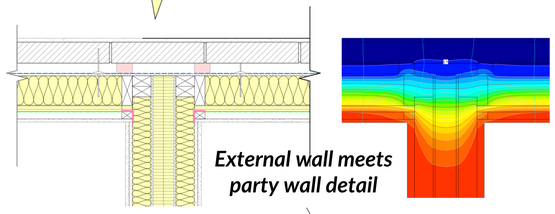
ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 5.675 W/m
θi = 20°C
θe = 0°C
θsi,min = 15.487 °C
U1 = 0.164 W/(m².K)
L1 = 0.4374 m

ψ = 0.212 W/(m.K)
f = 0.774

Window Head and Cill detail

ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 5.653 W/m
θi = 20°C
θe = 0°C
θsi,min = 14.859 °C
U1 = 0.171 W/(m².K)
L1 = 0.477463 m

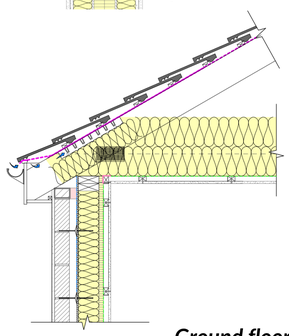
ψ = 0.201 W/(m.K)
f = 0.743



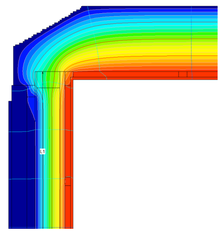
External wall meets party wall detail

ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 4.903 W/m
θi = 20°C
θe = 0°C
θsi,min = 19.007 °C
U1 = 0.162 W/(m².K)
L1 = 1.394 m

ψ = 0.020 W/(m.K)
f = 0.950

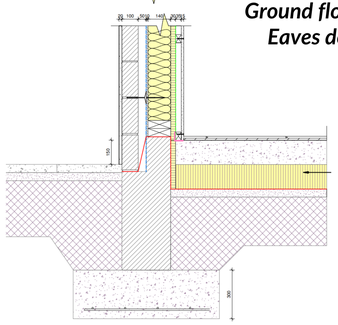


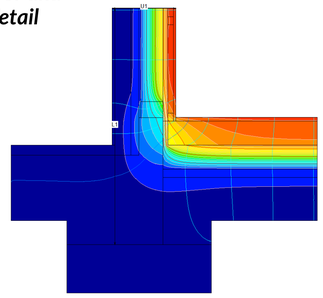
Ground floor and Eaves detail



ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 5.842 W/m
θi = 20°C
θe = 0°C
θsi,min = 19.339 °C
U1 = 0.086 W/(m².K)
L1 = 0.993 m

ψ = 0.207 W/(m.K)
f = 0.967

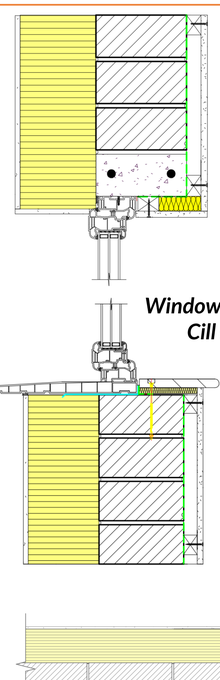




ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 8.128 W/m
θi = 20°C
θe = 0°C
θsi,min = 17.769 °C
U1 = 0.162 W/(m².K)
L1 = 1.474 m

ψ = 0.168 W/(m.K)
f = 0.888

Masonry Construction



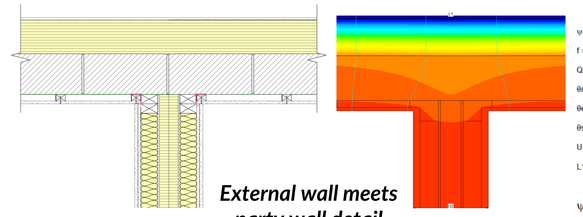
ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 5.239 W/m
θi = 20°C
θe = 0°C
θsi,min = 16.497 °C
U1 = 0.155 W/(m².K)
L1 = 0.4692 m

ψ = 0.189 W/(m.K)
f = 0.825

Window Head and Cill detail

ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 5.838 W/m
θi = 20°C
θe = 0°C
θsi,min = 16.914 °C
U1 = 0.154 W/(m².K)
L1 = 0.4299 m

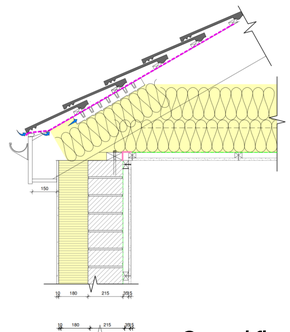
ψ = 0.225 W/(m.K)
f = 0.846

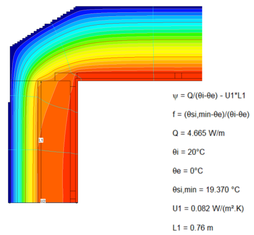


ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 4.700 W/m
θi = 20°C
θe = 0°C
θsi,min = 19.438 °C
U1 = 0.152 W/(m².K)
L1 = 1.57 m

ψ = -0.004 W/(m.K)
f = 0.972

External wall meets party wall detail

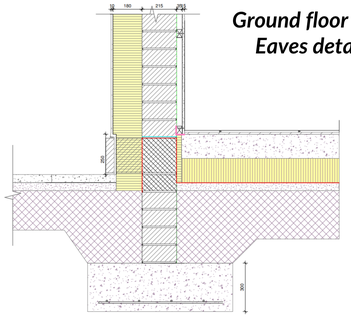


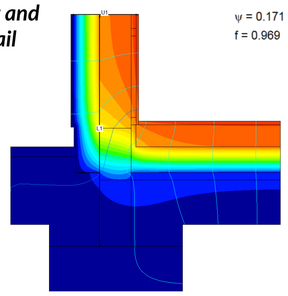


ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 4.665 W/m
θi = 20°C
θe = 0°C
θsi,min = 19.370 °C
U1 = 0.082 W/(m².K)
L1 = 0.76 m

ψ = 0.171 W/(m.K)
f = 0.969

Ground floor and Eaves detail





ψ = Q/(θi-θe) - U1*L1
f = (θsi,min-θe)/(θi-θe)
Q = 7.511 W/m
θi = 20°C
θe = 0°C
θsi,min = 18.698 °C
U1 = 0.152 W/(m².K)
L1 = 1.569 m

ψ = 0.137 W/(m.K)
f = 0.935

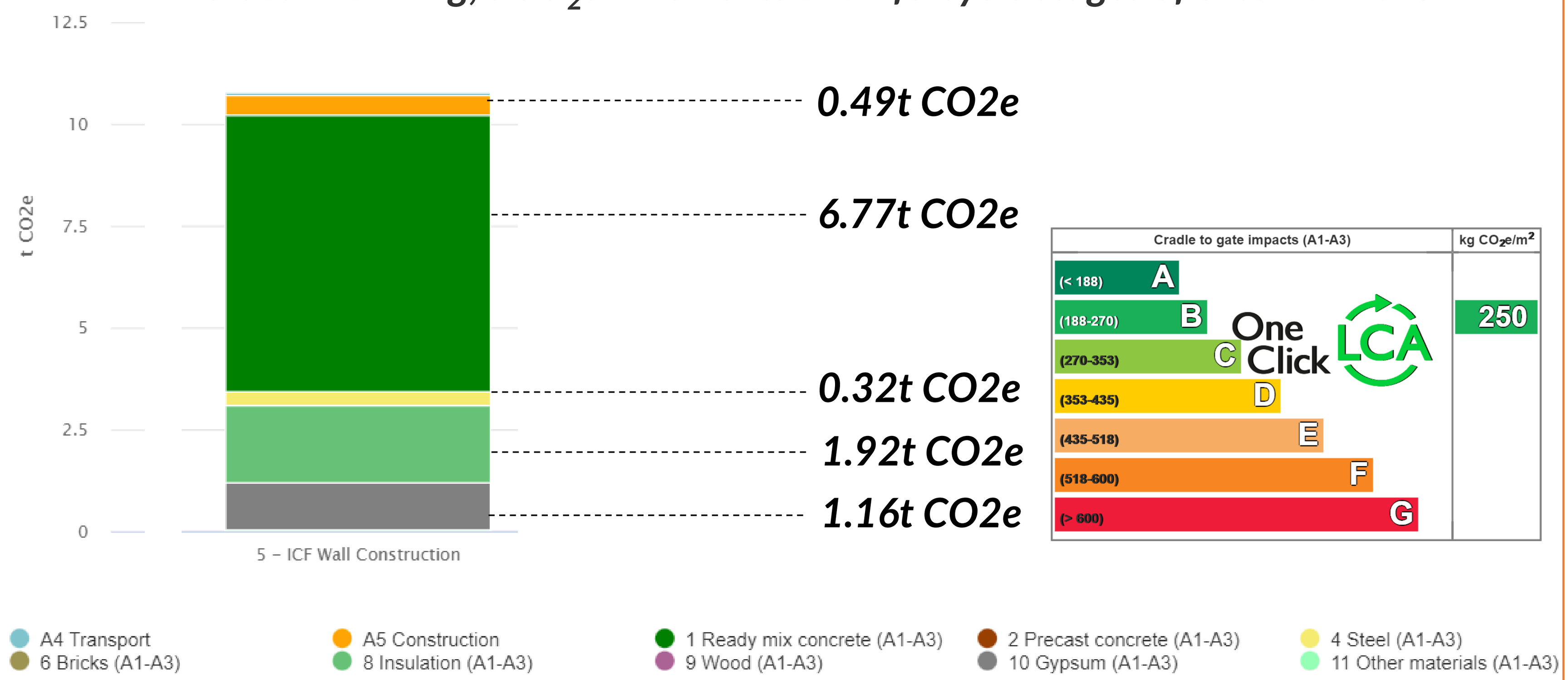
EMBODIED CARBON LIFE CYCLE ASSESSMENT

I.C.F Construction

CO_2 35 Tonnes CO_2e

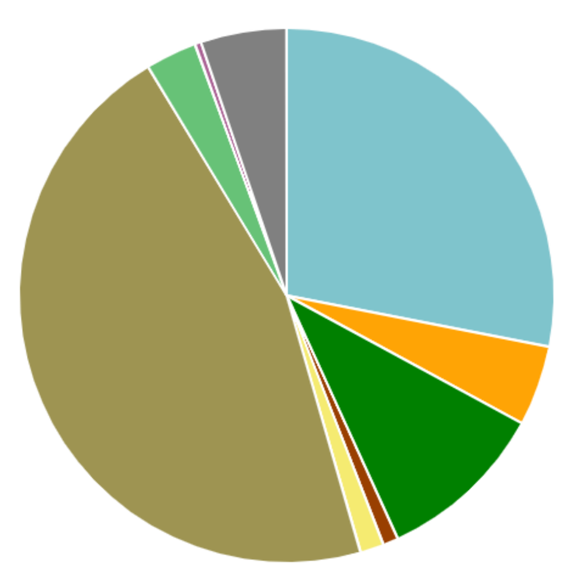
1 748 € Social cost of carbon

Global warming, t CO_2e - Elements and life-cycle stages of external walls



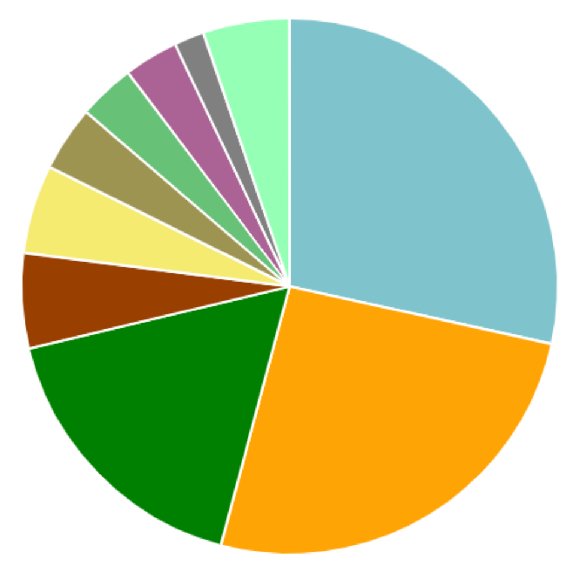
Global Warming t CO2e – Life Cycle stages

- 1 Ready mix concrete (A1-A3) - 28.1%
- 11 Other materials (A1-A3) - 10.3%
- 6 Bricks (A1-A3) - 1.4%
- 9 Wood (A1-A3) - 3.1%
- A5 Construction - 5.2%
- 10 Gypsum (A1-A3) - 4.9%
- 4 Steel (A1-A3) - 0.9%
- 8 Insulation (A1-A3) - 45.8%
- A4 Transport - 0.4%

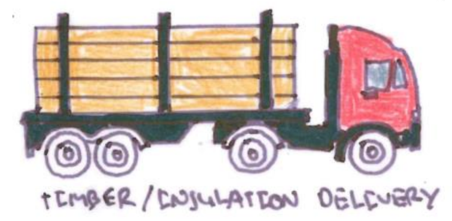


Global Warming t CO2e – Resource Types

- Ready-mix concrete for external walls and floors - 28.4%
- Rock wool insulation - 25.7%
- PIR (polyisocyanurate foam) insulation - 17.1%
- EPS (expanded polystyrene) insulation - 5.7%
- Regular gypsum board - 5.4%
- Wooden frame windows - 3.9%
- Plain wood/timber (softwood and hardwood) - 3.4%
- Plastic membranes - 3.3%
- Resilient flooring - 1.8%
- Other resource types - 5.2%



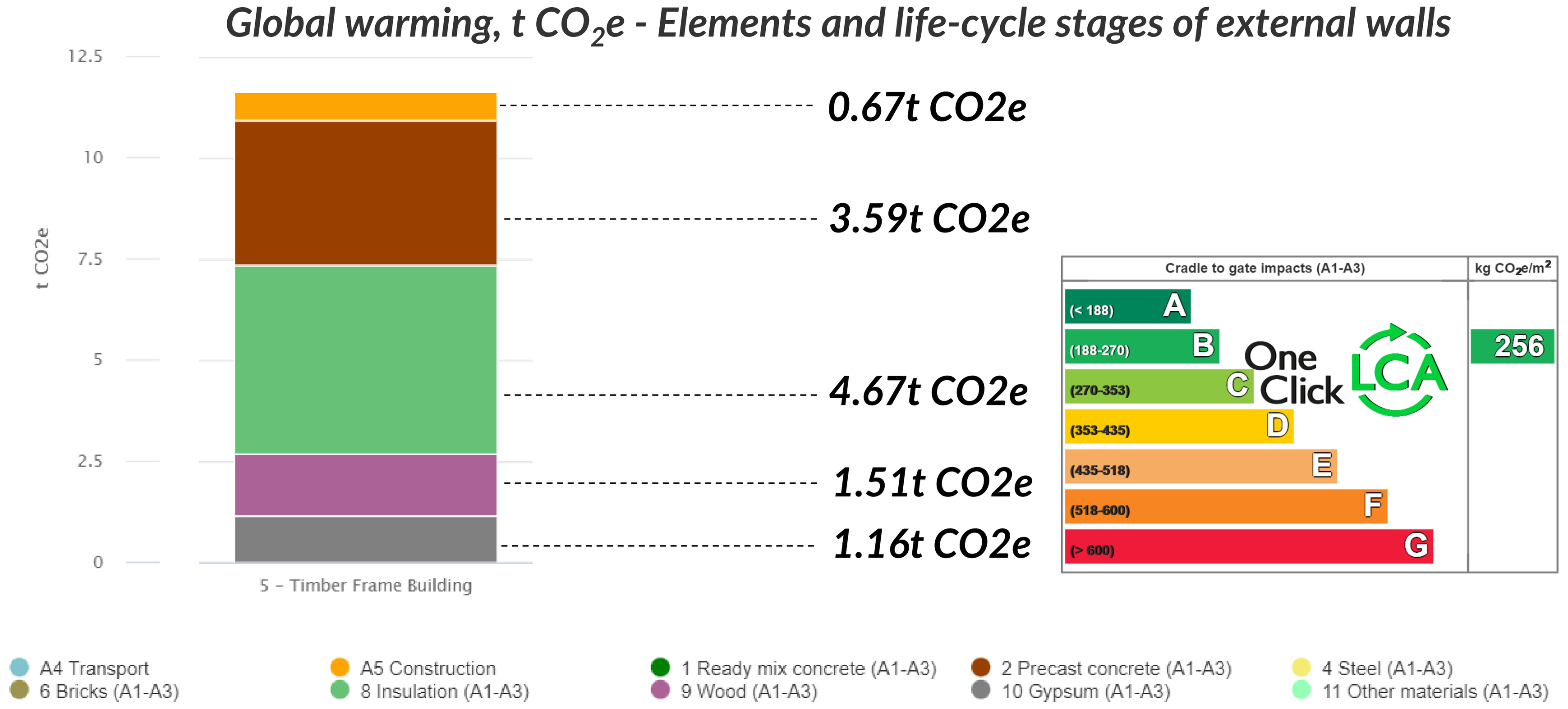
Timber Frame Construction



CO_2 37 Tonnes CO_2e

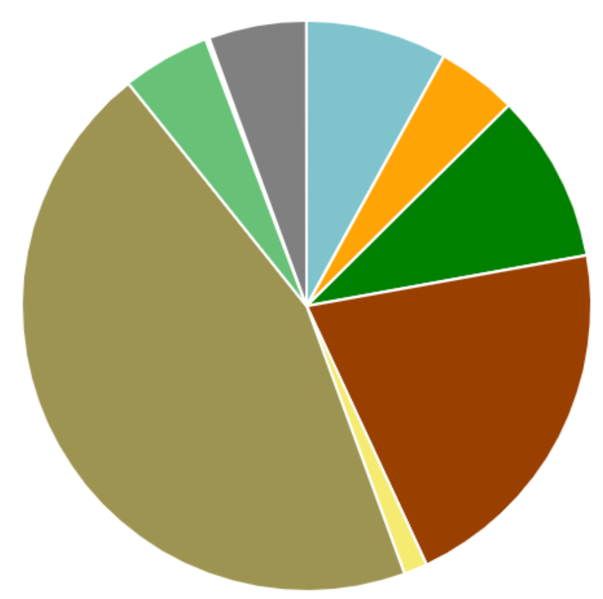
1 859 € Social cost of carbon

Global warming, t CO_2e - Elements and life-cycle stages of external walls



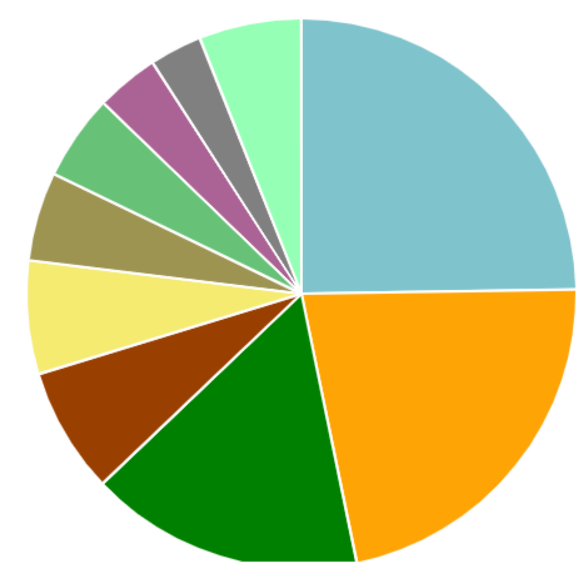
Global Warming t CO2e – Life Cycle stages

- 1 Ready mix concrete (A1-A3) - 8.0%
- 11 Other materials (A1-A3) - 9.6%
- 6 Bricks (A1-A3) - 1.3%
- 9 Wood (A1-A3) - 5.0%
- A5 Construction - 5.6%
- 10 Gypsum (A1-A3) - 4.6%
- 2 Precast concrete (A1-A3) - 20.9%
- 8 Insulation (A1-A3) - 44.8%
- A4 Transport - 0.2%



Global Warming t CO2e – Resource Types

- Rock wool insulation - 24.8%
- Concrete masonry units (CMU) - 22.0%
- PIR (polyisocyanurate foam) insulation - 16.1%
- Ready-mix concrete for external walls and floors - 7.4%
- EPS (expanded polystyrene) insulation - 6.7%
- Plain wood/timber (softwood and hardwood) - 5.2%
- Regular gypsum board - 5.0%
- Wooden frame windows - 3.7%
- Plastic membranes - 3.1%
- Other resource types - 6.0%

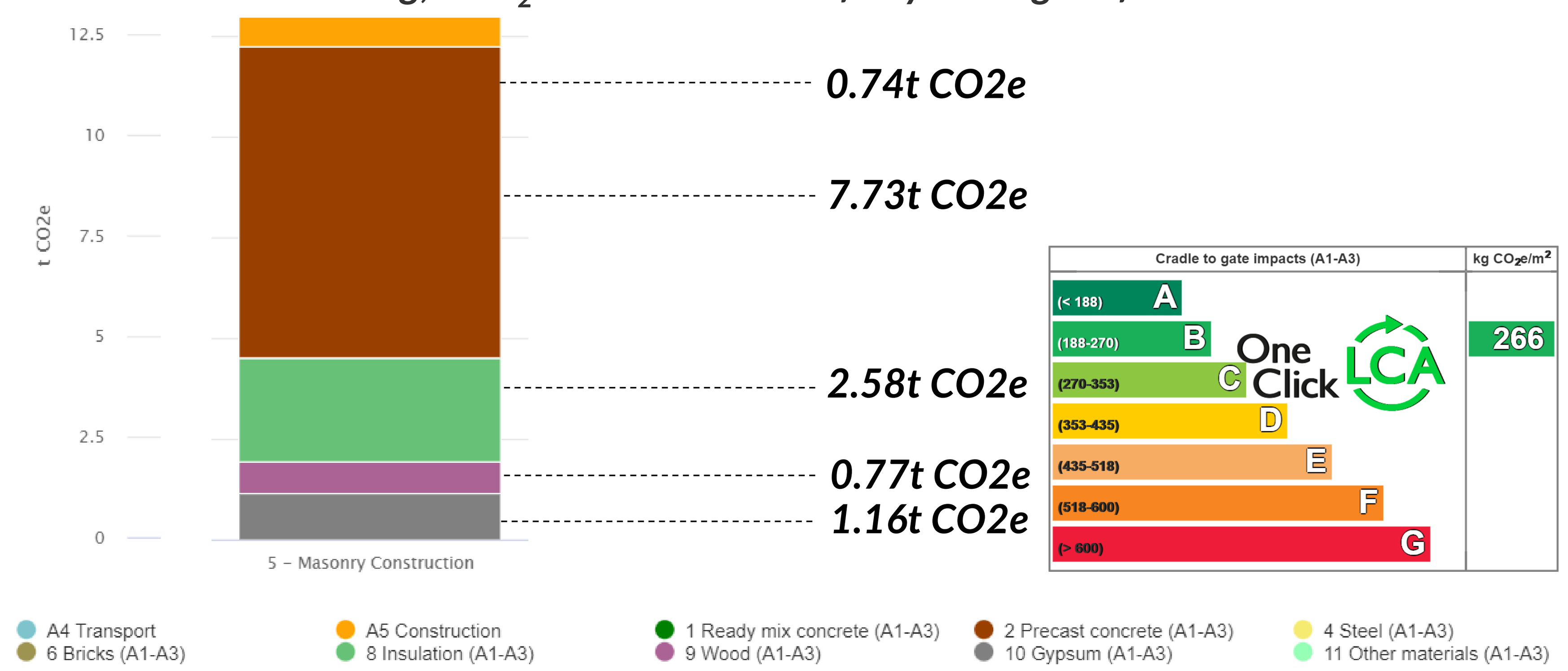


Masonry Construction

CO_2 36 Tonnes CO_2e

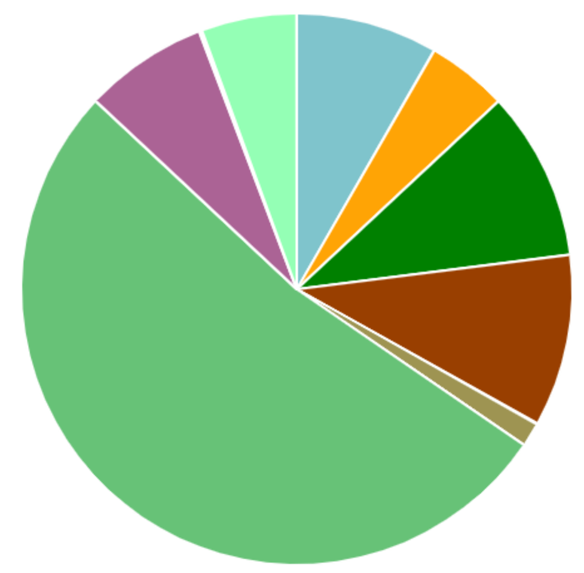
1 791 € Social cost of carbon

Global warming, t CO_2e - Elements and life-cycle stages of external walls



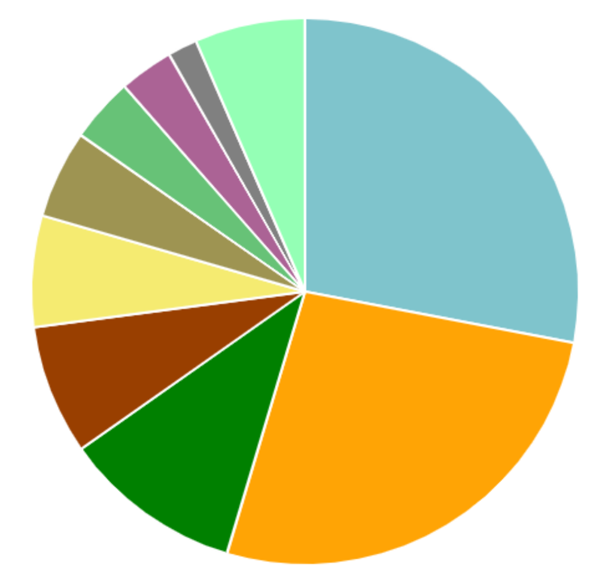
Global Warming t CO2e – Life Cycle stages

- 1 Ready mix concrete (A1-A3) - 8.3%
- 11 Other materials (A1-A3) - 10.0%
- 4 Steel (A1-A3) - 0.0%
- 8 Insulation (A1-A3) - 52.4%
- A4 Transport - 0.2%
- 10 Gypsum (A1-A3) - 4.7%
- 2 Precast concrete (A1-A3) - 10.1%
- 6 Bricks (A1-A3) - 1.4%
- 9 Wood (A1-A3) - 7.3%
- A5 Construction - 5.6%

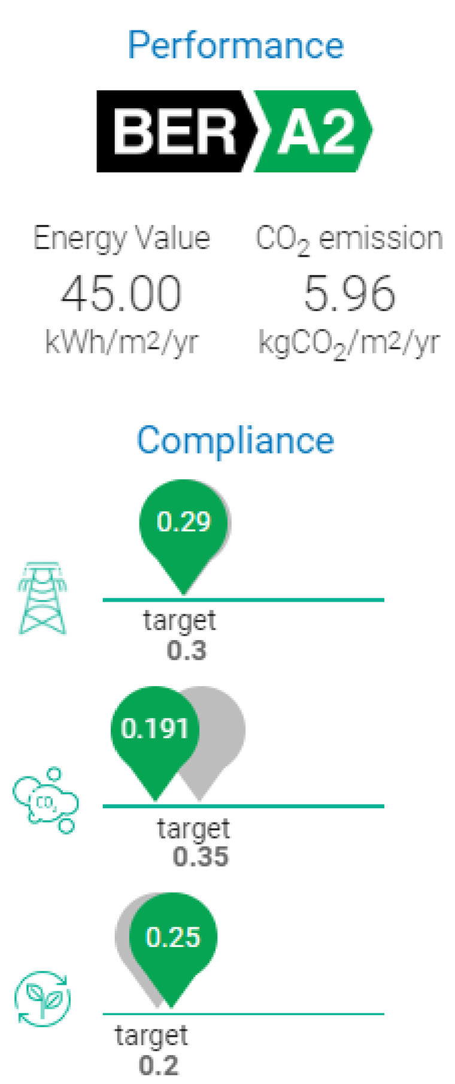


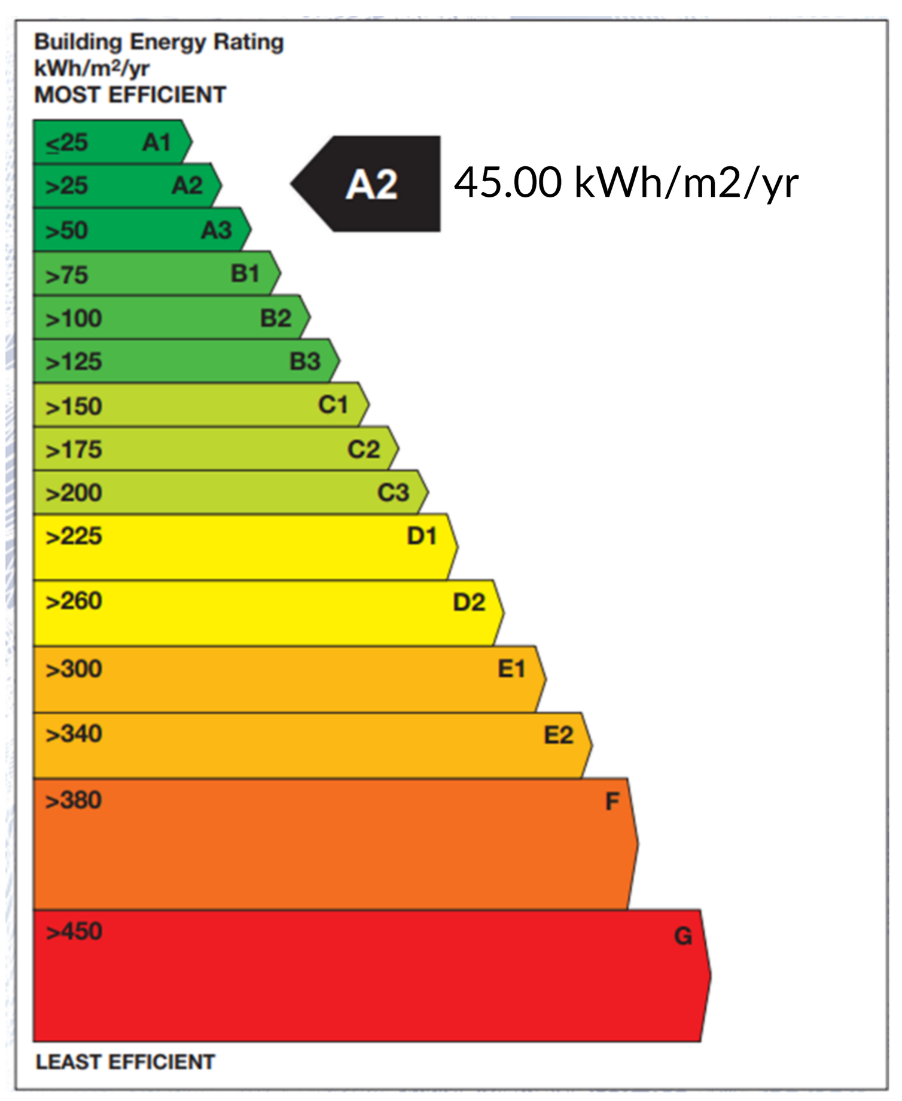
Global Warming t CO2e – Resource Types

- Rock wool insulation - 28.0%
- PIR (polyisocyanurate foam) insulation - 26.6%
- Concrete masonry units (CMU) - 10.6%
- Ready-mix concrete for external walls and floors - 7.7%
- Plain wood/timber (softwood and hardwood) - 6.6%
- Regular gypsum board - 5.2%
- Wooden frame windows - 3.8%
- Plastic membranes - 3.2%
- Resilient flooring - 1.8%
- Other resource types - 6.5%

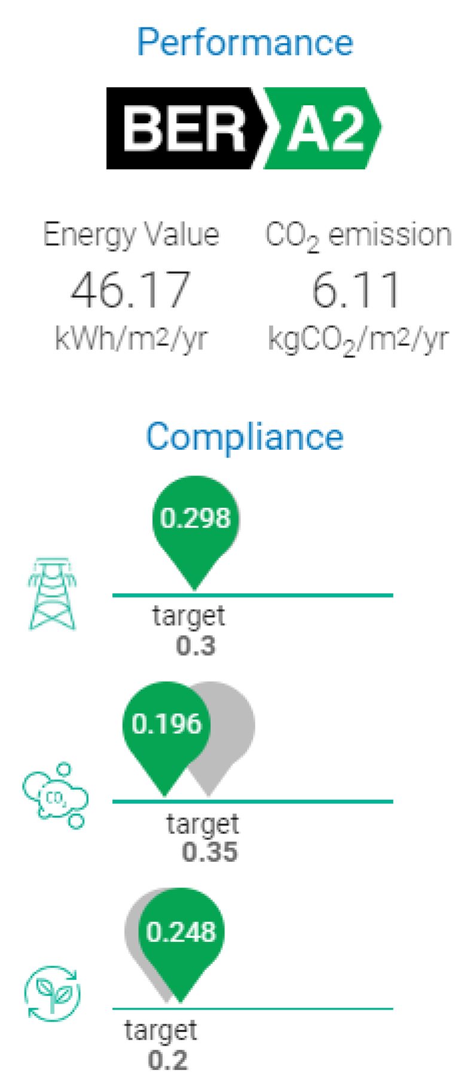


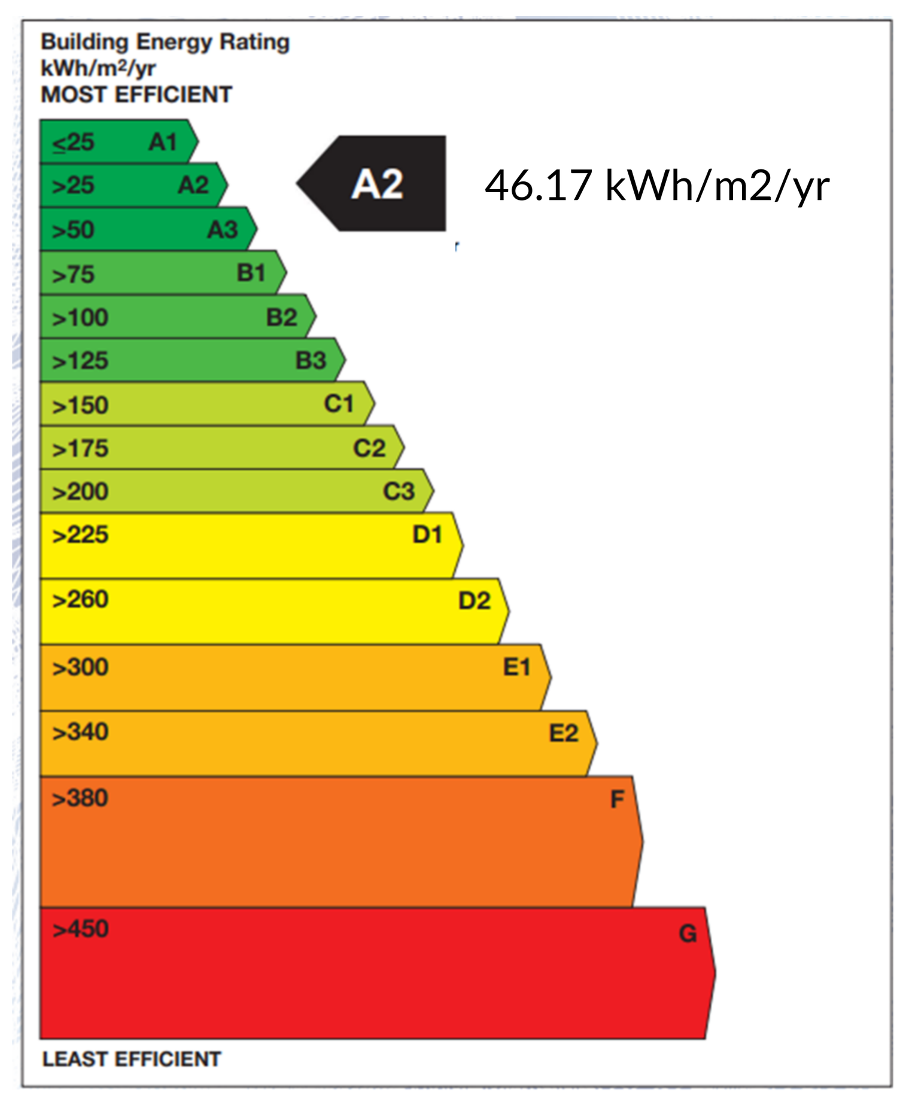
OPERATIONAL CARBON DEAP ASSESSMENT



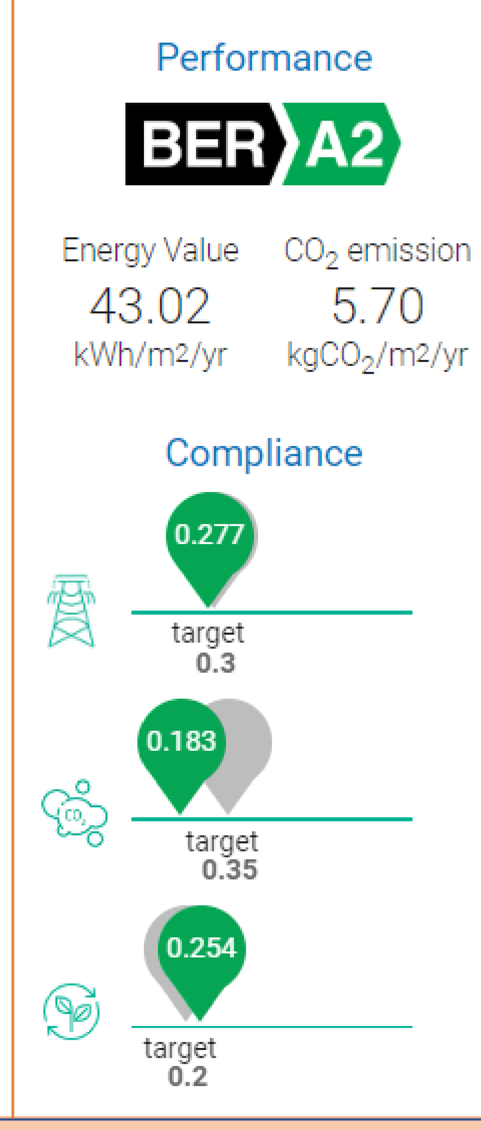


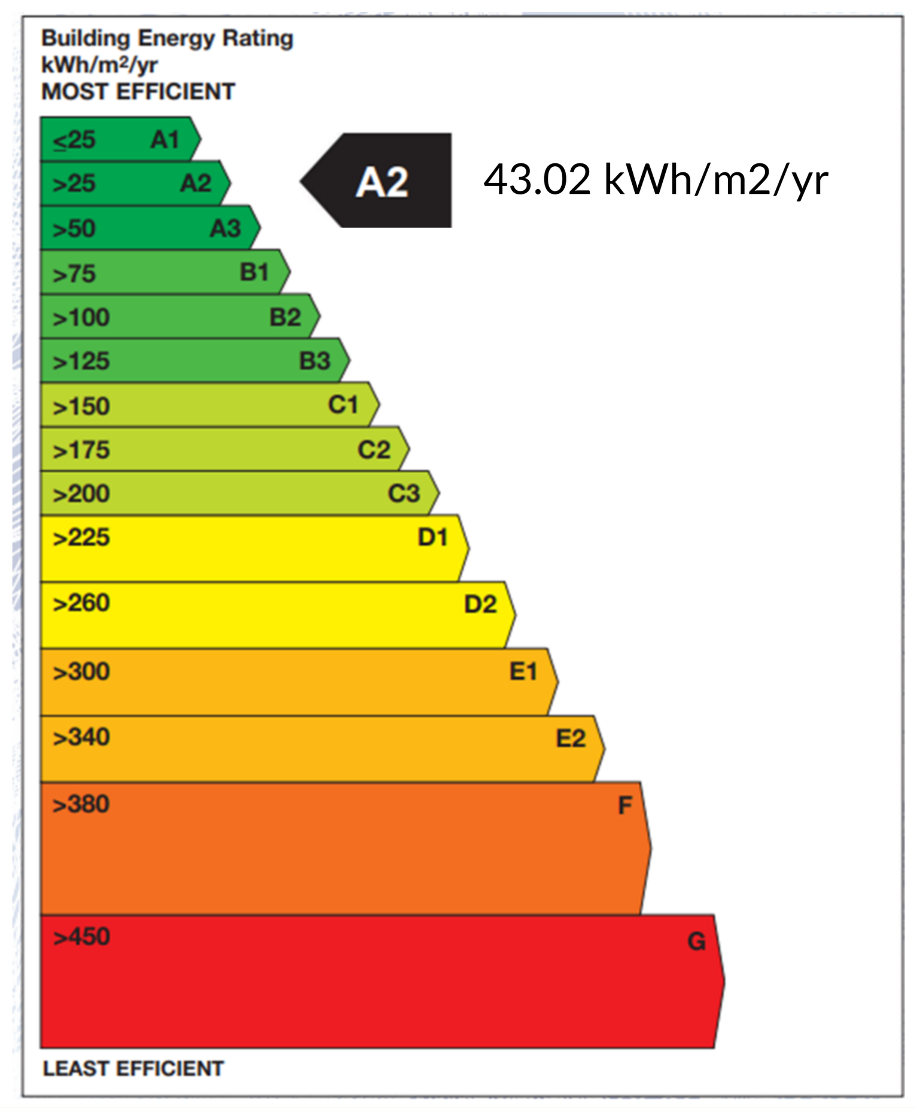
ICF BER Rating Performance and Energy Values





Timber Frame BER Rating Performance and Energy Values





Masonry Construction BER Rating Performance and Energy Values

KEY FINDINGS

Operational Carbon

I.C.F Construction

45 kWh/m²/yr
5.96 KgCO2/m²/yr — 1 Year

450 kWh/m²/yr
59.6 KgCO2/m²/yr — 10 Years

2250 kWh/m²/yr
298 KgCO2/m²/yr — 50 Years

Timber Frame Construction

46.11 kWh/m²/yr
6.11 KgCO2/m²/yr — 1 Year

461.7 kWh/m²/yr
61.1KgCO2/m²/yr — 10 Years

2305.5 kWh/m²/yr
305.5 KgCO2/m²/yr — 50 Years

Masonry Construction

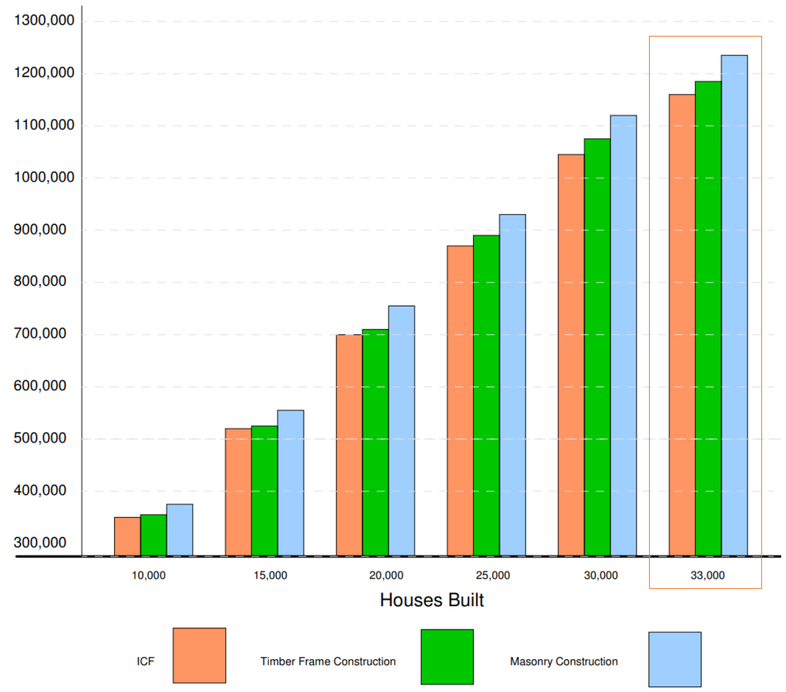
43 kWh/m²/yr
5.70 KgCO2/m²/yr — 1 Year

430 kWh/m²/yr
57 KgCO2/m²/yr — 10 Years

2150 kWh/m²/yr
285 KgCO2/m²/yr — 50 Years

Embodied Carbon

Carbon levels if each house type is built



LIMITATIONS

FUTURE PROPOSAL – FEASABILITY STUDY

A feasibility study would be a valuable addition to this thesis, as it would allow for a more detailed evaluation of the economic and practical aspects of implementing the wall types considered. This could involve conducting a cost-benefit analysis to assess the financial feasibility of each wall type, including factors such as material and labor costs, as well as any potential savings in energy costs and maintenance over the lifetime of the building.

By conducting a feasibility study, a more comprehensive evaluation of the different wall types could be achieved, allowing for more informed decision-making and ultimately leading to more sustainable building practices in the residential sector.