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WHITE PAPER

White Paper on the Performance Benefits in Dwellings and Offices Buildings from the use of C.U.in Ultra Insulated Glass

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Contents

1. Energy Consumption and Carbon Emissions of Buildings

1.1. Buildings are responsible for significant proportions of global energy use and carbon emissions. In the UK around 49% of annual carbon emissions are attributable to buildings and similar proportions are seen across the major economies of the world. The UK is targeting being Net Zero by 2050, although many experts and pressure groups believe that we should be striving to make all new buildings achieve this by 2030. On top of this, most existing buildings in the UK, which make up the majority of the building stock, are generally in poor condition in terms of their thermal performance, requiring improvements to the thermal envelope (walls, floors, roofs, doors and windows). Of the thermal elements, windows are commonly the least efficient part of the building fabric, giving rise to increased heating in winter and overheating in summer. C.U.in glazing offers an ultra-insulated glazing product to reduce heating demand in winter but can also be combined with the latest solar coatings to reduce overheating in summer.

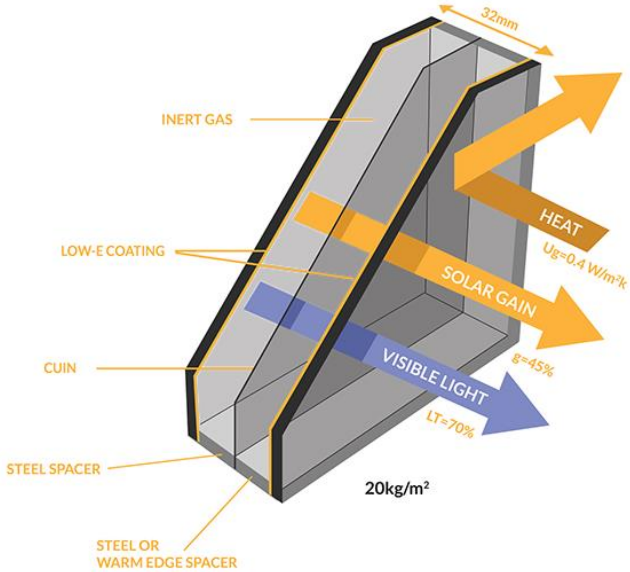
1.2. Alongside the operational energy in buildings, the embodied carbon in building products is an important part of reducing carbon emission. Embodied carbon is the amount of energy required to create a product, from the extraction of the raw materials, its processing, construction, and transport/shipping to the final location for use. Traditionally, to achieve higher levels of thermal insulation, triple glazing has been used. C.U.in's technology reduces the quantity of materials being used as well as providing improved levels of insulation above that found in even triple glazed products.

2. C.U.in Glazing

2.1. C.U.in is an innovative product that incorporates unique suspended film technology inside the glazing, resulting in the most thermally efficient glazing available today. C.U.in works in a similar way to triple glazing, but the invisible C.U.in film acts as the third pane of glass encapsulated in the centre of the glazing. C.U.in suspended film is thinner, lighter, and more thermally insulating than glass, resulting in considerably reduced heat loss through your window compared to double and triple glazing, keeping your home warmer.

2.2. C.U.in is over twice as thermally insulating as double glazing and 50% more thermally insulating than triple glazing when glazed into a typical house window, meaning the cold areas near to windows are eliminated.

2.3. The C.U.in technology using the film to create a thinner lighter triple glazed unit reduces the quantity of materials used, thus reducing its embodied carbon. Furthermore, the lighter window offers an additional advantage by allowing for a lighter building structure, saving additional embodied carbon. This is particularly beneficial on taller buildings where the total weight of all the glazing is a major factor.



3. Energy Benefits of C.U.in Glass

3.1. Thermal transmission is expressed as a U-value which has units of W/m^{2}K. This is the heat loss per metre squared of surface area per degree difference between the inside and outside temperatures. For example, if the heating setpoint on a thermostat is set to 20°C, the outside air temperature is 0°C, and the U-value of the window is 1.2 (typical high performing double glazing), then the heat loss is 24W/m^2 of window area. A typical house window is around 2.1m^2 and houses have on average 8 windows, therefore the instantaneous heat loss will be 400W. Consequently, over the course of a cold day this could translate to 9.6kWh. However, switching to C.U.in glazing (which has a much lower U-value of 0.4W/m^{2}K) could reduce heat loss to 3.2kWh, a saving of 6.4kWh per day. Out of the UK housing stock of 29million homes it is estimated that 19 million need to be made low carbon ***(House of Commons Environmental Audit Committee, 2021)***, the above heat loss savings, if every refurbished house was fitted with C.U.in, could reduce the UK peak energy demand by around 4.5GW. This is equal to around 60% of the current nuclear power station power production capacity.

4. Impact of C.U.in on Building Performance

4.1. In order to quantify the effectiveness of C.U.in to impact on building energy consumption a number of tests were carried out. These tests looked at several key areas:

- Domestic energy consumption
- Domestic overheating
- Embodied carbon
- Office building energy consumption

4.2. Testing Methodologies

4.2.1. Domestic energy consumption

Energy consumption, CO_2 emissions and running costs were analysed using the SAP tool. SAP is the official UK compliance tool for assessing domestic energy and carbon emissions, therefore any product such as C.U.in needs to show benefits in these assessments. This study has been carried out in the latest version of the SAP standard, SAP10 (Building Regulation Part L 2021). The software calculates the energy consumption of a dwelling for a whole year based on the building’s construction (walls, floors, ceilings, windows etc.) and the resulting energy required to provide heating, hot water and lighting to the home.

For this assessment C.U.in glazing was tested against both typical double and triple glazed units. The rest of the dwellings' thermal performance was standardised as set out in the below table.

	C.U.in Ultra 36mm"double glazed"	Double glazed typical unit 28mm	Corresponding Triple glazed typical unit 36mm	Triple glazed typical unit 50mm
Centre pane U value W/m²K	0.4	1.0	0.9	0.6
g-value	0.45	0.42	0.42	0.41

Table 1- Glazing Performance Figures

Building elements		BENCHMARKS (Residential)	Assessed development
		Building Regulations Pt L 2021 Limiting Factors	Flats
U-values W/m²K	External wall	0.26	0.17
	Party wall	0.20	0.00*
	Ground floor and exposed floors	0.18	0.10
	Roof and exposed ceiling	0.16	0.11
	Windows including frames	1.6	1.25
	Doors including frames	1.6	1.25
	Thermal bridging	-0.15	0.15
	Glass g-value	-	0.42
	Air-tightness, m³/h/m² @ 50Pa	8.00	3.5

Table 2- Building Fabric Performance Figures

Three different technologies were used to heat the dwellings: a gas boiler, a district heating network and a heat pump. These represent the broad range of typical technologies used in modern dwellings. Their efficiencies were taken from the SAP database and are 88.9% for the gas boiler, 170% for the heat pump and the district heating network is set up as the table below.

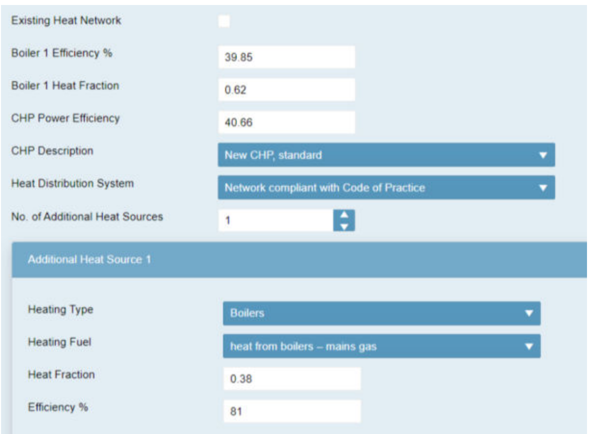


Table 3 - District heating efficiencies

The results look at three key metrics:

- The Domestic Emission Rate (DER). This is how much carbon the dwelling will emit over a year

- Domestic Fabric Energy Efficiency (DFEE). This measures the dwelling's insulation effectiveness
- Energy Performance Certificate (EPC) rating. This is the energy label that all dwellings (and other building types) must produce and shows the dwelling's energy and carbon efficiency.

4.2.2.Domestic overheating

Thermal Comfort has been measured against UK Building Regulations Part O. This analysis was carried out using EDSL's TAS dynamic thermal modelling (DTM) tool. This is a government approved tool and predicts risk of overheating homes during the summer months (May to September).

4.2.3.Embodied carbon

Embodied carbon calculations have been carried out using HM's bespoke database (in line with of EN 15804) and eTool. Two systems (C.U.in glazing vs a Triple glazed unit) have been assessed in line with the methodology described in EN 15804 and by only reporting the environmental indicator of Global Warming Potential (or the so-called Embodied Carbon). The system boundary will focus on both Product Stage A1-A3 and Module A4 Transport.

4.2.4.Office building energy consumption

The analysis of the commercial offices has been undertaken using the NABERS standard. NABERS is a method for modelling a building through the design process and then validating this once the building is completed by measuring the actual energy usage on site. Various models are run as part of this to test different operational scenarios to see how these affect the building's energy use. For this test the central case dynamic thermal model was used as it is seen as the most typical for 'normal' operation and therefore best suited to these comparison tests. The modelling was carried out using EDSL's TAS dynamic thermal modelling (DTM) tool.

5. Summary of Findings

5.1. Domestic energy consumption

The results of the SAP calculations investigate three key areas:

- The Domestic Emission Rate (DER)
- Dwelling Fabric Efficiency Improvement
- EPC rating

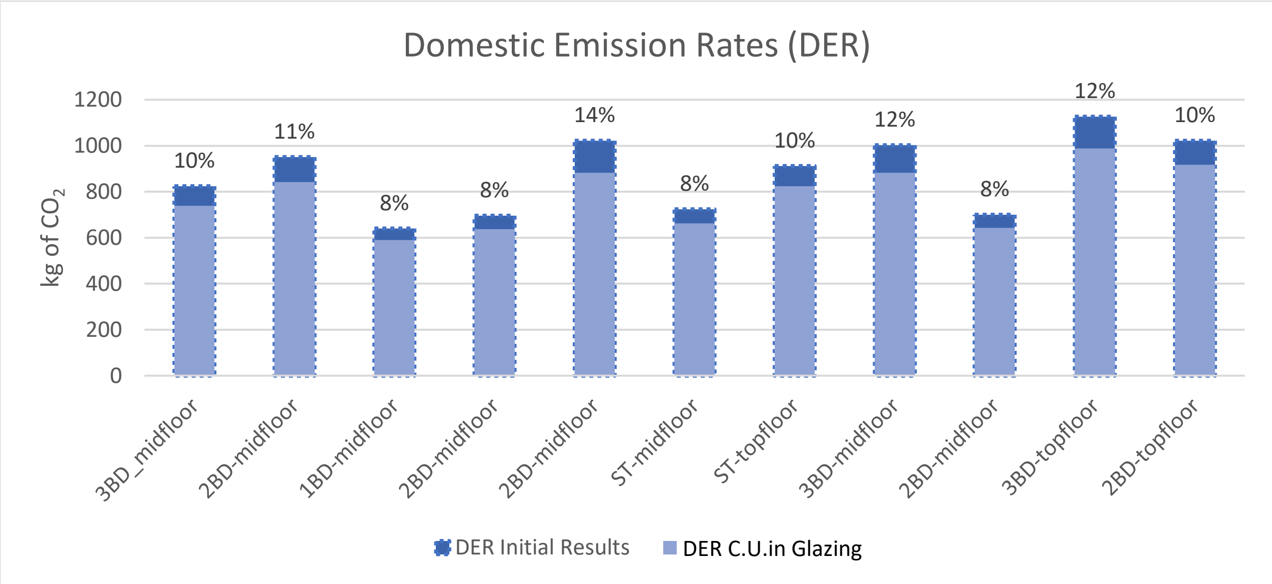


Figure 1- Gas Boiler, Domestic Emission Rate comparison of double glazing with C.U.in

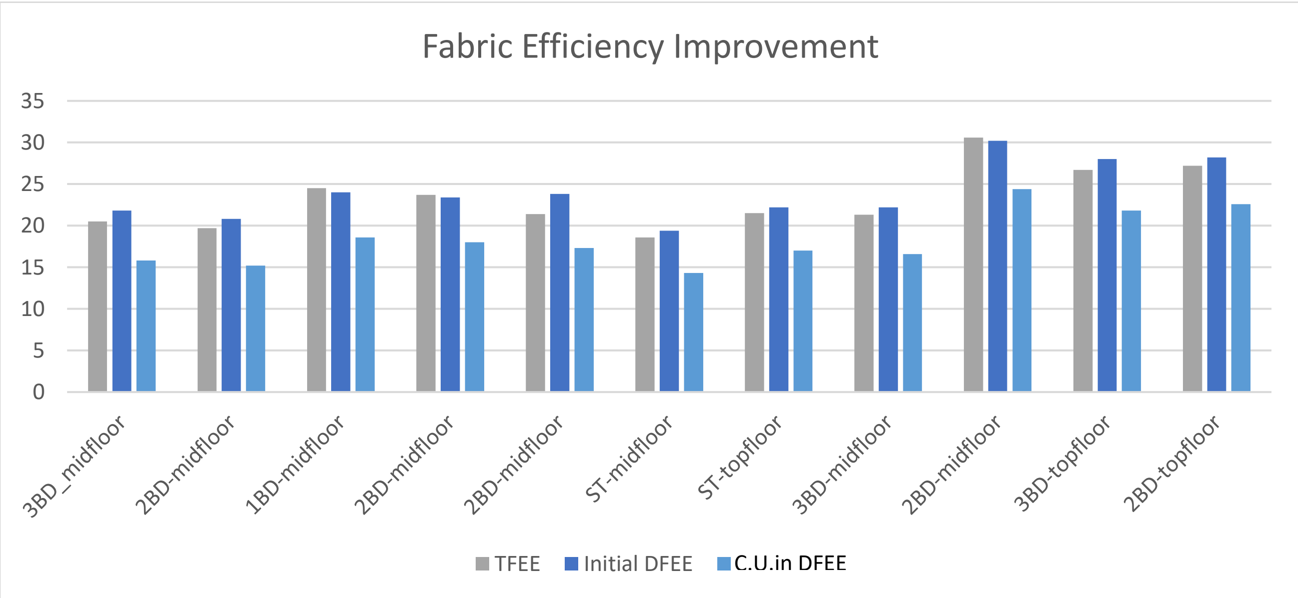


Figure 2 – Gas Boiler Fabric Efficiency Improvement, comparison of double glazing with C.U.in

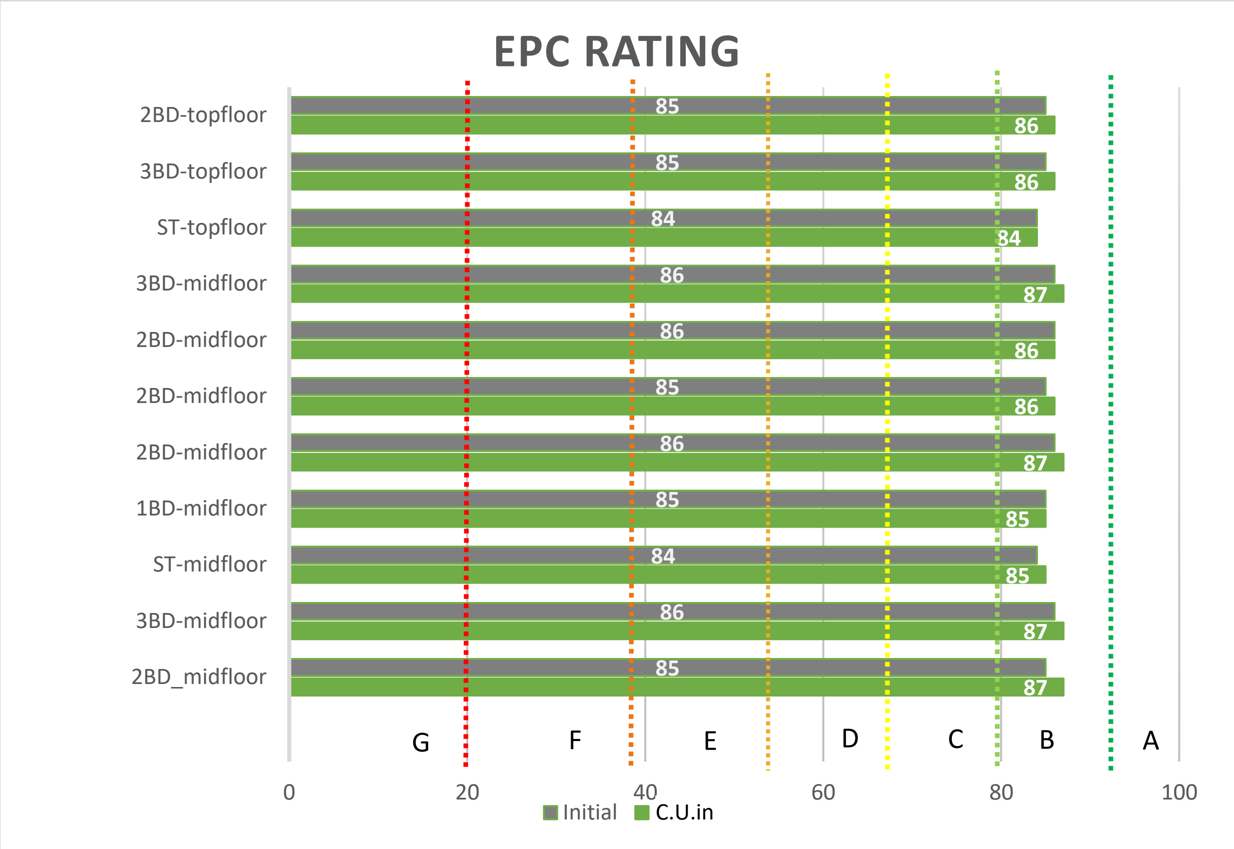


Figure 3 – Gas Boiler, EPC Comparison, comparison of double glazing with C.U.in

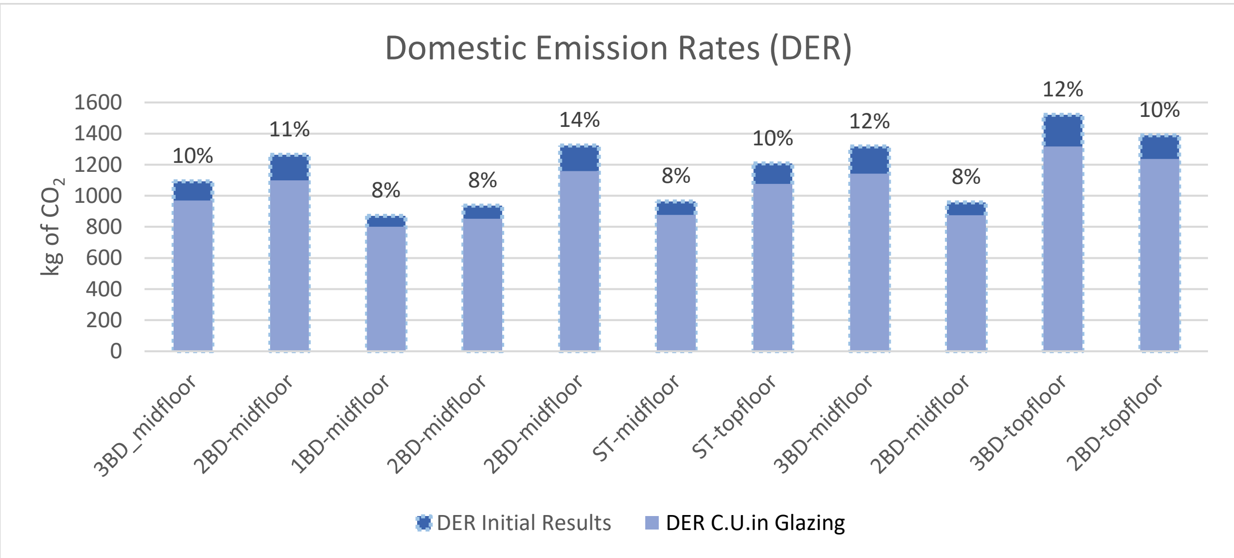


Figure 4- District Heating Domestic Emission Rate comparison of double glazing with C.U.in

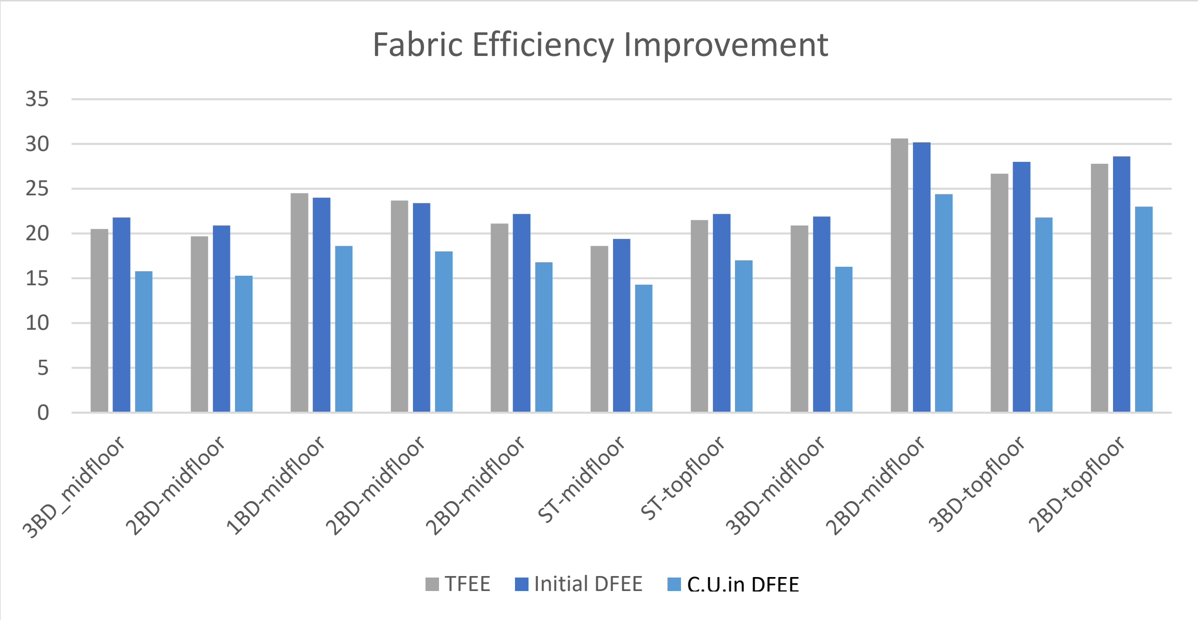


Figure 5- District Heating Fabric Efficiency Improvement, comparison of double glazing with C.U.in

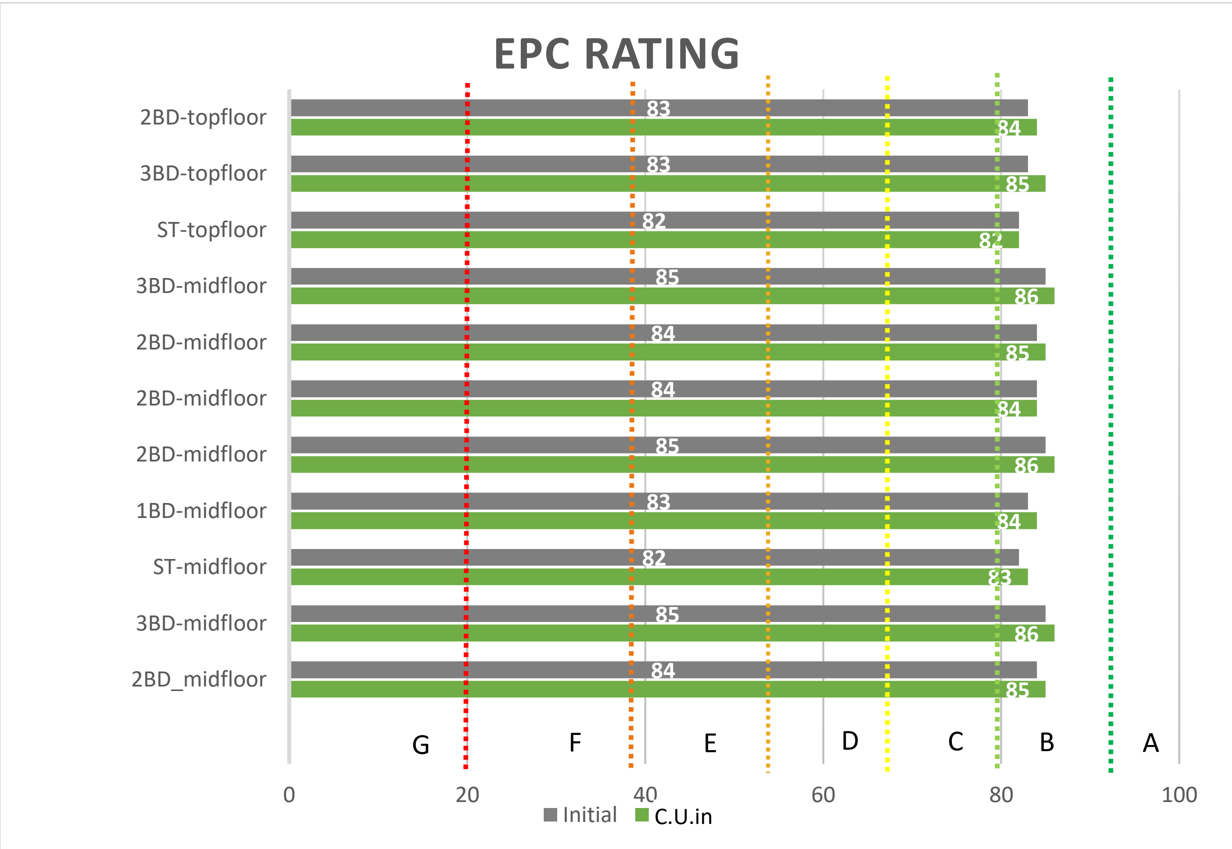


Figure 6- District Heating, EPC Comparison, comparison of double glazing with C.U.in

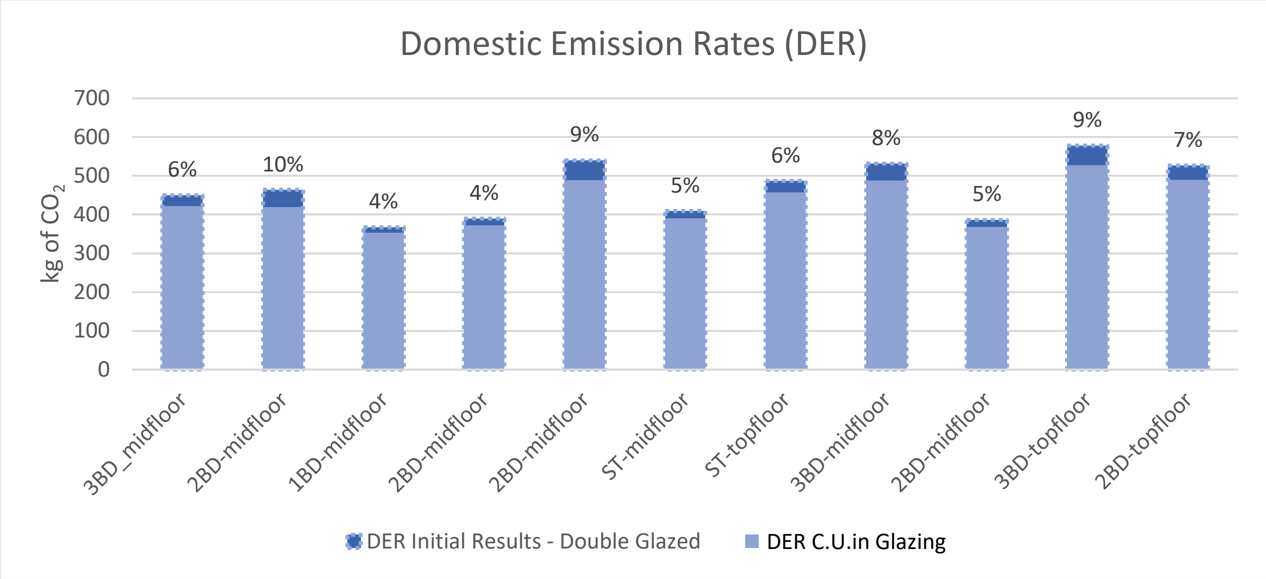


Figure 7- Heat Pump, Domestic Emission Rate comparison of double glazing with C.U.in

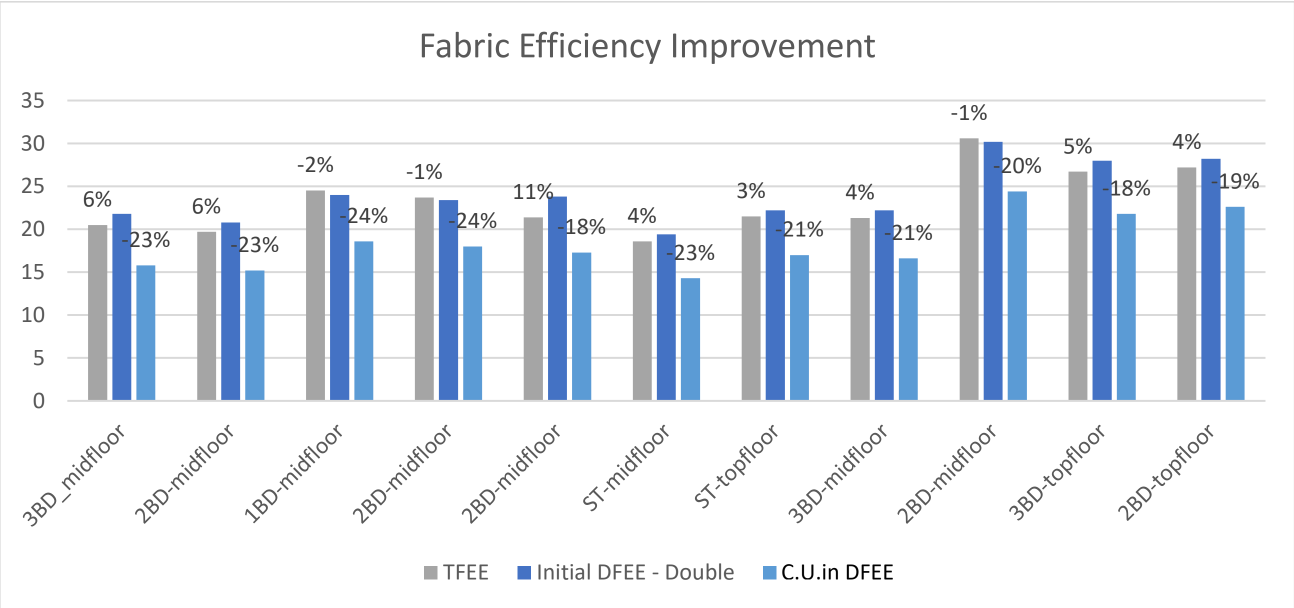


Figure 8 – Heat Pump, Fabric Efficiency Improvement, comparison of double glazing with C.U.in

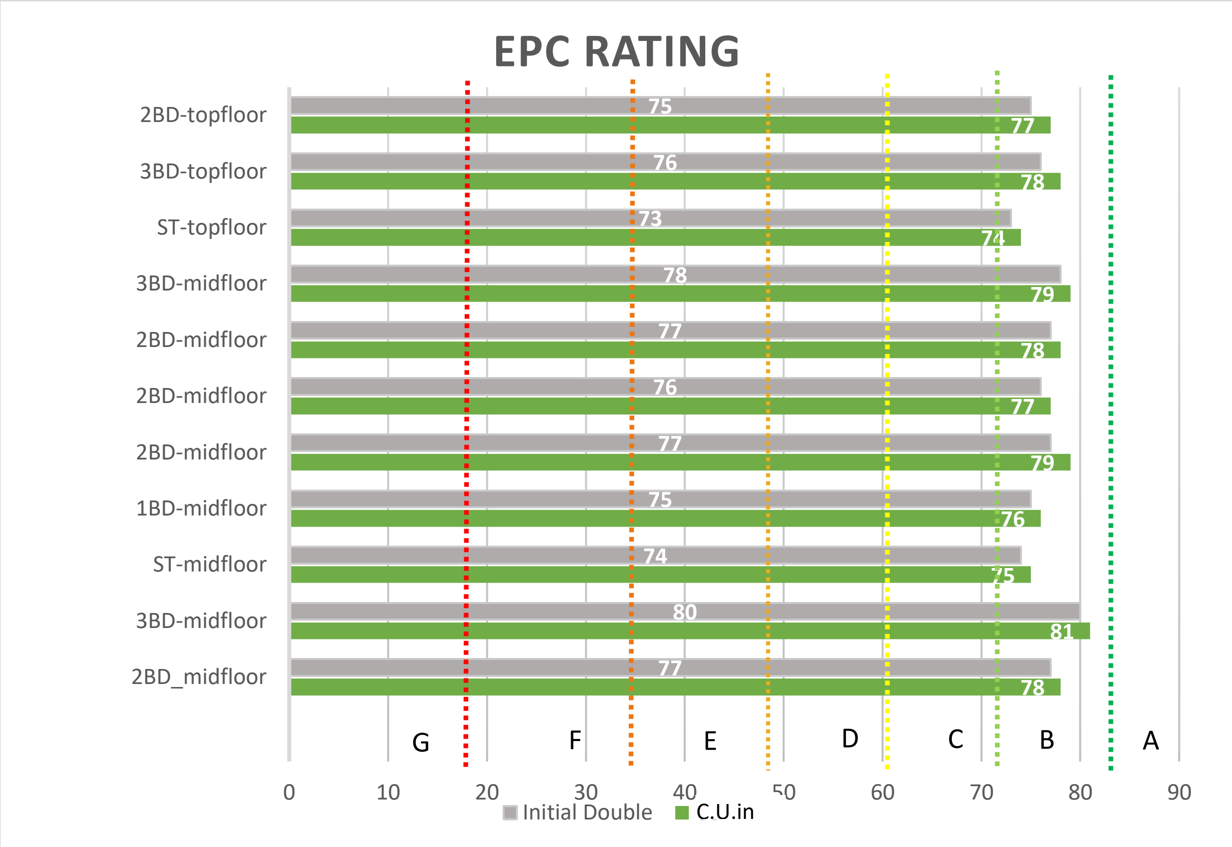


Figure 9- Heat Pump, EPC Comparison, comparison of double glazing with C.U.in

Summary of improvements					
	EPC rating	Domestic Emissions Rate (DER)	Domestic Fabric Efficiency (DFEE)	Heat requirement annually	Heating cost annually
C.U.in vs double-glazed unit	"+1"	-9%	-24%	-45%	-57%
C.U.in vs triple glazed unit (36mm)		-8%	-21%	-40%	-48%
C.U.in vs triple glazed unit (50mm)		-4%	-11%	-23%	-29%

Figure 10 - Results Summary

5.2. Domestic overheating

In December 2021 Building Regulation Part O was released, coming into force in June 2022. This regulation adopted the CIBSE TM59 methodology (with some minor adjustments) to ensure overheating was considered in all future dwelling design.

Domestic buildings must be able to demonstrate thermal comfort in order to comply with UK Building Regulations. Approved Document O provides guidance on how to mitigate overheating, with two routes to compliance: A simplified method and a dynamic thermal modelling (DTM) approach, based on the methodology described in CIBSE TM59. For this study, the DTM approach was used.

Living rooms and bedrooms, as the main occupied zones in all apartments on these floors, are assessed using the CIBSE Design Summer Year (London DSY, in this case) weather files. The assessment period runs from May to September and the criteria for each space type are as below:

Assessment Criteria		Acceptable deviation
Criterion A	*Living rooms, kitchens and bedrooms:* Frequency of occupied hours when ΔT ≥ 1 Kelvin (K)	3% of occupied hours during May-September
Criterion B	*Bedrooms only:* Frequency of occupied hours when operative temperature ≥ 26 ◦C	1% of annual hours from 10 pm to 7am

Table 4 – TM 59 Overheating criteria

ΔT is the difference between the operative temperature and the maximum acceptable operative temperature,[1] therefore:

ΔT= Operative temperature – maximum acceptable comfortable temperature

[1] ΔT is measured in °K rounded to the nearest integer

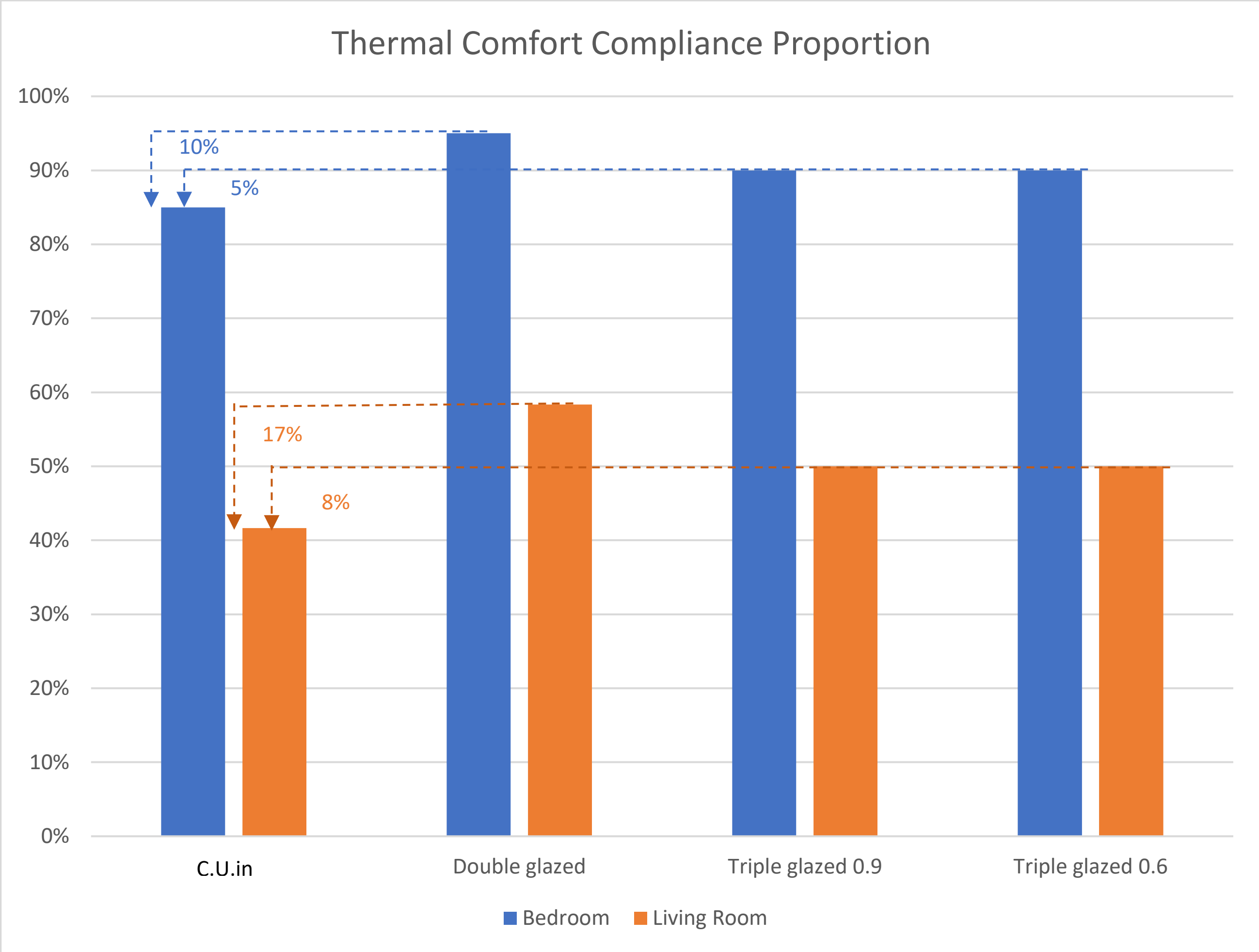


Figure 11- Number of rooms achieving thermal comfort, C.U.in vs DGU vs TGU(U=0.9) vs TGU (U=0.6)

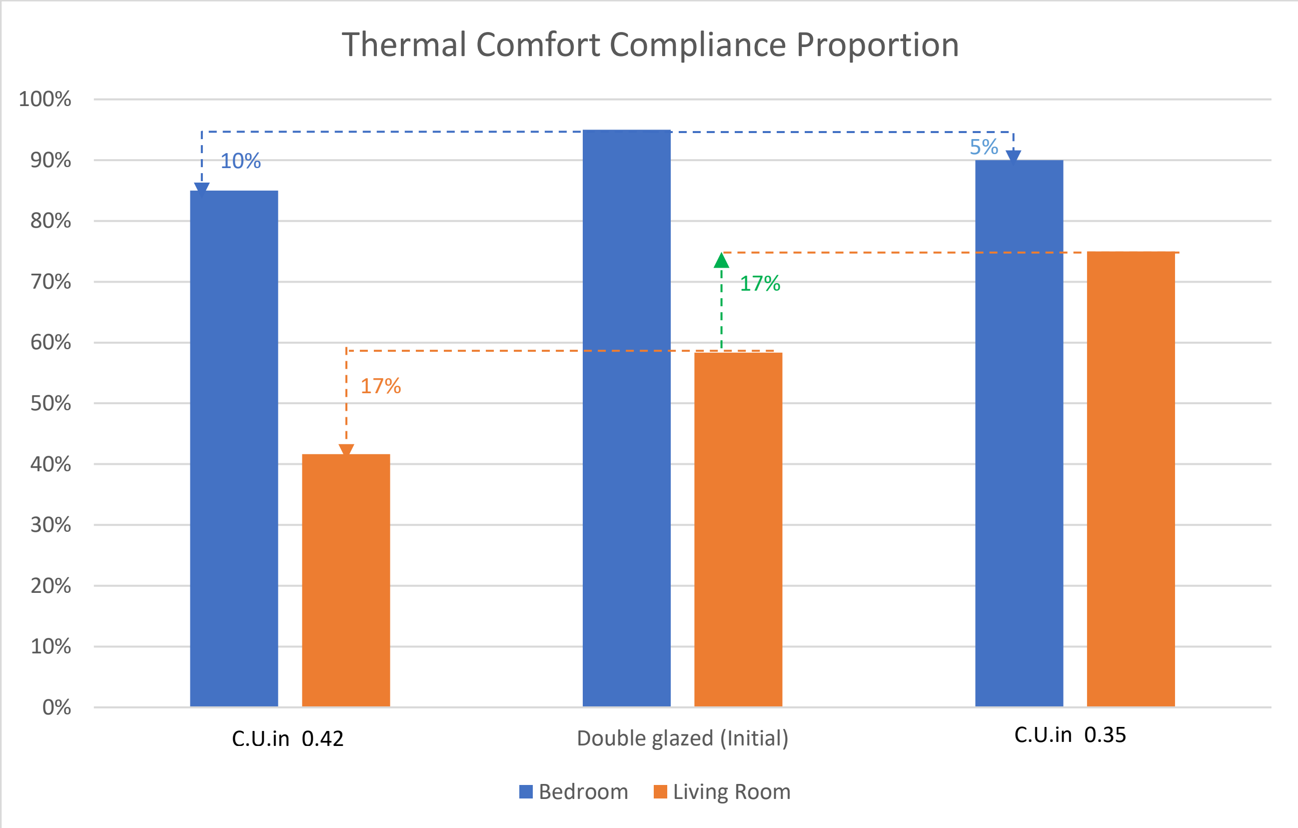


Figure 12- Number of rooms achieving thermal comfort, C.U.in 0.42 vs 0.35 g-Values

For thermal comfort, the reduction of the U-value automatically means a reduction of heat loss, thus an increase in the overheating risk. When comparing a simple double glazed unit with the C.U.in unit there is a decrease in areas achieving thermal comfort compliance in the range of 10-17%. Similarly, when comparing a typical triple glazed unit and C.U.in, there is a decrease in bedrooms achieving compliance of 5% and a decrease in the number of living rooms achieving compliance of 8%. The observed reduction of thermal comfort compliance from C.U.in can be counterbalanced when using a lower g-value; this is seen to have a minor impact on the energy saving benefits but still achieves a significant energy saving annually compared to typical glazing units. It should be noted that for the double glazed C.U.in unit with a g-value of 0.35 there was an increase in the number of compliant living rooms, but a small decrease in the number of compliant bedrooms. All but two bedrooms were complying with thermal comfort as per the simple double glazed unit but also 17% more living room areas achieved compliance with TM59. This is a quite important observation, as living room areas are more likely to have overheating risks and this is a positive outcome.

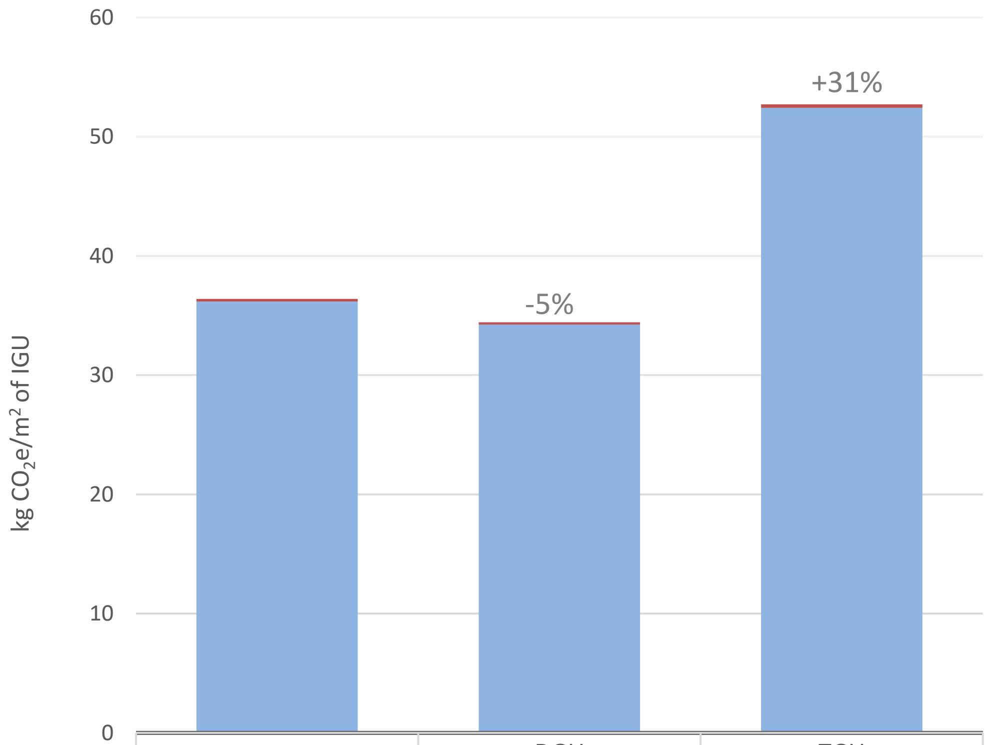
5.3. Embodied carbon

Embodied carbon is defined as *‘**carbon emissions associated with energy consumption (embodied energy) and chemical processes during the extraction, manufacture, transportation, assembly, replacement and deconstruction of construction materials or products. Embodied carbon can be measured from cradle-to-gate, cradle-to-site, cradle-to-end of construction, cradle-to-grave, or even cradle-to-cradle. The typical embodied carbon datasets are cradle-to-gate. Embodied carbon is usually expressed in kilograms of CO_{2e} per kilogram of product or material**’*

The below study was prepared in line with the embodied carbon standard EN 15804 by reporting the environmental indication Global Warming Potential (GWP) or the so-called Embodied Carbon. The study was based on the system boundary of Stage A1-A3 Product and Module A4 Transport. The transport distance used for the analysis was 18 km, based on a travel distance from C.U.in headquarters to a potential building site in the City of London.

The outcomes in the analysis showed that the Double-Glazed Unit (DGU) is 5% less carbon intensive than C.U.in Double Glazed Unit, whereas the Triple Glazed Unit (TGU) is 31% more carbon intensive than C.U.in per m^2 of IGU.

The benefits in reduced structural weight of the building, by using C.U.in over a triple glazed window, has not been examined in this study. However, as the structure of a building accounts for 50-60% of the embodied carbon, any reduction in the weight of the windows will mean the structure has less load to support and can therefore needs less material (thinner floor slabs, smaller steel beams for example).



	C.U.in_DGU	DGU	TGU
Module A4 Transport	0.205	0.199	0.303
Stage A1-A3 Product	36.180	34.248	52.418

Figure 13 - *Embodied Carbon Comparative Study, C.U.in vs. double and triple glazing*

5.4. Office Building Energy Consumption

Building energy modelling is most commonly carried out using the Building Regulation Part L methodology, however this is a standardised approach which is known to under predict likely actual energy consumption in real life. NABERS UK is a methodology recently introduced into the UK (having been developed and used in Australia for over 20 years) which predicts during design then measures and rates the actual energy use of offices, helping building owners to accurately track and communicate the energy performance of their buildings. It also helps identify areas for savings and improvements. The modelling approach for NABERS UK is Design for Performance (DfP) which looks at accurately modelling as close as possible the actual design and operation of the building. This modelling approach also considers 'off-axis' scenarios to test resilience to different operational and use types. For this test the 'central case' was used, which represents the most typical of normal operation.

For the C.U.in glass evaluation, two typical office buildings were tested - one located in central London and one in Cambridge, with C.U.in glazing and the results compared to those from the original DfP models.

Energy consumption results for heating and cooling were measured against the 'as-designed' buildings and the relative improvements over these baselines reported.

5.4.1. Cambridge Office Building

Energy Consumption (Building 1)	Lower g-value DGU	C.U.in Glass	Lower G-Value C.U.in
Heating	-2%	-5%	-5%
Cooling	-4%	7%	1%

Figure 14- Energy consumption relative to 'as-designed' Cambridge office

Results indicate that, compared to the original DfP model, overall heating energy consumption was reduced by around 5% for both the different types of C.U.in glazing. However, cooling energy consumption increased by around 7% for the higher g-value and 1% for the lower g-value C.U.in glass. This represented an overall decrease of around 5% in heating with neutral effect on cooling when a lower g-value C.U.in glass is used.

5.4.2. London Office Building

The second office building has a higher proportion of glazing on the façade and is therefore more sensitive to changes in the glazing type, thus greater savings were observed. Since the north façade is fully glazed, an additional scenario was tested where only the glazing on the north facade was changed. As can be seen, significant savings can be obtained in reducing heating requirements, but this must be balanced against increased cooling demand due to the better retention of heat. The below results were not an exhaustive test of all possible options and there will be a 'sweet spot' unique to each building balancing the U and g values. However, the benefits of applying C.U.in to the north façade of the building are clear.

Energy Consumption (Building 2)	Lower g-value DGU	C.U.in glass on North Facade	C.U.in North + Low g on other Facades	C.U.in Glass on all facades
North g-value	0.24	0.31	0.31	0.31
North glazing u-value	1	0.4	0.4	0.4
All other glazing g-value	0.24	0.31	0.24	0.31
All other glazing u-value	1	1	1	0.4
Heating consumption	3%	-13%	-10%	-35%
Cooling consumption	-10%	7%	-2%	33%

Figure 15- Energy consumption relative to 'as-designed' London office

6. Conclusions

The C.U.in technology has been shown to make significant energy savings to both dwellings and commercial office buildings, particularly focusing on reducing heating demand and therefore also carbon emissions and energy bills. With greater insulation comes greater heat retention, which can lead to an elevated risk of overheating in the summer. This can be countered by improving the solar performance (lowering the g-value) of the glazing in the C.U.in product but retaining its high insulation/low heat loss properties.

The other considerable advantage of C.U.in is the reduction in embodied carbon. In order to get the very best thermal performance traditionally this would mean using a triple glazed unit. C.U.in's technology reduces the embodied carbon in the window unit by 30%. This reduction is without accounting for the additional reduction in structural weight of the building due to the lighter C.U.in windows so there will be additional benefits in reduced embodied carbon for the building structure.

Overall, the C.U.in technology should keep buildings warmer and cheaper to run, it can also reduce the embodied carbon and structural weight of the building.