



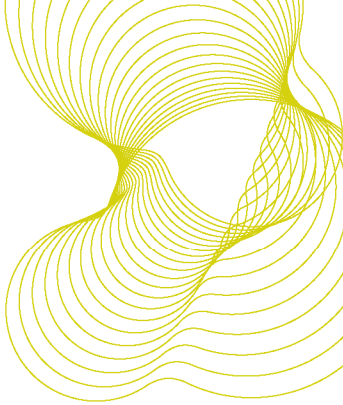
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**Life cycle environmental
and economic analysis
of polyurethane
insulation in low energy
buildings**

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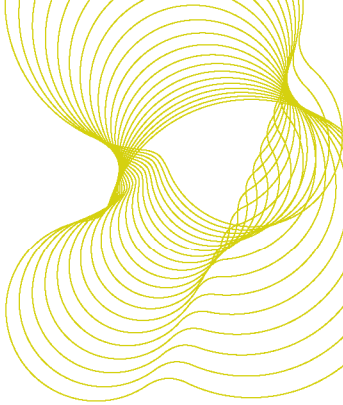


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Executive Summary

Purpose

The purpose of this project is to quantify the overall environmental and economic costs of using polyurethane (PU) insulation in low energy buildings. This has been demonstrated by balancing the embodied environmental impact in manufacturing the PU product and similar products with the environmental benefits of reduced energy used for heating and, for the economic analysis, a comparison of the life cycle costs of each.

Three scenarios were modelled using a 3-bedroom, 5-person two-storey detached house, with masonry cavity walls, solid concrete floor and pitched or flat roof. Each scenario considered three different climatic zones: Temperate Oceanic, Temperate Mediterranean and Cool Continental, as referenced in the Köppen Climate Classification.

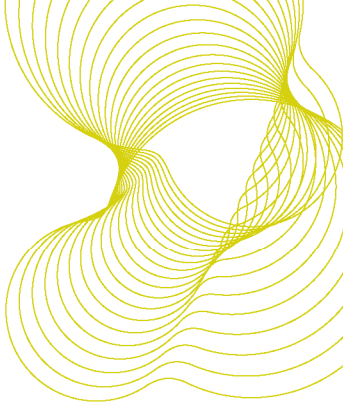
Part 1 New building scenario Using polyurethane, stone wool, glass wool or expanded polystyrene insulation material, as appropriate, in a new build cavity wall, pitched roof and ground floor to achieve target U values and hence the same energy consumption for all scenarios.

Part 2 Refurbishment scenario Using 50mm thickness of polyurethane, stone wool or glass wool insulation materials to upgrade (refurbish) the external wall of an existing building with an internal lining, resulting in different U values and hence different energy consumptions

Part 3 Flat roof scenario Using polyurethane, stone wool and expanded polystyrene insulation material of varying thicknesses for a flat roof to achieve a common U value and assess the impact of the density of each material.

The report has been formatted as follows:

Executive summary		
Part 1 New build scenario	Part 2 Refurbishment scenario	Part 3 Flat roof scenario
Identification of environmental impacts (life cycle assessments)	Identification of environmental impacts (life cycle assessments)	Identification of environmental impacts (life cycle assessments)
Identification of cost impacts (life cycle costs)	Identification of cost impacts (life cycle costs)	Identification of cost impacts (life cycle costs)
Affect on building footprint of using different insulation materials		Impact of weight of insulation on building construction and building costs
Background report – methodology, detailed results for internal reference		



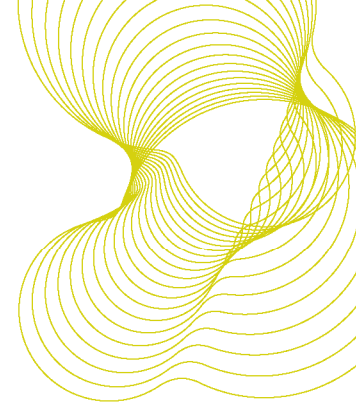
Environmental impacts

LCA assessments were carried out to investigate the environmental impacts associated with the materials and energy consumption for the alternative designs included in the project. The objective of this work was to consider how the impact of the materials compared with each other and with the impact of energy consumption during use.

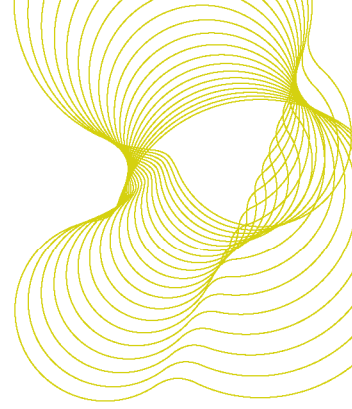
The LCA work used a study period of 50 years in line with the life cycle costing part of the project, as requested by the client. Results are presented as characterised and normalised data for the environmental impact categories of Global Warming, Stratospheric Ozone Depletion, Eutrophication, Photochemical Ozone Creation, and Acidification. These indicators were used as they were the impact indicators proposed in TC350 at the time the project was initiated. Data was normalised to the annual impacts of a Western European citizen, covering the EU15 (plus Norway and Switzerland).

Note: The approach used in this study differs from that of BRE Global’s Environmental Profiles Methodology, which underpins the Green Guide to Specification, and therefore the results produced are not comparable with other results published by BRE Global for the environmental impact of construction products or specifications. Section (Introduction to LCA) provides more details of the differences from the Environmental Profiles Methodology.

The table below summarises the aspects modelled within the LCA work. Part 1 considers the environmental impacts associated with new build, Part 2 investigates refurbishment by applying an internal lining to existing external walls, and Part 3 models flat roofs.



Part	Element	Climate Zone	Energy for space heating	Insulations	Materials
1	Cavity Wall	<ul style="list-style-type: none"> • Temperate Oceanic • Temperate Mediterranean • Cool Continental 	Gas	<ul style="list-style-type: none"> • PU • stone wool • glass wool 	Brick, dense blockwork, plaster, paint Extra wall, roof & foundations compared with PU wall
	Pitched roof	<ul style="list-style-type: none"> • Temperate Oceanic • Temperate Mediterranean • Cool Continental 	n/a	<ul style="list-style-type: none"> • PU • stone wool • glass wool 	Concrete tiles, battens, underfelt, trussed rafters. For ceiling below joists: plasterboard, paint
	Ground floor	<ul style="list-style-type: none"> • Temperate Oceanic • Temperate Mediterranean • Cool Continental 	n/a	<ul style="list-style-type: none"> • PU • EPS 	Reinforced concrete, reinforced screed
	Whole house	<ul style="list-style-type: none"> • Temperate Oceanic • Temperate Mediterranean • Cool Continental 	Gas	<ul style="list-style-type: none"> • PU, walls + roof • stone wool, walls + roof • glass wool, walls + roof 	External wall, & roof as for each insulation type; all with PU ground floor, upper floor with I-joists, painted timber windows
2	Internal Lining of external wall (refurbishment)	<ul style="list-style-type: none"> • Temperate Oceanic • Temperate Mediterranean • Cool Continental 	Gas	<ul style="list-style-type: none"> • PU • EPS • stone wool • glass wool 	Plasterboard, plaster adhesive, paint Battens, plasterboard, paint
3	Flat roof	<ul style="list-style-type: none"> • Temperate Oceanic • Temperate Mediterranean • Cool Continental 	n/a	<ul style="list-style-type: none"> • PU • stone wool • EPS 	EPDM, vapour control layer, OSB, timber joists, plasterboard, paint



Summary of models used for the study

The original project brief requested wood wool (cellulose) board insulation to be assessed in Part 1, new build, pitched roof. However, no suitable LCI data is available in the public domain to allow this product to be included in the LCA work.

The results from Part 1 indicated that the PU designs tended to have similar or higher environmental impacts than those for designs with the alternative insulation materials at the same thermal performance. Part 3's results indicated that when insulations need mechanical properties in addition to their thermal performance, then solutions using PU can have environmental impacts similar to or lower than alternative insulations.

The results from Part 2 show that where the amount of insulation is fixed, rather than the U-value, then the greater energy savings achieved with using PU insulation offset the higher environmental impact of the PU insulation itself.

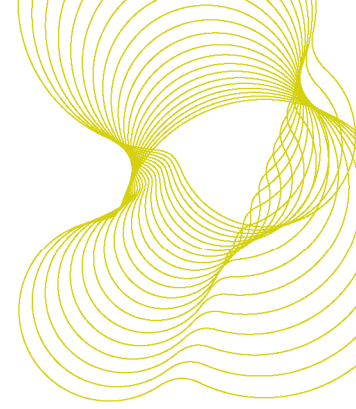
Part 1 further indicates that the materials of the modelled highly insulated house accounted for around one third of the total Global Warming and 50 to 90% of the whole house impact in Ozone Depletion, Eutrophication, Photochemical Ozone Creation and Acidification for Air and Water over 50 years for all climate zones.

However, the results from Part 2 imply that:

- a) if the cavity is kept at the greater thickness needed for stone wool and glass wool in Part 1 to achieve the set U-value of $0.15 \text{ W m}^{-2}\text{K}^{-1}$ then the extra PU insulation that could be incorporated would save energy in use, which could be enough to offset the extra impact of the PU material, and may offer greater benefits as demonstrated in Part 2;
- b) if stone wool and glass wool were modelled at the same cavity thickness as for the PU model in Part 1 of this project, it is likely that stone wool and glass wool would require more energy during use, which might more than offset the lower environmental impacts of these insulations.

We would recommend that consideration is given to carrying out the assessments outlined in a) and b) above ensuring that the specifications and energy models are relevant to the climate zones where the models are set.

Additionally, the energy models have assumed a common airtightness and junction γ value for all models. The relevance of this assumption to the results is another further area of research.



Cost impacts

Life cycle costing (LCC) is a technique to establish the total cost of ownership. It is a structured approach which addresses all the elements of this cost and can be used to produce a spend profile of the asset over its anticipated life-span

LCC estimates were undertaken using BRE's cost model which is compliant with BS/ISO 15686-5 Buildings and constructed assets Service life planning Part 5 life cycle costing. The life cycle costs have allowed for normal maintenance and time expired components as appropriate.

The specification for the elements and the cost of all components are intended to represent the typical cost incurred by building owners. The values in the assessment are based on those required for a two storey detached property with a gross internal floor area of 104m².

The results for Part 1 cavity wall infill indicates that for all regions considered, 180mm polyurethane insulation used in the cavity has the lowest life cycle cost, followed by 270mm glass wool and 270mm stone wool.

To achieve the required u values, different thicknesses of insulation required different quantities of materials for the wall and hence higher construction costs. An additional cost/m² for this is included with the new wall calculations.

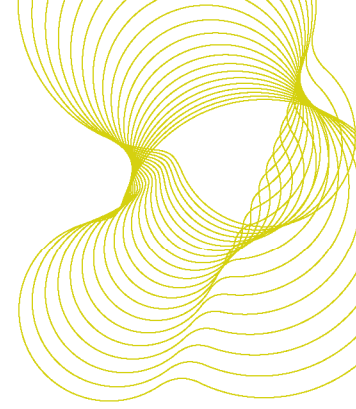
One effect of a thicker new cavity wall is the additional footprint area required for roof and floor. On a large building site this may affect the density or number of properties that could be built on the site, e.g. in the worst case, 8.00m² extra on the roof area for each property may mean that only 9 properties could be fitted in an area that may be able to accommodate 10 if the external walls were thinner.

The results for a new pitched roof with insulation between and over the rafters to achieve a common U value indicate that 190mm polyurethane has the lowest life cycle cost when used in all regions followed by 300mm glass wool insulation and 310mm stone wool.

The results for the new ground floor indicates that 95mm polyurethane insulation has the lower life cycle cost when used in all regions, followed by 185mm expanded polystyrene.

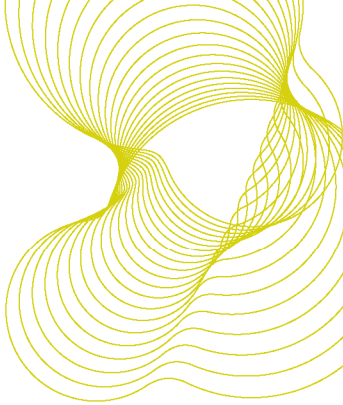
The results for Part 2 refurbishment of an existing wall by the addition of 50mm insulation to the inside face indicates that polyurethane insulation has the lowest life cycle cost, followed by expanded polystyrene, glass wool and stone wool in all regions.

The results for Part 3 new warm deck flat roof indicates that 150mm polyurethane has the lowest life cycle cost when used in all regions, followed by 255mm expanded polystyrene and 255mm stone wool insulation.



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1 Description of the project

Outline of the brief

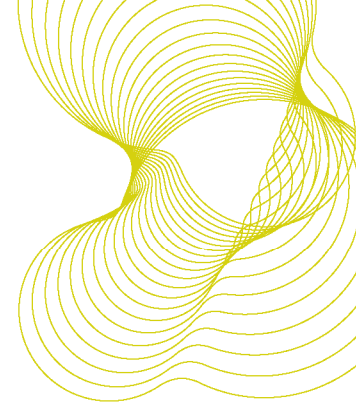
BING -The Federation of European Rigid Polyurethane Foam Associations, (now renamed as PU Europe) has asked BRE Global to undertake a research project to examine the life cycle environmental and economic analysis of polyurethane insulation in low energy buildings. This entails carrying out a review of the life cycle costs (LCC) and life cycle assessment (LCA) of polyurethane (PU) insulation in buildings compared with glass wool (GW), stone wool (SW), expanded polystyrene (EPS) or wood wool (cellulose) insulation as appropriate to the location within the building. To do so BRE Global has assumed a 3-bedroom, 5-person two-storey detached house, with masonry cavity walls, solid floor and pitched roof for whole house analysis and flat roof for the flat roof analysis.

Wood wool (cellulose) board insulation has been omitted from this report as no suitable LCI data is available in the public domain to allow this product to be included in the LCA work.

The project brief requires a comparison to be made of the overall environmental impact and cost implications when applying the model to 3 different climate zones, Temperate Oceanic (TO), Temperate Mediterranean (TM) and Cool Continental (CC) as referenced in the Köppen Climate Classification. These climate zones relate broadly to Western Europe (TO), Southern Europe (TM) and Northern Europe (CC). The construction is assumed to be the same, but the energy inputs will vary with the different climatic regions.

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Background report – methodology, detailed results for internal reference		



2 Identification of environmental impacts

2.1 Introduction to LCA

LCA modelling has been undertaken to determine the environmental impacts associated with using different insulation materials during new build (Part 1), refurbishment of existing external walls (Part 2) and for a warm deck flat roof (Part 3).

The following models have been generated:

1. Part 1 – new build with target u values
 - a. Cavity walls - plus any additional roof, external brick leaf and foundations (PU, stone wool batts or glass wool batts)
 - b. Pitched roof (PU, stone wool or glass wool)
 - c. Ground floor (PU or EPS)
 - d. Whole house (External walls + roof + ground floor & foundations + upper floor + windows + energy) in use over 50 years
2. Part 2 – refurbishment with target thickness
 - a. Internal lining of existing external walls (PU, stone wool, glass wool or EPS – refurbishment materials + energy) in use over 50 years
3. Part 3 – flat roof with target u values
 - a. Flat roofs (PU, stone wool or EPS)

These models allow the following comparisons to be made:

1. Part 1, new build
 - a. Constructions with each other (insulation & other materials needed)
 - b. Whole house models with each other & energy use – within & between climate zones
2. Part 2, refurbishment
 - a. Constructions with each other (insulated drylining only)
 - b. Constructions & energy use – within & between climate zones
3. Part 3, new flat roof
 - a. Constructions with each other (insulation & other materials needed)



The LCA studies have been performed using a methodology based on BRE Global's Updated Environmental Profiles Methodology¹. The table below addresses the key aspects of methodology, and highlights where modifications to the Environmental Profiles methodology have been made.

Aspect	BING Study	Modifications to BRE Methodology
<i>Study Period</i>	Any maintenance and replacement over a 50-year study period, plus demolition at or after the end of the study period.	60-year study period used in Environmental Profiles and Green Guide. Data on service life and calculation of replacement factor unchanged.
<i>Indicators</i>	Global Warming (100-year): kg CO ₂ equivalents Ozone Depletion: kg CFC-11 equivalents Eutrophication: kg phosphate (PO ₄) equivalents Photochemical Ozone Creation: kg ethene (C ₂ H ₄) equivalents Acidification for Air and Water: kg sulphur dioxide (SO ₂) equivalents	Additional 8 indicators used in Environmental Profiles and the Green Guide.
<i>Indicators: Characterisation Factors</i>	Characterisation factors are an update of the CML 2002 indicators, based on those in spreadsheet version 2.7 (issued April 2004) which were downloaded from http://cml.leiden.edu/software/data-cmlia.html , as integrated by Pre into the Simapro Software (v 2.02 in 2005).	
<i>Treatment of Group parameters</i>	Group parameter emissions of VOCs are considered in terms of Photochemical Ozone Creation Potential only, based on characterisation factors (calculated by averaging factors for a given group of emissions) provided in the draft of prEN15804 from 26.8.2009 and earlier.	In the BRE Global Methodology, group parameter emissions are characterised using the methodology proposed in the CML Operational Appendix (Part 2b) ² to break down group parameters (e.g. emissions of NMVOCs etc) into their individual constituents. Thus a reported emission of a group (eg alkanes) would be considered to be made up of the mass

¹ The BRE Environmental Profiles Methodology can be downloaded from www.bre.co.uk/greenguide.

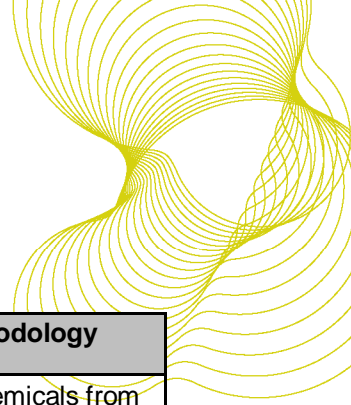
² Guinée et al, Life cycle assessment: an operational guide to the ISO standards. CML, Leiden University 2000. This can be downloaded in 4 parts from

Part 1: LCA in perspective: <http://www.leidenuniv.nl/cml/ssp/projects/lca2/part1.pdf>

Part 2a: Guide: <http://www.leidenuniv.nl/cml/ssp/projects/lca2/part2a.pdf>

Part 2b: Operational Appendix: <http://www.leidenuniv.nl/cml/ssp/projects/lca2/part2b.pdf>

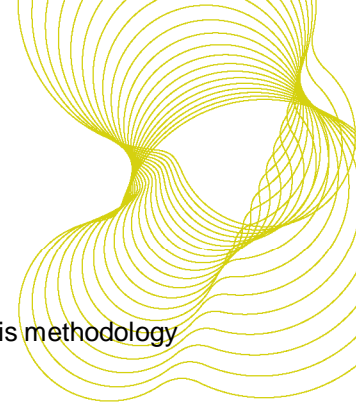
Part 3: Scientific Background: <http://www.leidenuniv.nl/cml/ssp/projects/lca2/part3.pdf>



Aspect	BING Study	Modifications to BRE Methodology
		proportion of the relevant chemicals from the group listed in Derwent et al (1996) ³ provided in Part 2b. This is done for factors for POCP, Global Warming and Stratospheric Ozone Depletion.
<i>Cradle to Gate LCA Data</i>	<p>Data for typical European PU manufacture provided by BING, and modelled using ecoinvent v2.0 datasets.</p> <p>Data for stone wool and glass wool insulation based on data provided through the Environmental Profiles project from members of Eurisol in the UK, and modelled using ecoinvent v2.0 datasets.</p> <p>Data for EPS taken from ecoinvent v2.0.</p> <p>Data for natural gas production and combustion used in building energy modelling taken from ecoinvent v2.0.</p> <p>All other construction products for the buildings modelled using ecoinvent v1.3.*</p>	<p>Data for PU based on UK Manufacturers only and modelled using ecoinvent v1.3 datasets.</p> <p>Data for stone wool and glass wool insulation based data provided through the Environmental Profiles project from members of Eurisol in the UK and modelled using ecoinvent v1.3 datasets.</p> <p>Data for EPS taken from ecoinvent v.1.3.</p> <p>No building level energy use taken into consideration within Environmental Profiles and the Green Guide – this is covered within BREEAM and the Code for Sustainable Homes.</p> <p>All other construction products for the buildings modelled using ecoinvent v1.3.</p>
<i>LCA data for Transport of material to site</i>	Data from the Environmental Profiles project used.	Data from the Environmental Profiles project used.
<i>Wastage on site</i>	Data from the Environmental Profiles project used.	Data from the Environmental Profiles project used.
<i>Disposal Routes for construction waste and demolition waste</i>	<p>Data from the Environmental Profiles project used.</p> <p>For PU note this covers 90% landfill and 10% incineration of polyurethane which is representative of UK practice.</p>	Data from the Environmental profiles project used.

* Note that within this project there was neither time nor budget to update all the underlying LCA models supporting the BRE Global Environmental Profiles Database from ecoinvent v1.3. However as the data for other building materials is largely common and the difference between ecoinvent v1.3 and v2.0 is small, this is not considered to be important.

³ Derwent RG, ME Jenkin and SM Saunders , 1996. Photochemical ozone creation potentials for a large number of reactive hydrocarbons under European conditions. Atmospheric Environment 30 (2): 181-199.



- Results are presented using characterised and normalised⁴ data generated by this methodology and for the five environmental impact categories.

Key assumptions and decisions made during the LCA work are:

- Polyurethane (PU) insulation is pentane-blown
- Other materials for the houses are modelled based on data held in the BRE Global Environmental Profile Database. These are generally for 'as consumed' products in the UK
- Characterised data is normalised using the annual impacts of a European citizen (EU15 plus Norway & Switzerland) – this data has been taken directly from those provided by CML in spreadsheet version 2.7 (issued April 2004) which were downloaded from <http://cml.leiden.edu/software/data-cmlia.html>, as integrated by Pre into the Simapro Software (v 2.02 in 2005).
- The modelled constructions are assumed to be the same for all zones studied. Calculation of service life is based on the BRE Global's Environmental Profiles Methodology⁵ and has been used for all climate zones.
- Energy sources for all space heating is natural gas.
- U-values for modelled new build elements are lower (better) than required for English building regulations meaning that the modelled designs use less energy than would be the case for current UK practice. This results in materials having an increased relative importance in overall building impact.

The following sections present the results for each of the three parts of the assessment and discuss the implications of these results; the final section draws conclusions from the work and presents some recommendations for further study.

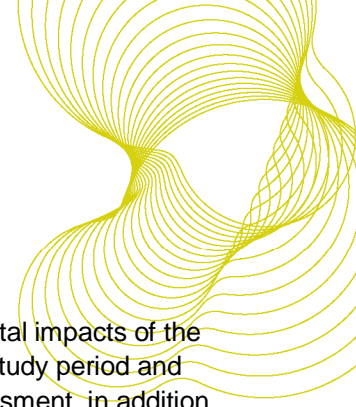
2.2 Part 1 New build LCA

This section presents the normalised and characterised data for the assessment of the following new build specifications:

- Cavity walls with a common U value – PU; stone wool; glass wool, plus extra brick outer leaf, roof & footings for the stone & glass wool options as they will require a thicker wall construction.
- Pitched roof with a common U value – PU; stone wool; glass wool
- Ground floor with a common U value – PU; EPS
- Whole house with common U values – PU (external walls + roof + ground floor + upper floor + windows + energy in use); stone wool (external walls + roof + ground floor with PU + upper floor + windows + energy in use); glass wool (external walls + roof + ground floor with PU + upper floor + windows + energy in use).

⁴ To the annual impacts of a European citizen (EU15 plus Norway & Switzerland).

⁵ More detail is given in BRE Information Paper IP 1/09, Performance and Service Life in the Environmental Profiles Methodology and Green Guide to Specification, IHS BRE Press, 2009.



Assessments a-c were undertaken over a 50-year study period, covering the environmental impacts of the building materials used to build the house, and any maintenance, replacement over the study period and demolition at or after the end of the 50-year study period. For d – the whole house assessment, in addition to the materials assessment above, it also includes the environmental impacts associated with space heating over the 50-year study period, for three climatic zones, Cool Continental, Temperate Oceanic and Temperate Mediterranean.

Cavity wall

The characterised data for the new build cavity walls is presented in Table 1.

Cavity Walls	Characterised				
	Global Warming	Ozone Depletion	Eutrophication	Photochemical Ozone Creation	Acidification for Air and Water
	kg	kg	kg	kg	kg
Wall materials (stone & glass wool insulation)	8,730	0.0117	5.71	7.05	55.4
Wall materials (PU insulation)	8,590	0.0116	5.65	6.95	54.4
Extra roof (stone & glass wool insulation) = 3m ²	82	0.000189	0.109	0.219	1.98
Extra foundation (stone & glass wool insulation) = 3m	574	0.000325	0.351	0.254	2.56
Stone wool insulation	2,130	0.000400	1.06	1.05	14.1
Glass wool insulation	1,450	0.000264	0.95	1.05	5.85
PU (pentane blown) insulation	3,830	0.000235	3.3	6.38	22.4
Totals					
Stone wool total (materials + insulation)	11,516	0.0126	7.23	8.57	74.1
Glass wool total (materials + insulation)	10,836	0.0125	7.12	8.58	65.8
PU (pentane) total (materials + insulation)	12,420	0.0118	8.9	13.3	76.9

Table 1 Characterised data for the new build cavity walls.

The data from Table 1 is summarised graphically in Figure 1 below.

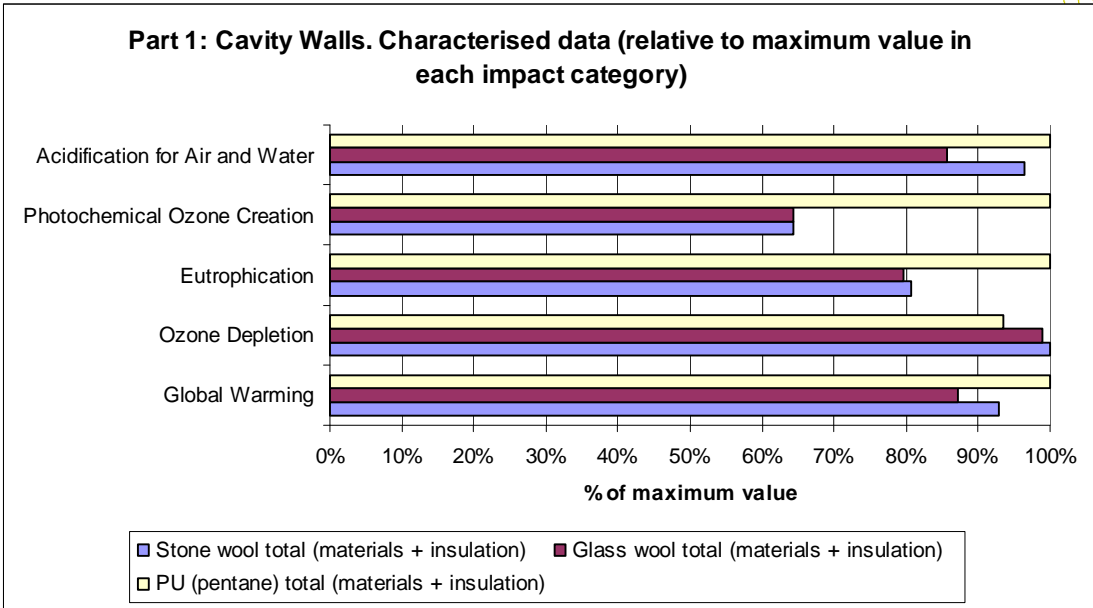
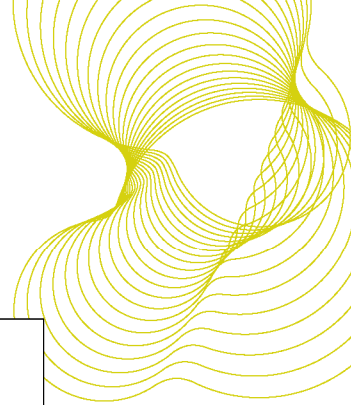


Figure 1 Part 1 Cavity wall with glass wool, stone wool or PU insulation (characterised).

The results in Figure 1 are the characterised data expressed as a proportion of the maximum impact in each category. The results show that the PU design had the highest impacts in four of the categories; the exception being Ozone Depletion, where the stone wool design had the greatest impact and the PU design the least.

The data in Table 1 indicate that the stone wool and glass wool options were 64 to 96% of the level of impacts found for the PU design in Global Warming, Eutrophication, Photochemical Ozone Creation and Acidification for Air and Water; the greatest difference being in the Photochemical Ozone Creation category. The least difference between the impacts was in the categories of Global Warming and Acidification for Air and Water. For Ozone Depletion, the glass wool design was 1% lower than the stone wool design and the PU was 7% less than the glass wool design’s impact.

The insulations accounted for only 2 to 3% of their design’s Ozone Depletion impact. The stone wool and the glass wool insulations accounted for 9 to 19% of their design’s impacts in the other four categories. The PU insulation accounted for 29 to 48% of its design’s total impact in these other categories, with the proportion being highest in Photochemical Ozone Depletion.

Normalising the data allows the levels of impact in each category to be seen in the context of the background levels of these impact categories. Since normalised data is in the same units⁶ the levels of impact in each category can be compared directly with each other.

⁶ The units are ‘impact per person per year’, so a normalised impact of one equates to the same impact as that caused annually by a single Western European citizen.

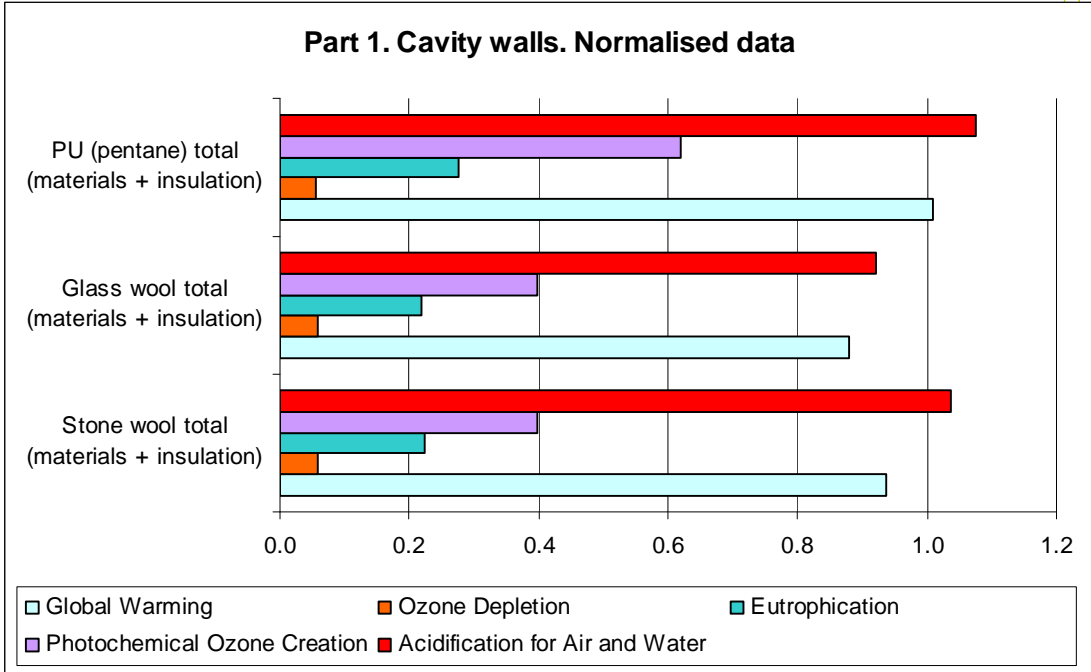
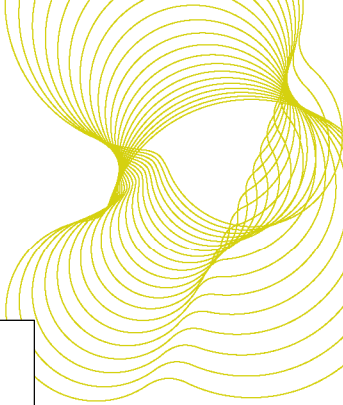
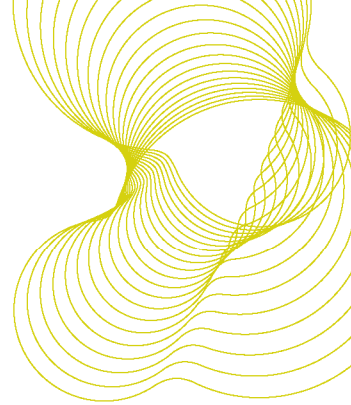


Figure 2 Part 1: Cavity wall with glass wool, stone wool or PU insulation (normalised).

The normalised impacts presented in Figure 2 show that, for all designs studied, Acidification for Air and Water was the highest impact, followed by Global Warming, Photochemical Ozone Creation, Eutrophication and Ozone Depletion.



Pitched roof (insulation on slope)

Appendix 2 describes how the different solutions to achieve the target U-value have been achieved. The characterised results are presented in Table 2.

Pitched Roofs	Characterised				
	Global Warming	Ozone Depletion	Eutrophication	Photochemical Ozone Creation	Acidification for Air and Water
	kg	kg	kg	kg	kg
PU (pentane)	2,360	0.000150	1.99	3.83	13.8
roofing materials (PU)	1,920	0.00332	1.90	4.26	44.2
Stone wool	2,680	0.000502	1.33	1.31	17.8
roofing materials (stone wool)	1,560	0.00410	2.11	4.68	45.6
Glass wool	769	0.000140	0.502	0.56	3.1
roofing materials (glass wool)	1,280	0.00458	2.22	4.91	46.3
Totals					
Stone wool total (materials + insulation)	4,230	0.00460	3.43	5.99	63.3
Glass wool total (materials + insulation)	2,050	0.00472	2.72	5.47	49.4
PU (pentane) total (materials + insulation)	4,280	0.00347	3.89	8.09	58.0

Table 2 Characterised data for the new build pitched roofs.

The results for the total impact of each design presented in Table 2 are shown in Figure 3 below.

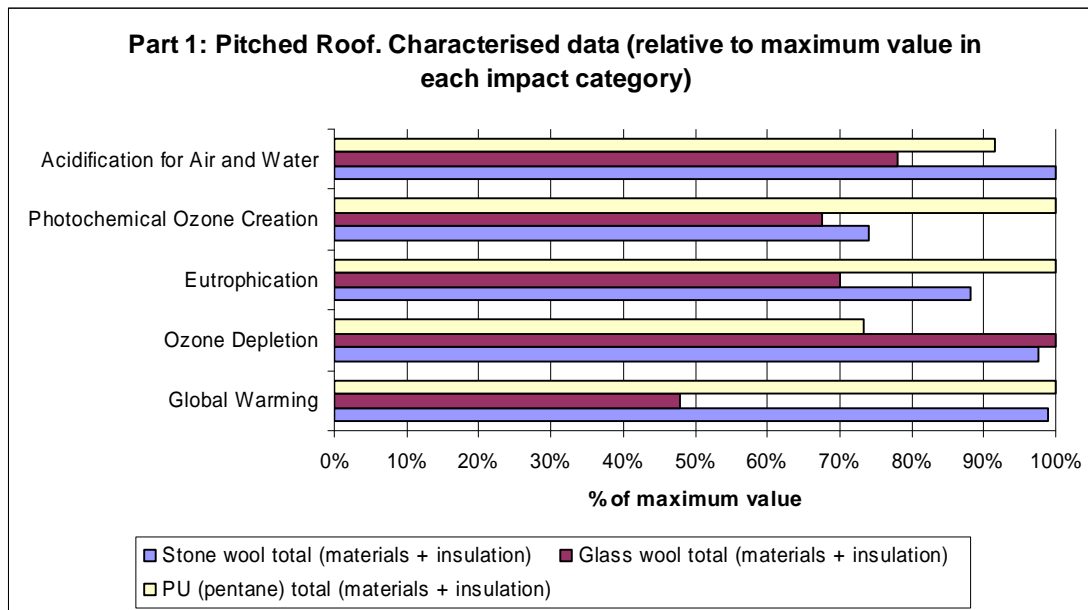
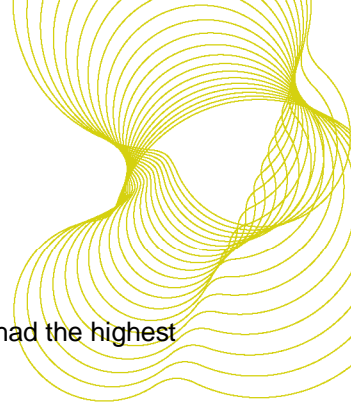


Figure 3 Part 1: pitched roof with PU, stone wool and glass wool insulation (characterised).

The characterised data in Figure 3 shows that the PU solution had the highest impacts in Global Warming, Eutrophication and Photochemical Ozone Creation, second highest in Acidification for Air and Water, and



the lowest in Ozone Depletion. For Acidification for Air and Water, the stone wool design had the highest impact, whereas for Ozone Depletion the glass wool had the greatest impact.

From Table 2, for Eutrophication and Photochemical Ozone Creation, the impacts of the stone wool and glass wool designs were between 68 and 88% those of the PU solution. For Global Warming, the glass wool design's impact was less than half that for both the stone wool and the PU designs, with the impact of the stone wool design only 1% less than the PU solution's impact. The Ozone Depletion of the stone wool design was 3% lower than the glass wool design's impact, and the PU option was 27% less.

The PU insulation accounted for 4% (Ozone Depletion) to 55% (Global Warming) of the impact of the PU design. The stone wool insulation accounted for 11%(Ozone Depletion) to 63% (Global Warming) of its design's impacts and the glass wool insulation represented 3% (Ozone Depletion) to 38% (Global Warming) of its solutions' impacts.

The normalised results are presented in Figure 4 below to compare the impacts of the roofing materials and the insulations.

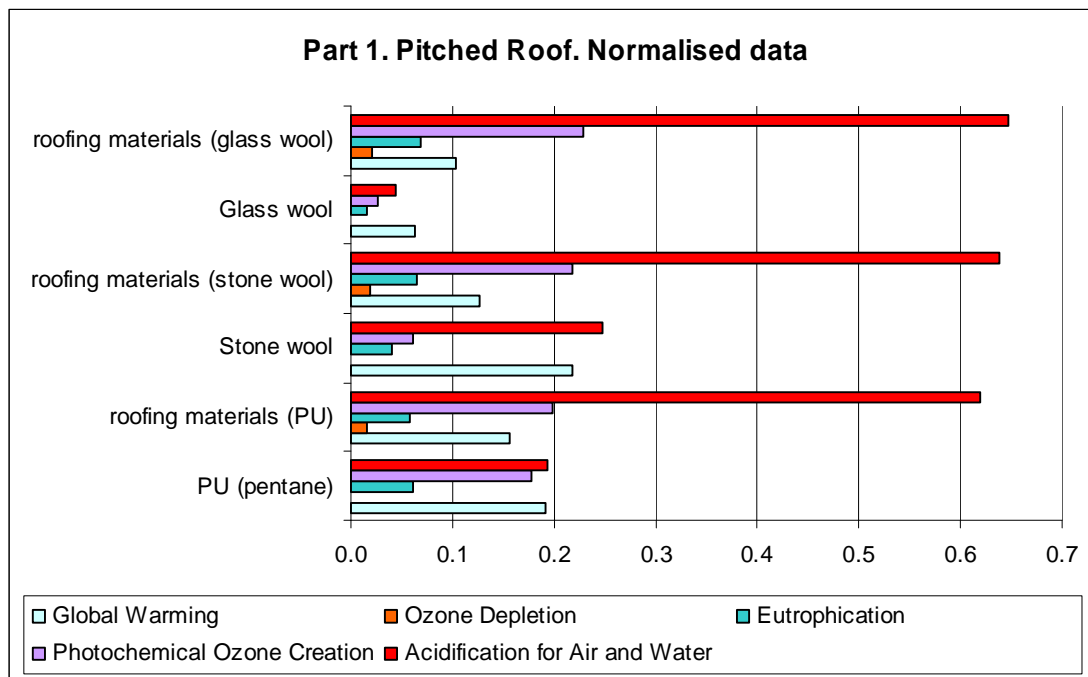
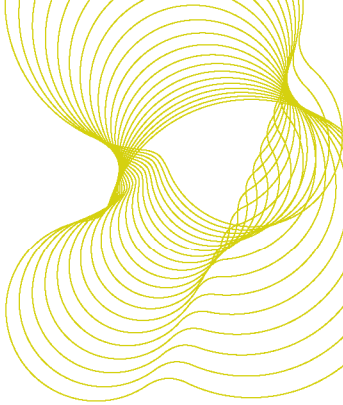


Figure 4 Part 1: pitched roof with PU, stone wool and glass wool insulation (normalised)

The normalised results in Figure 4 show that Acidification for Air and Water was the largest relative impact for the roofing materials for all the designs, and that the impacts in Ozone Depletion were the smallest. The results also show that the Ozone Depletion of the insulations was vanishingly small.

For the glass wool solution, the impacts of the insulation were largest for Global Warming and Acidification for Air and Water but these were much smaller than the impacts of the roof materials. The stone wool also had the largest impacts in Acidification for Air and Water and Global Warming, and, whilst the stone wool was generally of lower impact than the roof materials, the Global Warming of the stone wool was greater than for the roof materials.

For the PU, the insulations' highest impact was in Acidification for Air and Water, closely followed by Global Warming and Photochemical Ozone Creation. The PU insulation had higher impacts than the roof materials for Global Warming, and very similar impacts to the roofing materials for Photochemical Ozone Creation, and Eutrophication.



Ground floor

Appendix 2 describes how the different solutions to achieve the target U-value have been achieved. The characterised data is presented in Table 3.

Ground Floors	Characterised				
	Global Warming	Ozone Depletion	Eutrophication	Photochemical Ozone Creation	Acidification for Air and Water
	kg	kg	kg	kg	kg
Ground floor materials	5,280	0.00230	2.98	2.14	23.1
PU (pentane)	763	0.0000484	0.65	1.24	4.48
EPS	839	0.0000646	0.266	1.80	2.98
Totals					
PU (pentane) total (materials + insulation)	6,040	0.00235	3.62	3.38	27.5
EPS (pentane) total (materials + insulation)	6,120	0.00236	3.24	3.94	26.0

Table 3 Characterised data for the new build ground floors insulated with PU and EPS.

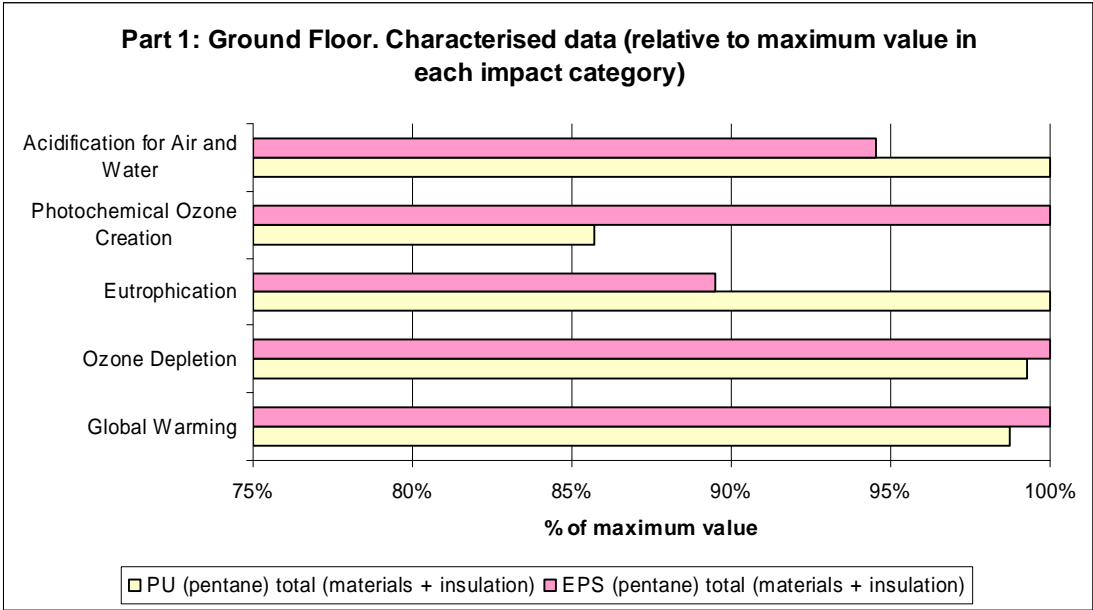


Figure 5 Part 1. Ground floor with PU or EPS insulation (characterised).

The characterised data in Figure 5 shows that the impacts of the PU solution were greater for Eutrophication and Acidification for Air and Water but the EPS design's impacts were greater for Global Warming, Ozone Depletion and Photochemical Ozone Creation. From Table 3, the PU insulation was responsible for 2% (Ozone Depletion) to 37% (Photochemical Ozone Creation) of its solution's impacts. The EPS was the source of 3% (Ozone Depletion) to 46% (Photochemical Ozone Creation) of its design's impacts.

The normalised results are set out in Figure 6 below.

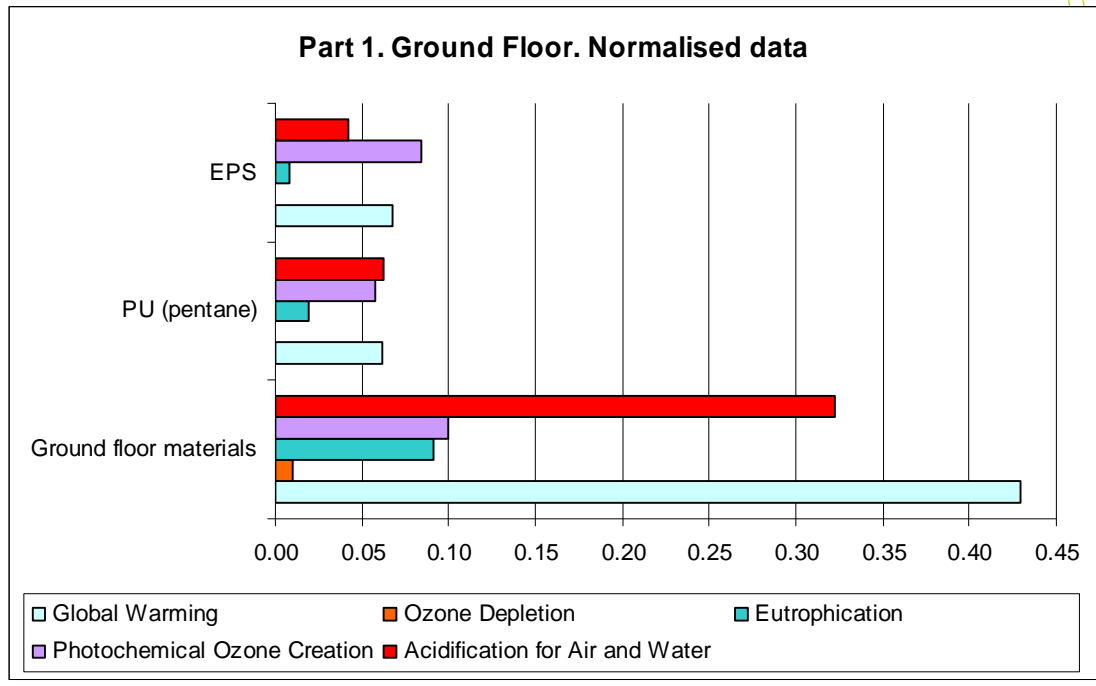
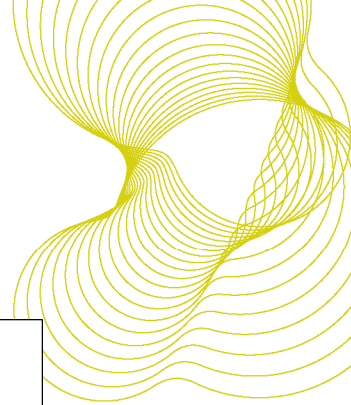


Figure 6 Part 1: ground floor with PU or EPS insulation (normalised).

Figure 6 indicates that the ground floor materials, which are common to both solutions, had higher impacts in all categories than the insulations. Both insulations' impacts were highest in Photochemical Ozone Creation, Acidification for Air and Water and Global Warming. Ozone Depletion is again shown to be a relatively small impact for both insulations and the designs containing each of them.

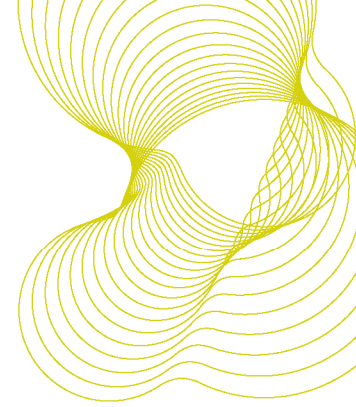
Whole house models

The three whole house models have been put together using the results from the assessments of the external walls, the pitched roofs and the PU ground floor in combination with an upper floor of timber I-joists with the same area as the ground floor and double glazed softwood windows according to the amount in the 3-bedroom house model.

The models have assumed that the same insulation is used in the external walls and the pitched roof. The PU ground floor was used for all as it was, marginally, the worst-case scenario assessed.

The energy source has been assumed to be natural gas for all climate zones: energy use is that for space heating and not the provision of energy necessary for lighting, cooking, refrigeration, entertainment etc.

Appendix 2 describes how the different solutions to achieve the target U-value have been achieved.



Model 1: PU insulation

The characterised data is presented in Table 4.

Model 1	Characterised				
	Global Warming	Ozone Depletion	Eutrophication	Photochemical Ozone Creation	Acidification for Air and Water
	kg	kg	kg	kg	kg
Wall materials (PU insulation)	8,590	0.0116	5.65	6.95	54.4
PU (pentane blown) insulation	3,830	0.000235	3.30	6.38	22.4
roof materials	1,920	0.00332	1.90	4.26	44.2
PU (pentane)	2,360	0.000150	1.99	3.83	13.8
Ground floor materials	5,280	0.00230	2.98	2.14	23.1
PU (pentane)	763	0.0000484	0.65	1.24	4.48
Upper floor (timber I-joint with chipboard plus plasterboard ceiling below)	293	0.00133	1.25	1.63	22.5
Window (preservative treated, painted softwood, high quality, double glazed)	3,460	0.00670	3.57	20.60	30.2
Totals					
<i>Total for non-insulation materials</i>	<i>19,543</i>	<i>0.0252</i>	<i>15.3</i>	<i>35.6</i>	<i>174</i>
<i>Total for insulation</i>	<i>6,953</i>	<i>0.000433</i>	<i>5.9</i>	<i>11.5</i>	<i>40.8</i>
<i>Grand total (materials + insulation)</i>	<i>26,496</i>	<i>0.0257</i>	<i>21.3</i>	<i>47.0</i>	<i>215</i>
Energy					
Temperate Oceanic	61,200	0.0080	5.25	14.1	56.6
Temperate Mediterranean	50,000	0.0065	4.28	11.5	46.2
Cool Continental	145,000	0.0189	12.42	33.4	134

Table 4 Characterised data for Part 1, new build: whole house model with PU insulation.

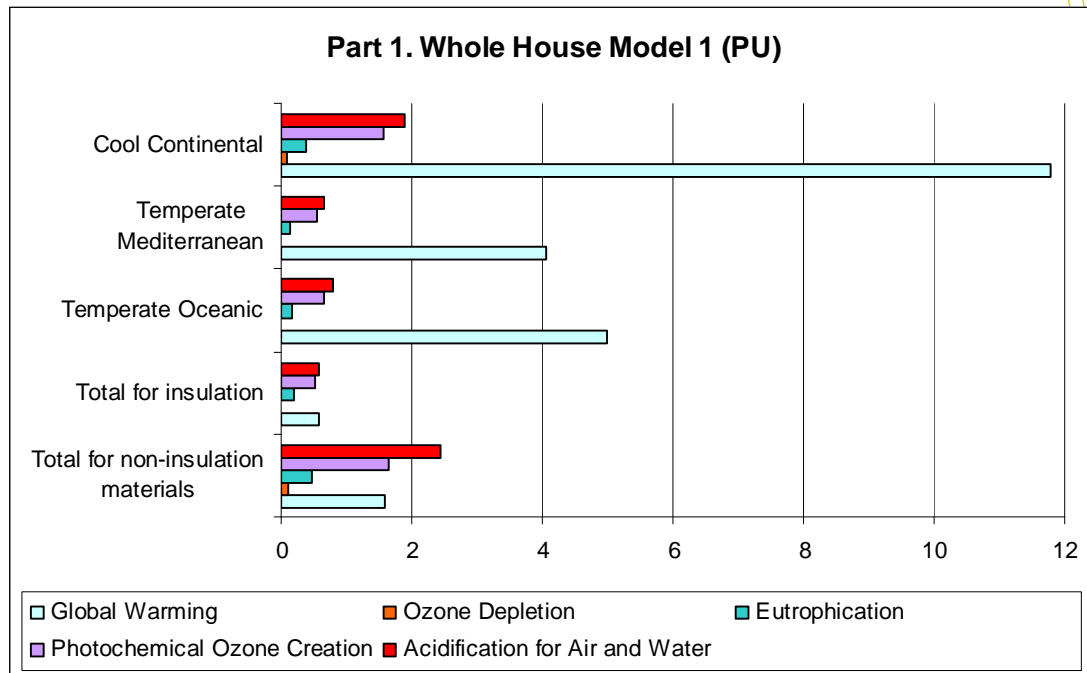


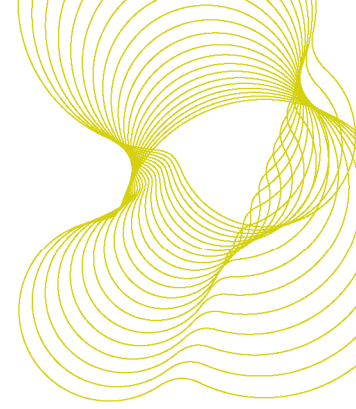
Figure 7 Part 1 New build whole house model: PU insulation (normalised).

Figure 7 shows that the energy use in all 3 climate zones give the greatest level of Global Warming impact. However, the materials (including the insulation) had higher impacts in Eutrophication, Photochemical Ozone Creation, Acidification for Air and Water and Ozone Depletion for all the climate zones. These results are as expected since natural gas use is not a high contributor to Eutrophication, Ozone Depletion or Acidification for Air and Water.

For Global Warming, the insulation was the source of 26% of the overall materials impact, with the overall materials impact causing 30% (Temperate Oceanic, TO), 35% (Temperate Mediterranean, TM) and 15% (Cool Continental, CC) of the total impact. This finding indicates how the relative importance of the environmental impact of the building's fabric increases as the level of insulation rises and operational heating energy decreases.

The materials were responsible for 58 to 83% of the impacts in Ozone Depletion, Eutrophication, Photochemical Ozone Creation and Acidification for Air and Water.

As expected, in the coldest climate (CC), the impact of energy use was highest.



Model 2: Stone wool insulation

Table 5 presents the characterised data for Model 2

Model 2	Characterised				
	Global Warming	Ozone Depletion	Eutrophication	Photochemical Ozone Creation	Acidification for Air and Water
	kg	kg	kg	kg	kg
Wall materials (stone & glass wool insulation)	8,730	0.0117	5.71	7.05	55.4
Stone wool insulation	2,130	0.000400	1.06	1.05	14.1
Extra roof (stone & glass wool insulation) = 3m ²	82	0.000189	0.109	0.219	1.98
Extra foundation (stone & glass wool insulation) = 3m	574	0.000325	0.351	0.254	2.56
roof materials	1,920	0.00332	1.90	4.26	44.2
Stone wool	2,680	0.000502	1.33	1.31	17.8
Ground floor materials	5,280	0.00230	2.98	2.14	23.1
PU (pentane)	763	0.0000484	0.65	1.24	4.48
Upper floor (timber I-joint with chipboard plus plasterboard ceiling below)	293	0.00133	1.25	1.63	22.5
Window (preservative treated, painted softwood, high quality, double glazed)	3,460	0.00670	3.57	20.60	30.2
Totals					
<i>Total for non-insulation materials</i>	20,339	0.0259	15.9	36.2	180
<i>Total for insulation</i>	5,573	0.000950	3.0	3.6	36.4
<i>Grand total (materials + insulation)</i>	25,912	0.0269	18.9	39.8	216
Energy					
Temperate Oceanic	61,200	0.00798	5.25	14.1	56.6
Temperate Mediterranean	50,000	0.00652	4.28	11.5	46.2
Cool Continental	145,000	0.0189	12.4	33.4	134

Table 5 Characterised data for Part 1, new build: whole house model with stone wool insulation

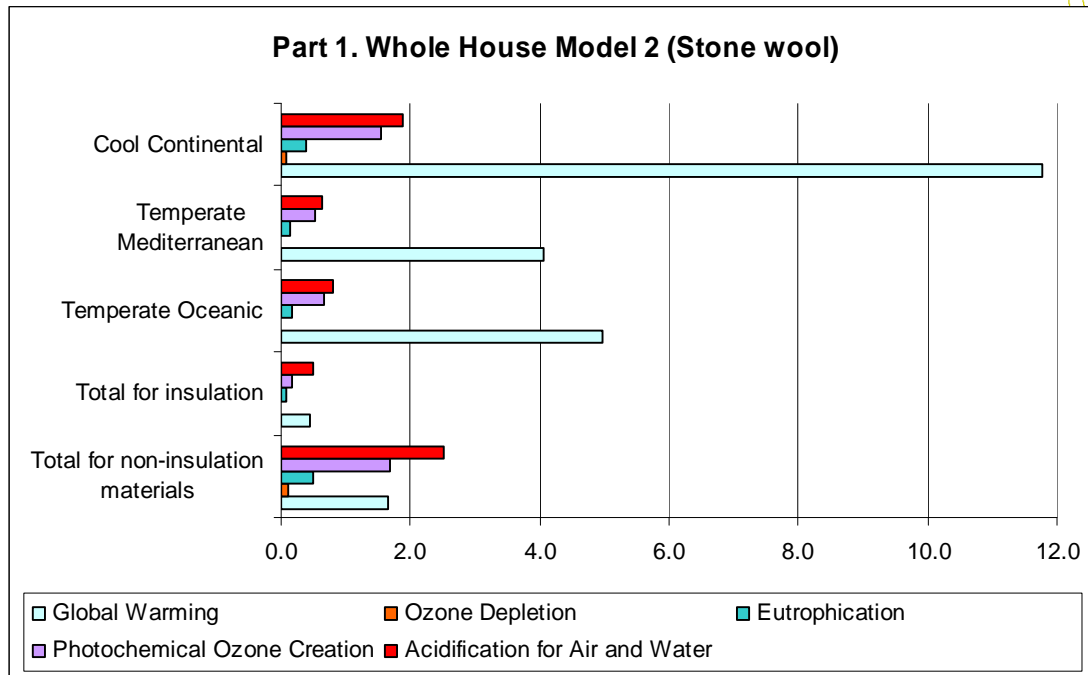
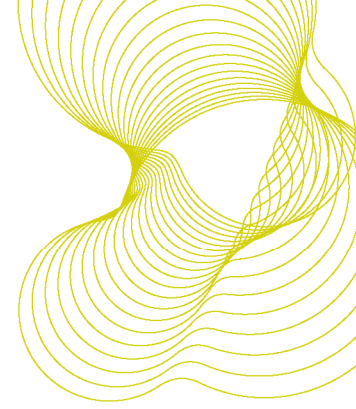


Figure 8 Part 1 new build whole house model: stone wool insulation (normalised).

The results in Figure 8 again show that energy use had the greatest impact in Global Warming but that the fabric and insulation were the greatest source of Eutrophication, Photochemical Ozone Creation, Acidification for Air and Water and Ozone Depletion for all climate zones.

For Global Warming, the insulation accounted for 22% of the overall materials impact, with the overall materials impact contributing 30% (TO), 35% (TM) and 16% (CC) of the total impact. The materials were the source of 56 to 92% of the total impacts in the remaining four categories.



Model 3: Glass wool insulation

Table 6 presents the characterised data for Model 3:

Model 3	Characterised				
	Global Warming	Ozone Depletion	Eutrophication	Photochemical Ozone Creation	Acidification for Air and Water
	kg	kg	kg	kg	kg
Wall materials (stone & glass wool insulation)	8,730	0.0117	5.71	7.05	55.4
Glass wool insulation	1,450	0.000264	0.947	1.05	5.85
Extra roof (stone & glass wool insulation) = 3m ²	82	0.000189	0.109	0.219	1.98
Extra foundation (stone & glass wool insulation) = 3m	574	0.000325	0.351	0.254	2.56
roof materials	1,920	0.00332	1.90	4.26	44.2
Glass wool	769	0.000140	0.502	0.557	3.10
Ground floor materials	5,280	0.00230	2.98	2.14	23.1
PU (pentane)	763	0.0000484	0.65	1.24	4.48
Upper floor (timber I-joint with chipboard plus plasterboard ceiling below)	293	0.00133	1.25	1.63	22.5
Window (preservative treated, painted softwood, high quality, double glazed)	3,460	0.00670	3.57	20.60	30.2
Total					
<i>Total for non-insulation materials</i>	20,339	0.0259	15.9	36.2	180
<i>Total for insulation</i>	2,982	0.000453	2.09	2.85	13.4
<i>Grand total (materials + insulation)</i>	23,321	0.0264	18.0	39.0	193
Energy					
Temperate Oceanic	61,200	0.00798	5.25	14.1	56.6
Temperate Mediterranean	50,000	0.00652	4.28	11.5	46.2
Cool Continental	145,000	0.0189	12.4	33.4	134

Table 6 Characterised data for Part 1, new build: whole house model with glass wool insulation

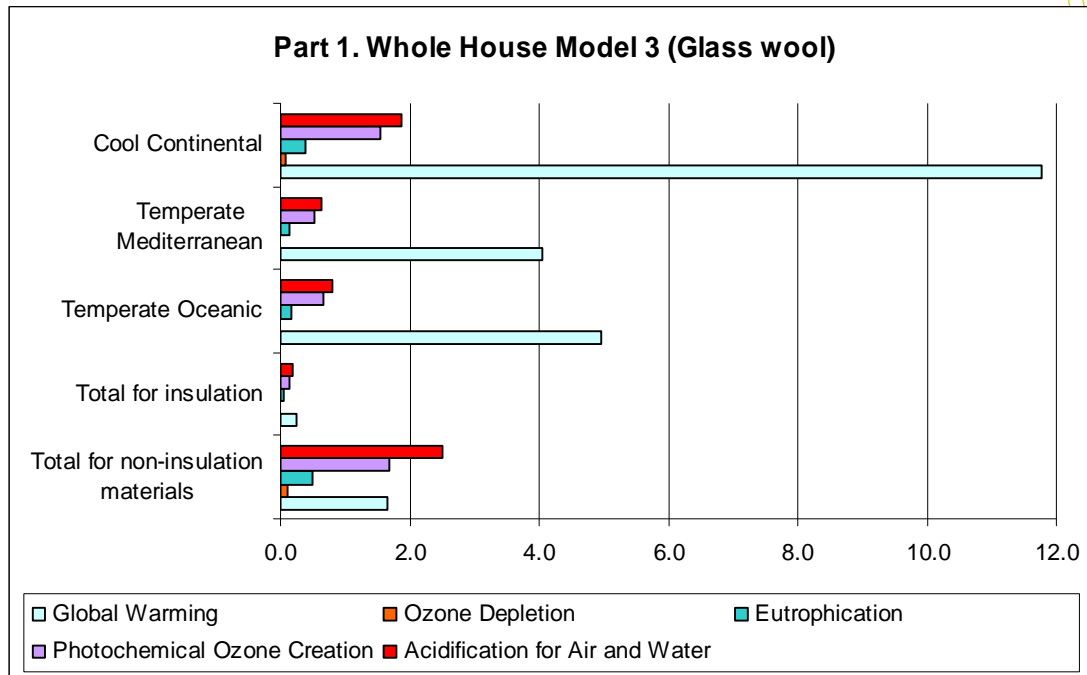


Figure 9 Part 1, new build whole house model: glass wool insulation (normalised).

As for Models 1 and 2, the greatest amount of Global Warming was for the energy consumption in Model 3 for all climate zones. Again the total material impact was higher than the energy impact for Eutrophication, Photochemical Ozone Creation, Acidification for Air and Water and Ozone Depletion.

The insulation accounted for 13% of the total materials Global Warming impact. Overall materials were the source of 31% (TO), 36% (TM) and 16% (CC) total Global Warming impact. Materials were responsible for 57 to 96% of the total impact in the other four categories.

The following graphs present the characterised data for the three whole house models for each individual impact category.

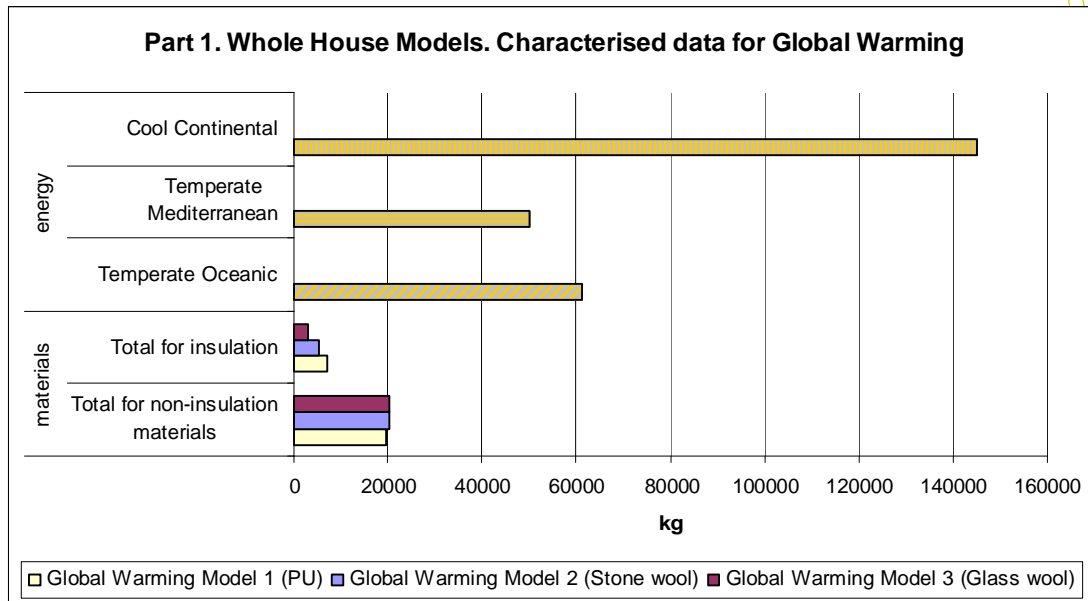


Figure 10. Part 1. Whole house models - Global Warming, kg CO₂ eq. (100 years) (characterised).

For each climatic zone, the energy use modelled for all three insulation options is the same, as the elements have common U values. The characterised Global Warming results in Figure 10 comparing the three whole house models show that the non-insulation materials' impact was lowest for the PU house (Model 1) but the impact of the PU insulation was larger than for either stone wool or glass wool.

The results also show that the building's materials were responsible for around one third of the total Global Warming impact for the TO and TM climates.

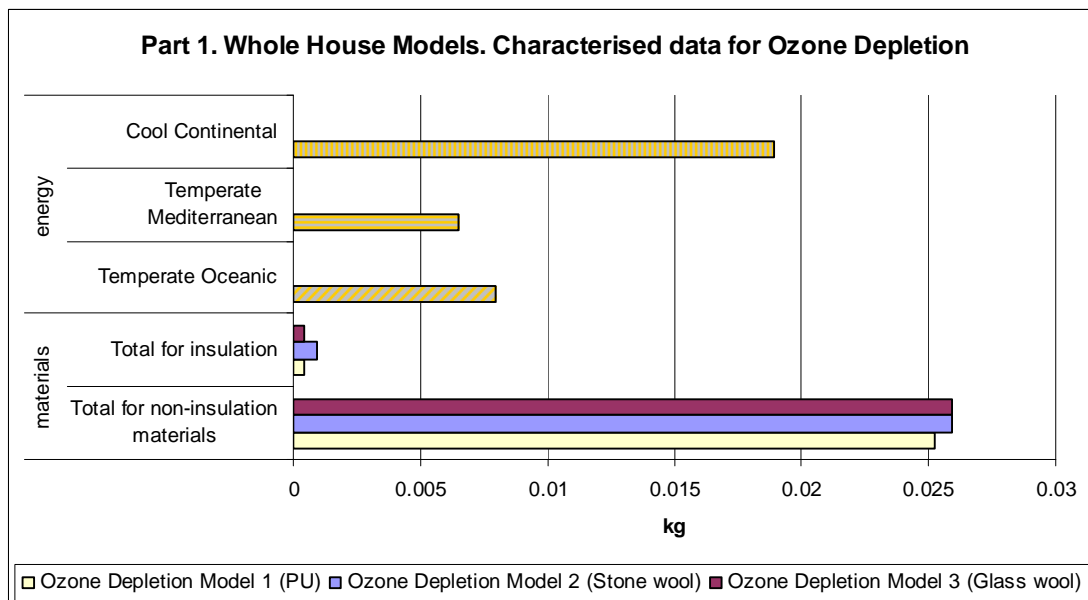
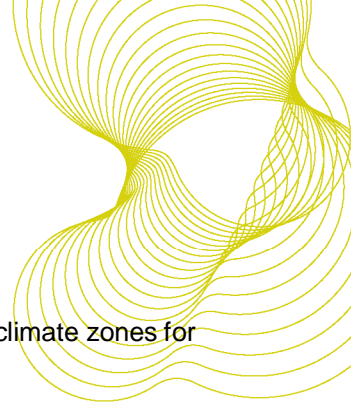


Figure 11. Part 1. Whole house models - Ozone Depletion, kg CFC 11 eq. (characterised)

For each climatic zone, the energy use modelled for all three insulation options is the same, as the elements have common U values. The results in Figure 11 for Ozone Depletion show that both the insulation and the non-insulation material impacts for Model 1 (PU) were lower than those for stone wool or



glass wool. The combined materials impact was greater than that from energy use for all climate zones for all models.

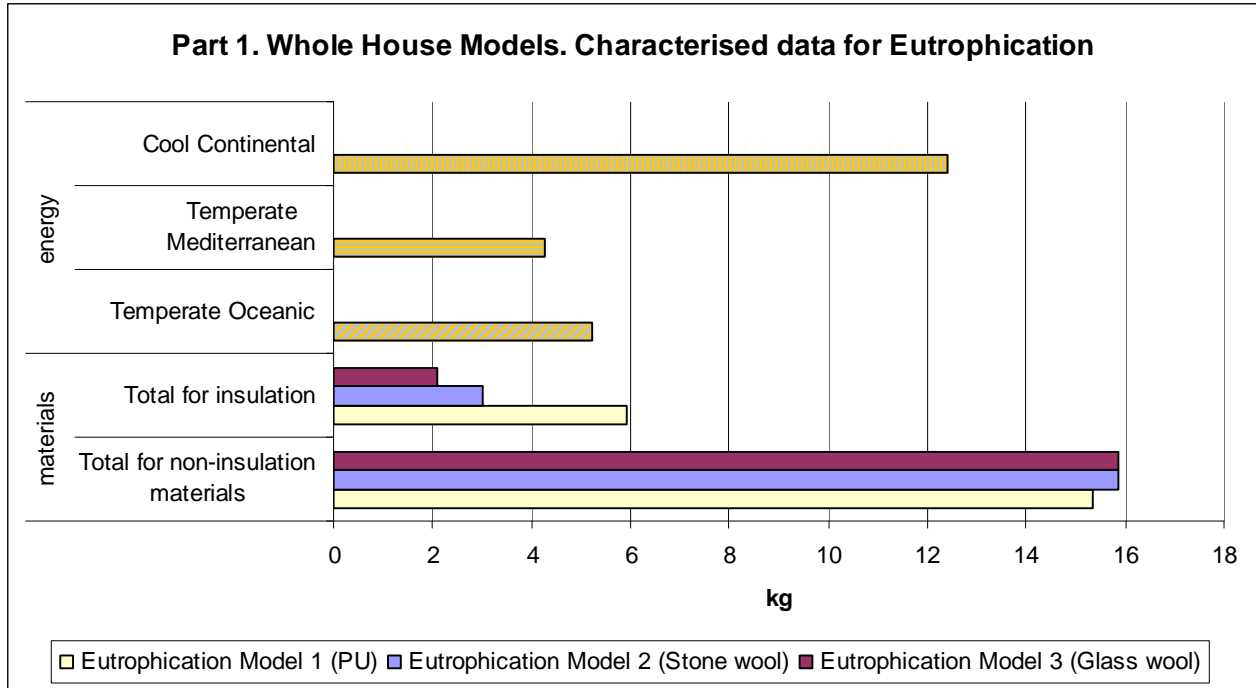


Figure 12. Part 1. Whole house models – Eutrophication, PO₄ eq. (characterised)

For each climatic zone, the energy use modelled for all three insulation options is the same, as the elements have common U values. The results in Figure 12 for Eutrophication, as for Global Warming, show that the non-insulation material impact for Model 1 was lower than for Models 2 and 3 but the impact for the insulation was higher for Model 1 than either Model 2 or 3. The results also show that the overall materials impact was greater than that for energy use for all 3 climate zones.

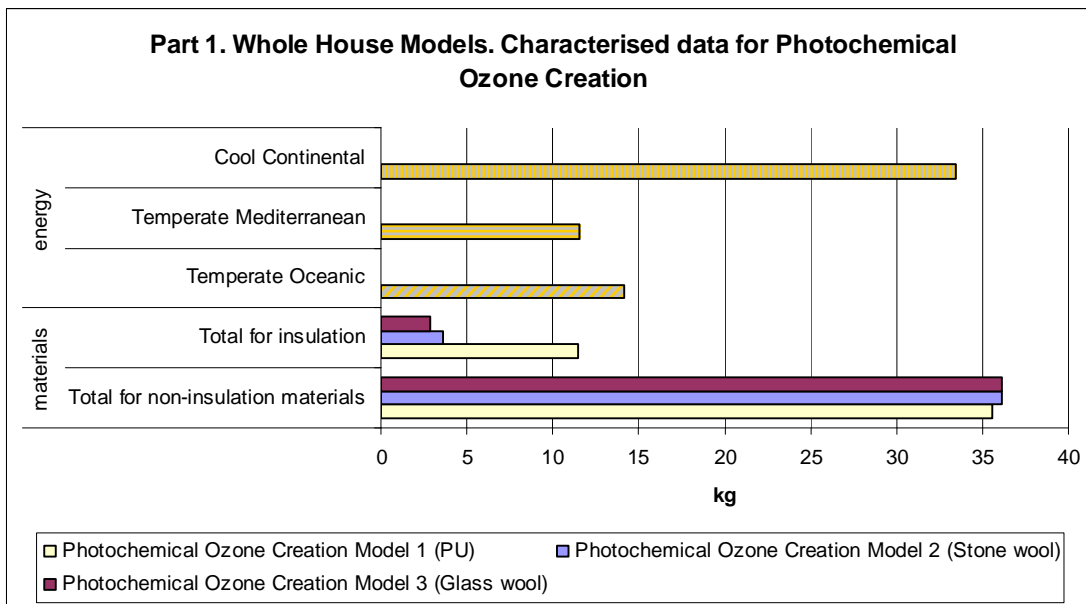
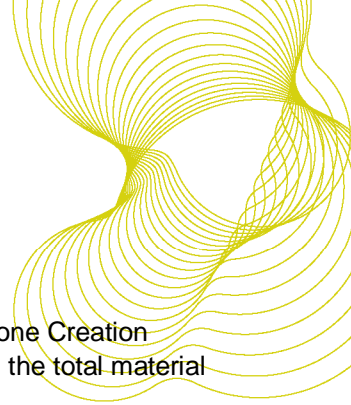


Figure 13. Part 1. Whole house models – Photochemical Ozone Creation, kg C₂H₄ eq. (characterised)



As for Global Warming and Eutrophication, the non-insulation material Photochemical Ozone Creation impacts for Model 1 were lower than those for Models 2 and 3. Also as for Eutrophication, the total material impacts were greater than those for energy for all 3 climate zones.

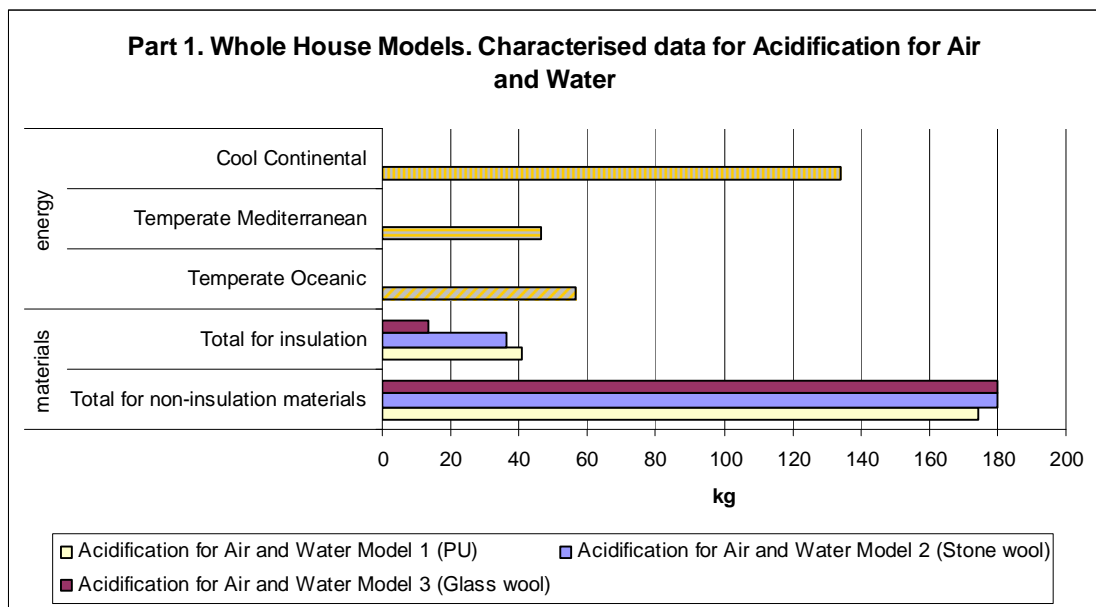


Figure 14. Part 1. Whole house models – Acidification for Air and Water, kg SO₂ eq. (characterised)

For each climatic zone, the energy use modelled for all three insulation options is the same, as the elements have common U values. Once more, the non-insulation material impacts of Model 1 were less than for Models 2 and 3 but the impact of the insulation in Model 1 was greater than for Models 2 and 3. As for Global Warming, Eutrophication and Photochemical Ozone Creation, the total materials impact was greater than that for energy for all 3 climate zones.

Figure 15 below compares the whole house models for all impact categories by expressing the results for each model relative to the maximum in each category.

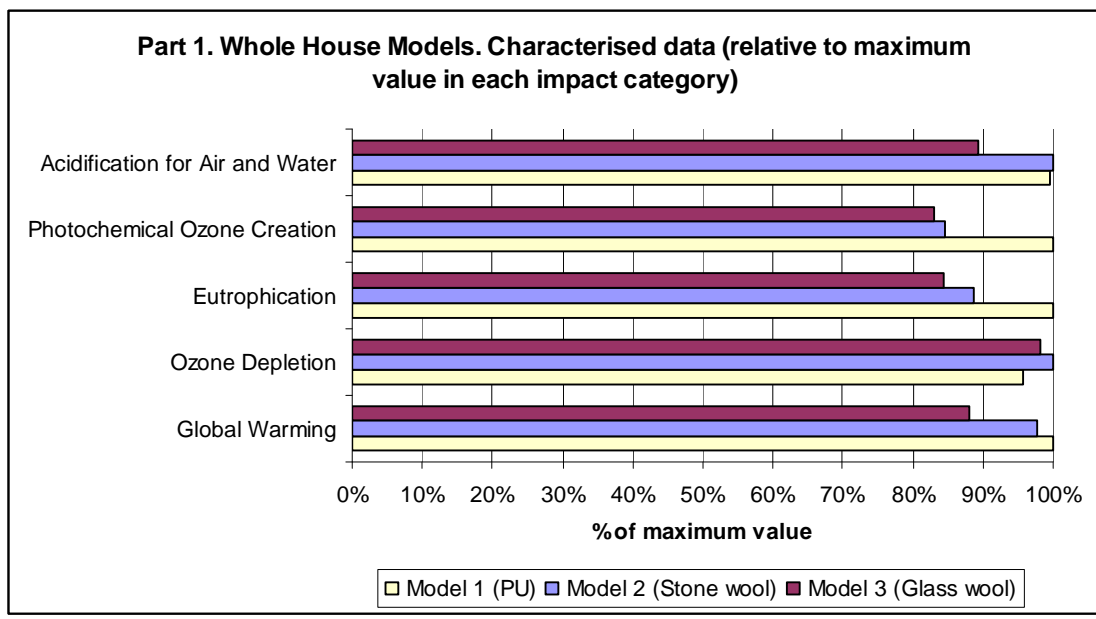
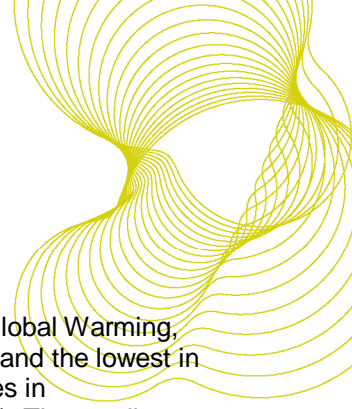


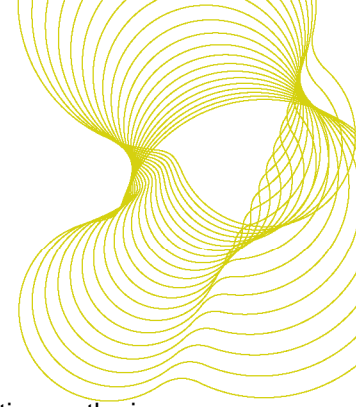
Figure 15 Part 1. Whole house models - material impacts (characterised)



The results in Figure 15 show that the PU design's materials had the greatest impact in Global Warming, Eutrophication & Ozone Depletion, the second highest in Photochemical Ozone Creation and the lowest in Ozone Depletion. The difference was typically more than 10% with the greatest differences in Photochemical Ozone Creation (maximum of 17%) and Eutrophication (maximum of 16%). The smallest difference was in Ozone Depletion (4%).

The results presented in Figures 7 to 9 indicate that Ozone Depletion was relatively small compared to background levels for all models.

Combined, these findings show that the overall performance of the whole house models was broadly similar but that the PU design's materials tended to have greater levels of impact.



2.3 Part 2 Refurbishment: internal lining of existing external walls LCA

This assessment has been done on the basis of the materials needed to install the insulation on the inner face of the external wall; the impacts associated with the existing external wall fabric have not been included. The EPS and PU insulation and plasterboard were installed with plaster adhesive whereas the stone wool and glass wool were installed with timber battens, breather membrane and screws to attach the battens to the external wall and the plasterboard to the battens.

Appendix 2 describes the models used for each solution. Table 7 presents the characterised data for the internal lining assessments.

Internal Lining (refurbishment)	Characterised					
	Global Warming	Ozone Depletion	Eutrophication	Photochemical Ozone Creation	Acidification for Air and Water	
	kg	kg	kg	kg	kg	
Installation materials (PU & EPS)	1,730	0.00162	1.237	2.725	47.905	
PU (pentane)	1,090	0.00007	0.895	1.699	6.432	
EPS	948	0.00007	0.300	2.038	3.361	
Installation materials (stone wool & glass wool)	1,060	0.00160	1.112	2.444	46.317	
Stone wool	337	0.00006	0.167	0.165	2.235	
Glass wool	323	0.00006	0.211	0.234	1.305	
Totals						
Stone wool total (materials + insulation)	1,400	0.00166	1.28	2.61	48.6	
Glass wool total (materials + insulation)	1,380	0.00166	1.32	2.68	47.6	
PU (pentane) total (materials + insulation)	2,820	0.00170	2.13	4.42	54.3	
EPS total (materials + insulation)	2,680	0.00170	1.54	4.76	51.3	
Energy Temperate Oceanic	PU	120,000	0.0156	10.3	27.6	111
	Stone wool	135,000	0.0176	11.6	31.1	125
	Glass wool	135,000	0.0176	11.6	31.1	125
	EPS	129,000	0.0168	11.1	29.8	119
Energy Temperate Mediterranean	PU	97,700	0.0127	8.37	22.5	90.4
	Stone wool	110,000	0.0144	9.46	25.5	102
	Glass wool	110,000	0.0144	9.46	25.5	102
	EPS	105,000	0.0138	9.04	24.3	97.6
Energy Cool Continental	PU	252,000	0.0329	21.6	58.2	234
	Stone wool	280,000	0.0365	24.0	64.6	259
	Glass wool	280,000	0.0365	24.0	64.6	259
	EPS	269,000	0.0351	23.1	62.1	249

Table 7 Characterised data for Part 2 Refurbishment lining of external walls with glass wool, stone wool, EPS and PU insulation.

The graphs below present the data from Table 7 in graphical form for comparison purposes.

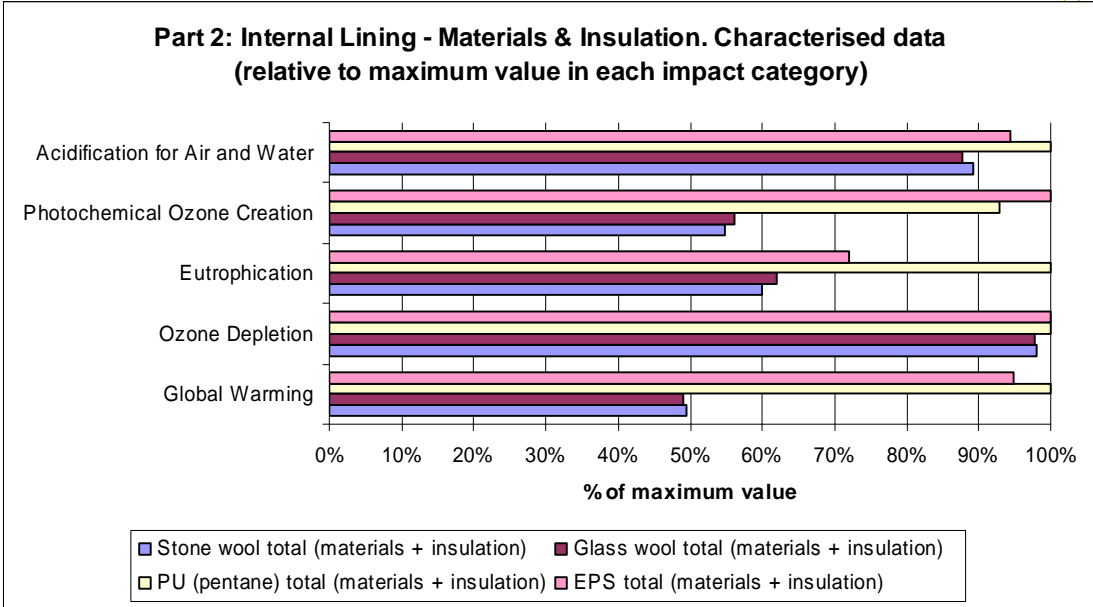
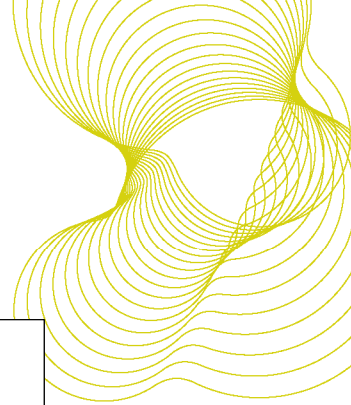
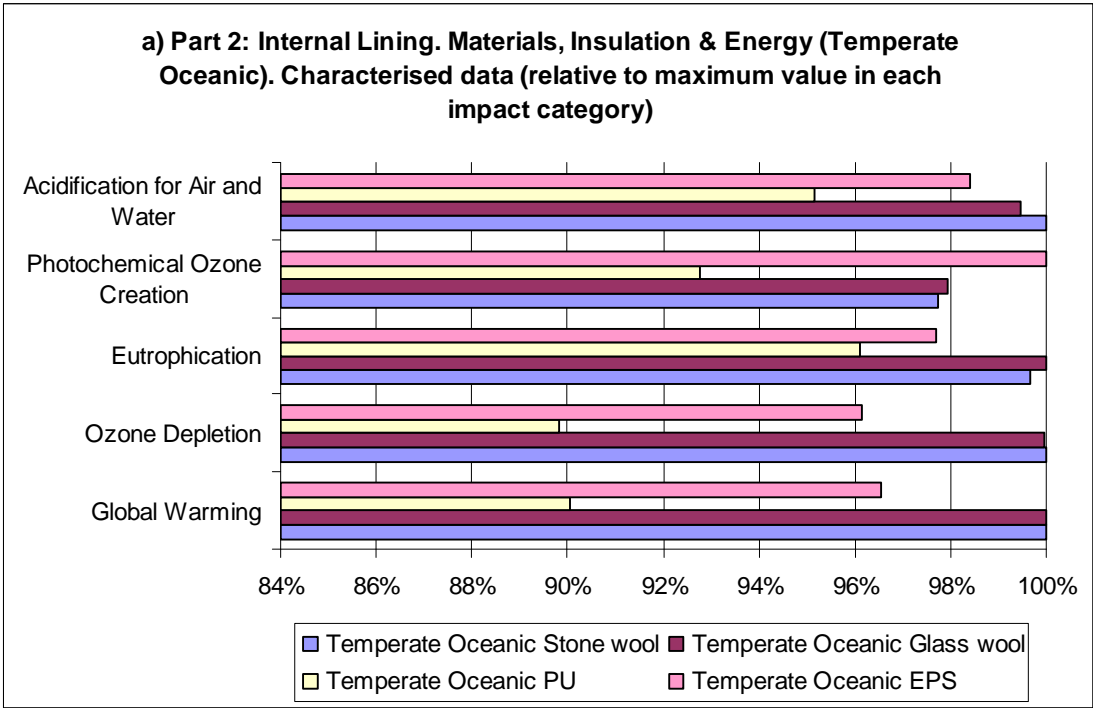


Figure 16 Part 2 Refurbishment of external walls with glass wool, stone wool, EPS and PU: materials only

The characterised results in Figure 16 show that, in terms of materials usage, the PU insulation solution had the greatest level of impact in the Global Warming, Eutrophication, Acidification for Air and Water, and Photochemical Ozone Creation impact categories. The PU design had the second highest impact in Ozone Depletion.

The graph below compares the impacts from the materials to those from the energy in the three climate zones.



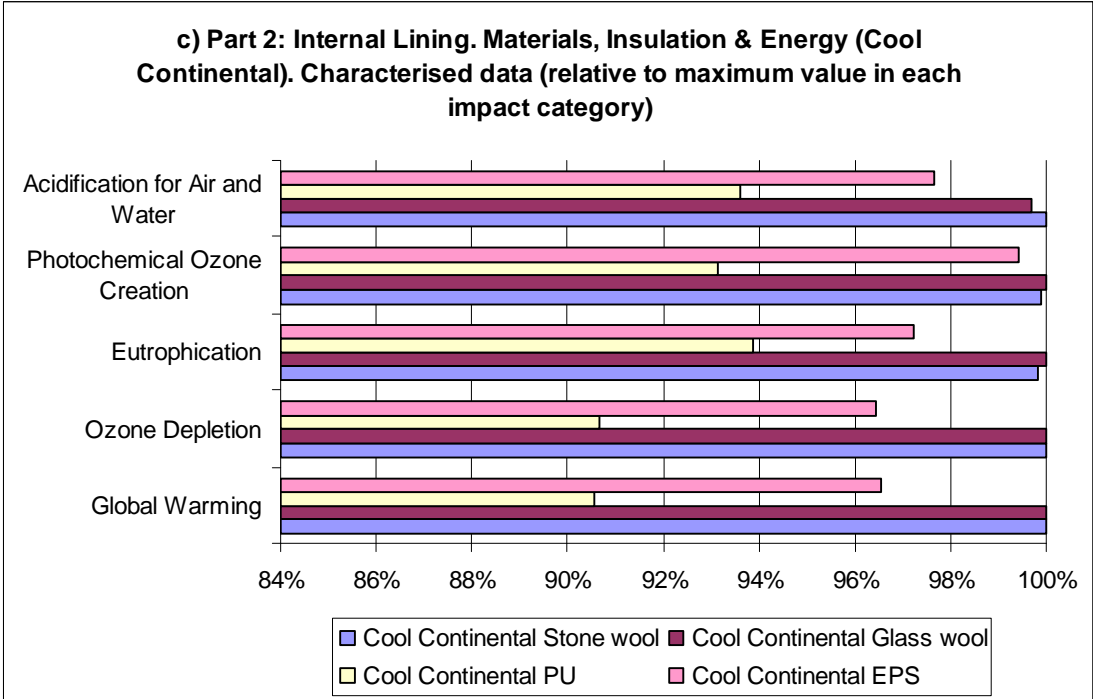
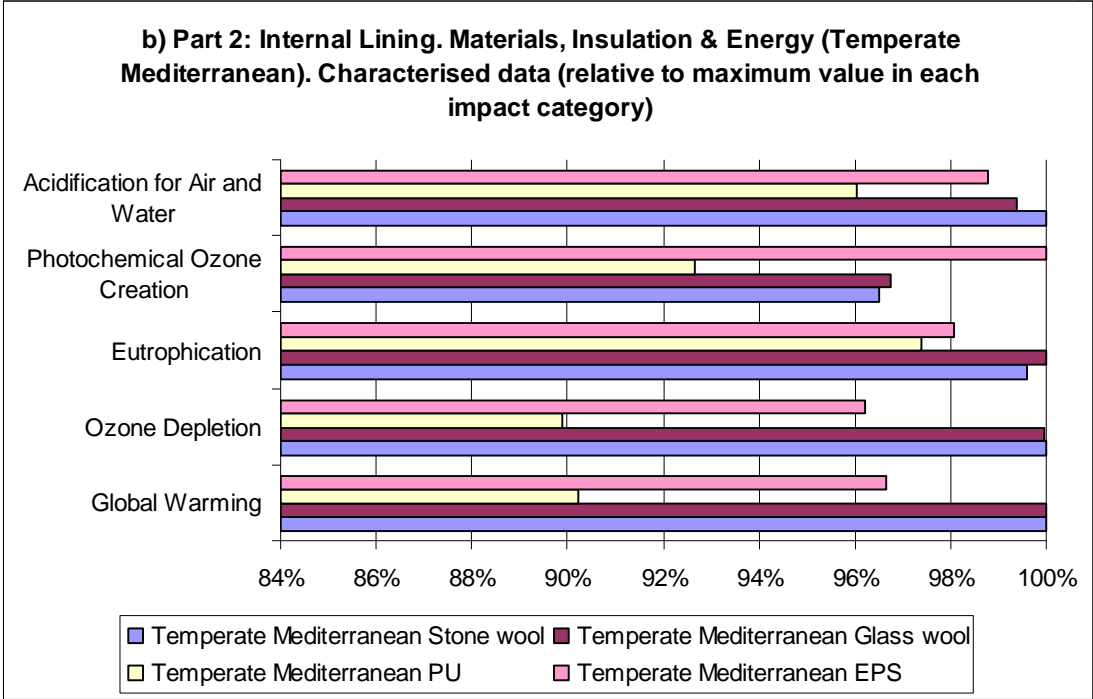
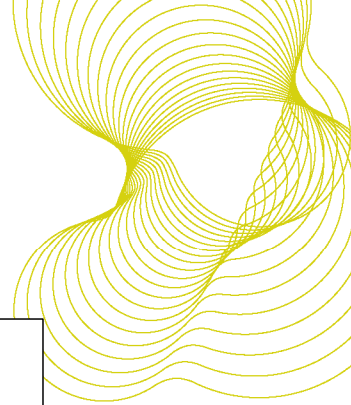
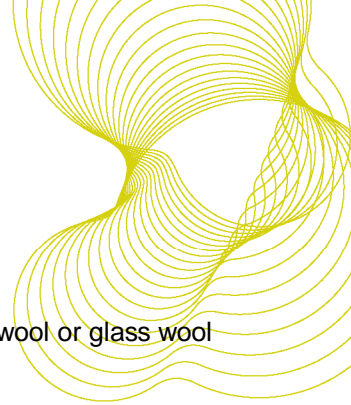
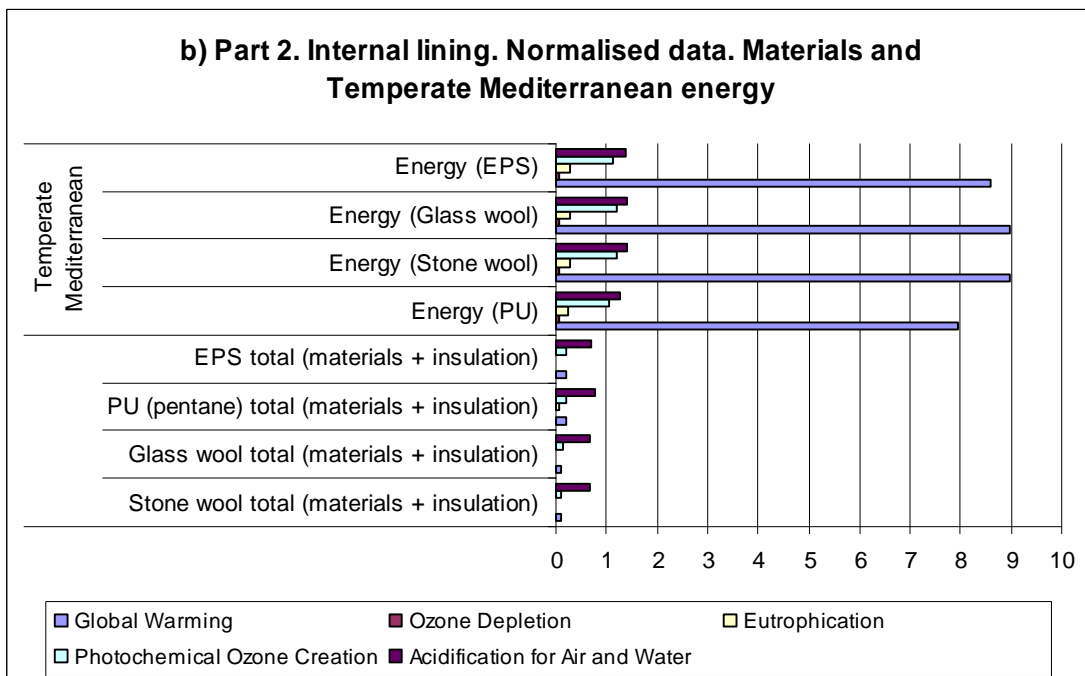
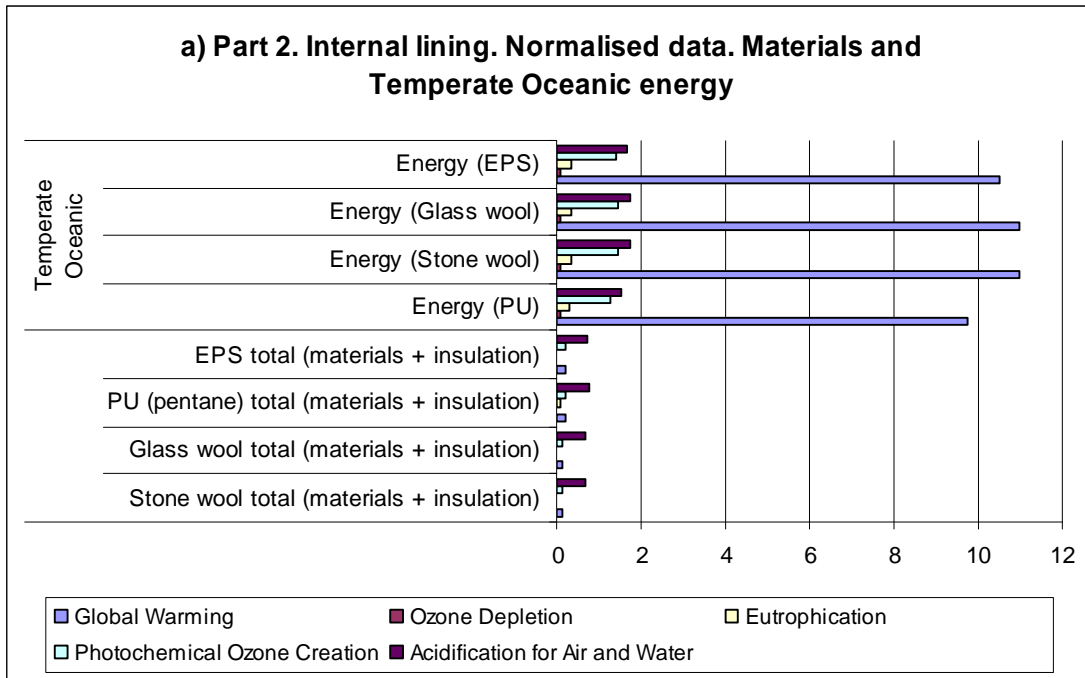


Figure 17 Part 2, refurbishment of external walls with glass wool, stone wool, EPS and PU. Characterised data: a) Temperate Oceanic; b) Temperate Mediterranean, and c) Cool Continental.

The characterised results in Figure 17 a) to c) show that the PU internal lining gave the lowest total impacts of all the solutions in all climate zones.



For Global Warming, overall, the PU design was around 10% lower than either the stone wool or glass wool designs and at least 5% better than the EPS design.



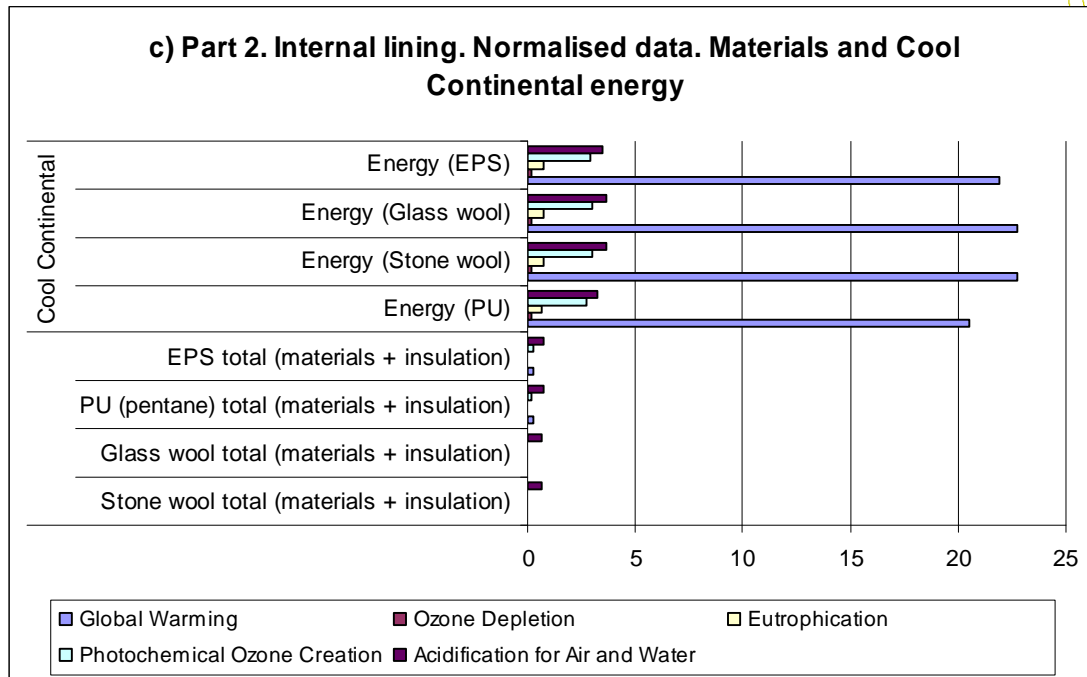
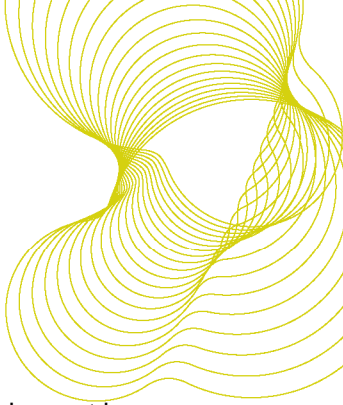


Figure 18 Part 2, refurbishment of external walls with glass wool, stone wool, EPS and PU: a) Temperate Oceanic, b) Temperate Mediterranean, and c) Cool Continental

The normalised results presented in Figure 18 a) to c) indicate that the greatest impact for each of the internal lining options was Acidification for Air and Water. However, the insulation was responsible for only 3% (glass wool), 5% (stone wool), 7% (EPS) and 12% (PU) for this Acidification for Air and Water impact.

The insulations' contribution to Global Warming of the design was higher: 24% for stone wool; 23% for glass wool; 39% for PU and 35% for EPS. The insulations were the source of 4% of the total material Ozone Depletion. For Eutrophication impacts, the PU was the source of 42% of the total material impact and the EPS 20%; stone wool and glass wool were responsible for around 15% of the total. For Photochemical Ozone Creation, the PU and EPS insulations were the cause of around 40% of the total material impacts, whereas the stone wool and glass wool were responsible for less than 10% of the total material impacts.



2.4 Part 3 New warm deck flat roof LCA

Appendix 2 describes the design solutions adopted to achieve the target U-values. Energy has not been modelled as it is assumed to be consistent for all three solutions.

The characterised data for these flat roofs are presented in Table 8.

Flat roof	Characterised				
	Global Warming	Ozone Depletion	Eutrophication	Photochemical Ozone Creation	Acidification for Air and Water
	kg	kg	kg	kg	kg
Flat roof materials	-310	0.00313	1.28	2.31	24.3
PU (pentane)	1,450	0.0000896	1.24	2.40	8.49
Stone wool	2,980	0.000560	1.48	1.46	19.8
EPS	2,310	0.000178	0.731	4.96	8.19
Totals					
<i>Stone wool total (materials + insulation)</i>	<i>2,670</i>	<i>0.00369</i>	<i>2.76</i>	<i>3.78</i>	<i>44.1</i>
<i>PU (pentane) total (materials + insulation)</i>	<i>1,140</i>	<i>0.00322</i>	<i>2.52</i>	<i>4.71</i>	<i>32.8</i>
<i>EPS total (materials + insulation)</i>	<i>2,000</i>	<i>0.00331</i>	<i>2.01</i>	<i>7.28</i>	<i>32.5</i>

Table 8 Characterised data for Part 3, warm deck flat roof with stone wool, EPS and PU insulation.

The following graph summarises the characterised data set out in Table 8.

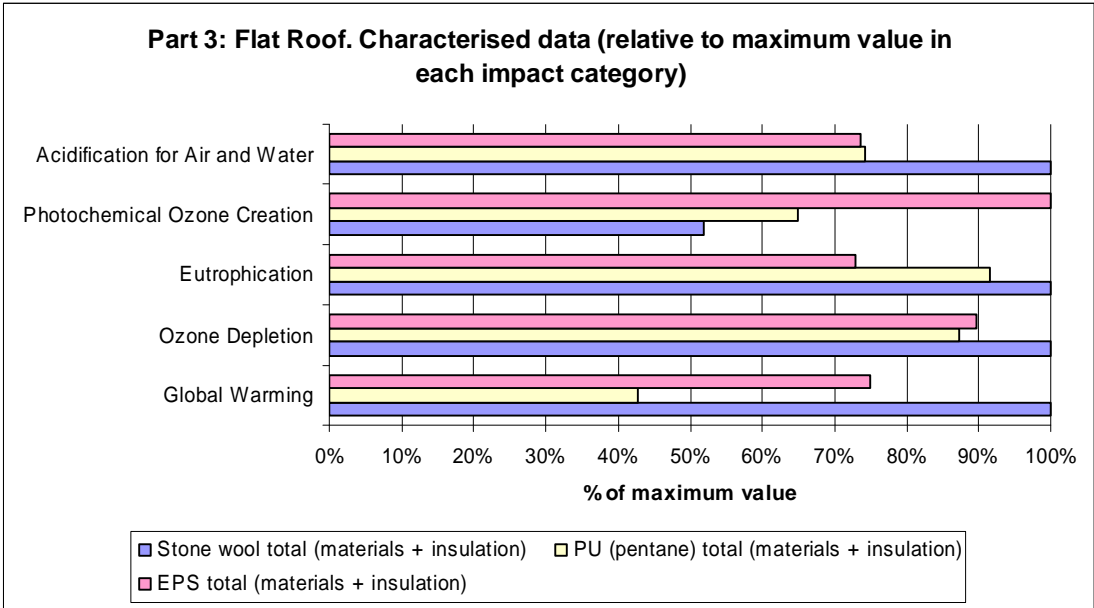


Figure 19. Part 3, warm deck flat roof with stone wool, EPS and PU insulation (characterised).

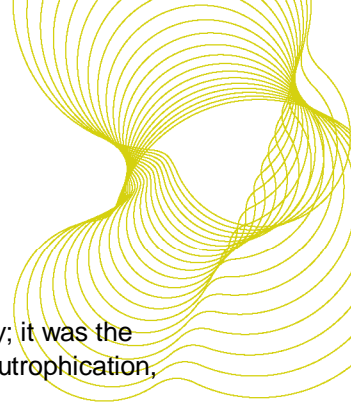


Figure 19 shows that the PU option was never the highest level of impact for any category; it was the lowest for Global Warming and Ozone Depletion. The PU option was second lowest for Eutrophication, Photochemical Ozone Creation and Acidification for Air and Water.

From Table 8, it can be seen that the flat roof materials achieved an overall negative (i.e. beneficial) Global Warming due to the carbon sequestered in the structure’s timber (joists and decking). Consequently, the insulation materials were solely responsible for the damaging Global Warming impacts. The insulations were responsible for 3 to 15% of the overall impacts for Ozone Depletion, and between 25 and 68% of the total Eutrophication, Photochemical Ozone Creation and Acidification for Air and Water.

The graph below shows the normalised impacts of the roofing materials and the insulations in each design.

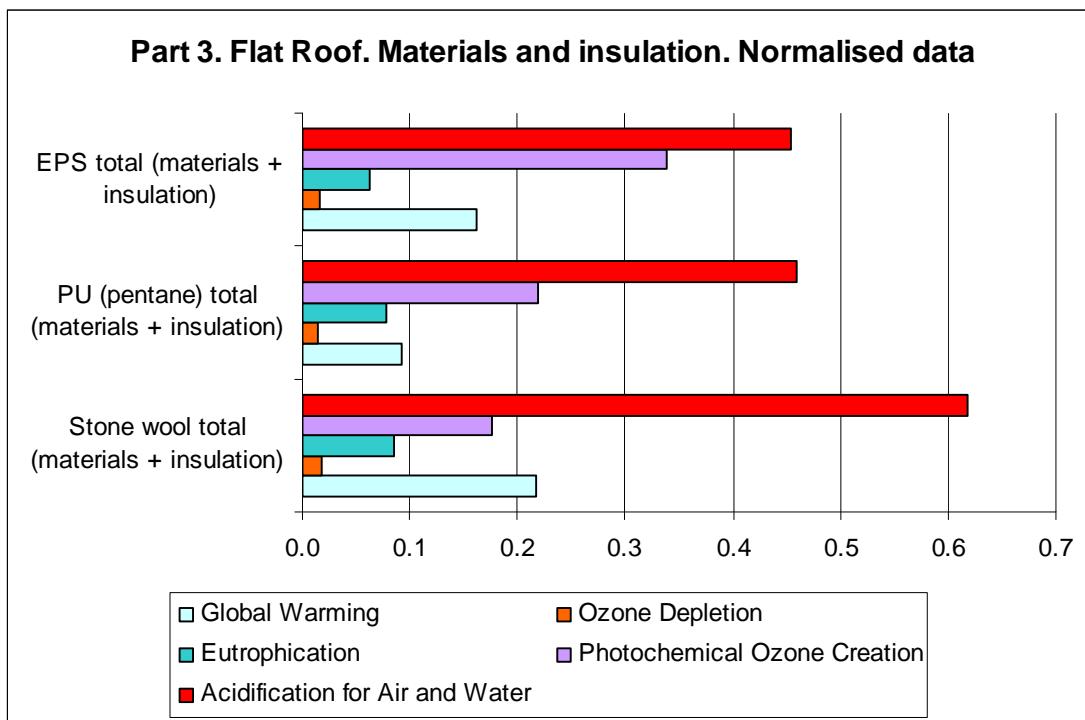


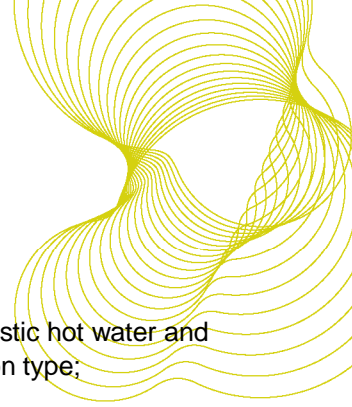
Figure 20 Part 3, warm deck flat roof with stone wool, EPS and PU insulation (normalised).

The normalised data in Figure 20 shows that the Acidification for Air and Water impact category was the largest for all of the solutions, followed by Photochemical Ozone Creation for the PU and EPS, and Global Warming for the stone wool. Ozone Depletion was the smallest relative impact for all solutions.

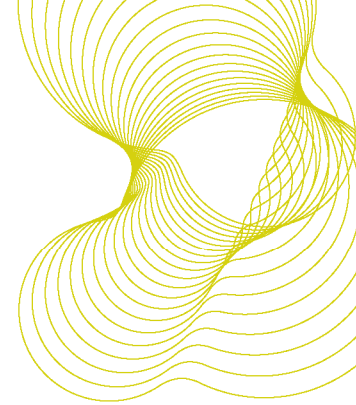
Comments on sensitivity of assumptions

The results presented here are influenced by the assumptions and decisions made during the analysis. The key assumptions that are likely to affect the findings are:

- Polyurethane (PU) insulation is pentane-blown - HFC-blown PU would have much greater environmental impacts;
- The modelled constructions are common and relevant for all climate zones studied;
- Energy source is natural gas;



- Space heating only is modelled; other energy use in the house, for lighting, domestic hot water and other electrical demand is not assumed to alter depending on location or insulation type;
- U-values for modelled new build elements are lower than for English building regulations (i.e. an improvement) meaning that the modelled designs use less energy than would be the case for current UK practice. This results in materials having an increased relative importance in overall building impact. Conversely, for the refurbishment assessment, the U-values of the walls are, with the exception of the PU, much lower than required by English building regulations for refurbishment for change of use (i.e. a deterioration) resulting in greater energy use than would be expected;
- PU insulation is disposed of 90% to landfill and 10% to incineration, based on UK practice. If PU was predominantly incinerated, it would have higher climate change impacts and lower POCP impacts, and slightly lower acidification impacts from disposal.



3 Identification of cost impacts

The purpose of this section of the report is to present the findings of the life cycle cost study undertaken. It provides a brief introduction to life cycle costing, and details the methodology adopted for the study. The results of the study are presented in both graphical and tabular format for ease of interpretation.

3.1 Introduction to LCC

Life cycle costing is a technique to establish the total cost of ownership. It is a structured approach which addresses all the elements of this cost and can be used to produce a spend profile of the asset over its anticipated life-span. The results of life cycle cost analysis can be used to assist in the decision-making process when there is a choice of product and provides the opportunity to optimise the allocation of benefits and costs to achieve “best value”.

For convenience these costs are usually considered under three headings

- Initial Cost
- Operational Costs
- Disposal Costs if applicable

Definition of Life Cycle Costs (LCC)

A life cycle cost is defined in ISO 15686 Part 5⁷ as follows:

- Cost of an asset or its parts throughout its life cycle, while fulfilling the performance requirements

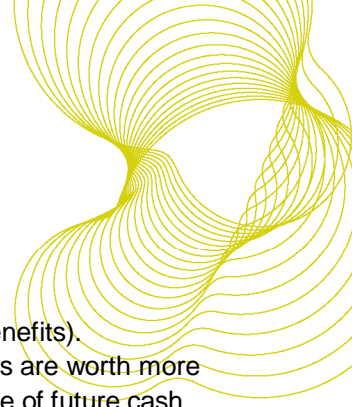
The use of life cycle costing presents a powerful tool to deliver economic sustainability within the construction industry and encourages the use of "Best Value" design solutions.

Life cycle cost modelling provides a *“rationale for choice in circumstances where there are alternative means of achieving a given object and where those alternatives differ not only in their initial costs, but also in subsequent operational costs”* (Seeley, 1996). The purpose of life cycle costing is to improve decisions regarding capital investment and the related future costs required to operate a built asset. It is a tool that can be used by various practitioners to aid the investment decision making process. Life cycle costing techniques aim to optimise decisions on designs, specifications for independent and interdependent building systems so as to ensure initial capital and through life expenditures, which often absorb large amounts of cash, are optimised.

Financial criteria

The LCC analysis requires that year on year cash flows are discounted to reflect the time value of money. The year on year cash flows (periodic money streams that are expected to continue in the future) are discounted to account for the fact that these monies will be worth less in the future than they are today. When the monies are discounted they are expressed as present values.

⁷ ISO 15686-5 2008 Buildings and constructed assets - Service-life planning -Part 5: Life-cycle costing



In order to compute present values, it is necessary to discount future costs (and hence benefits). Discounting reflects the time value of money. As a result of discounting, benefits and costs are worth more if they are experienced sooner. The higher the discount rate, the lower is the present value of future cash flows.

$X / (1+r)^n$ <p><i>When</i></p> <p><i>X = input value</i></p> <p><i>r = rate of interest or discount rate</i></p> <p><i>n = number of years</i></p>
--

Figure 21 Discount equation to allow for the time value of money (HM Treasury 1997)

Assumptions and other considerations

We have identified repair and maintenance activities for each specification, and identified a cost to carry out the task. This cost data has utilised the BMI Building Maintenance Price Book (2009 edition)⁸, Spons or other price books, manufacturers and installers information and BRE data.

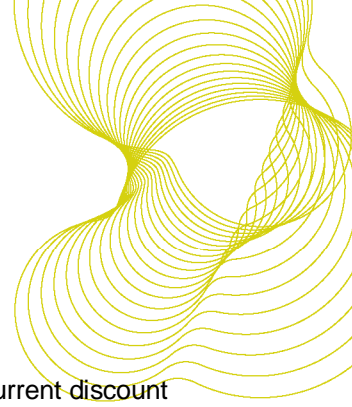
During the 50 year study period, maintenance operations for the elements include internal redecoration, brickwork repointing and replacing single ply roof finish to the flat roof. Costs also have allowances for associated waste, labour, overheads and profit.

Estimated service life

The estimated service lives are taken from BLP Component Life Manual (CLM), which attaches 'insured lives' on an extensive list of components. It is important to note that the Component Life Manual⁹ has a range of insured lives for each component. Generally, the service life of a component can be assumed to be the insured life + 20%. In this study we have referenced the insured life that meets the relevant British Standard, meets our maintenance assumptions, and is either the highest or second highest service life prediction. The publication also highlights the factors that may affect their deterioration or failure. We have compared these with the expected lives as published by the Building Cost Information Service (BCIS) of the Royal Institution of Chartered Surveyors. This publication presents a survey of the life expectancies of common building components. For the purposes of this exercise, we have used the data from the CLM as it appears to provide a realistic average of all the sources available and indicates service lives for all components in the situations in which they are used in excess of 50 years, which is the limit of this study. The exceptions to this are the single ply flat roof membrane and decorations to the plaster or plasterboard finish.

⁸ BCIS, BMI Building Maintenance Price Book: 2009 Edition, Building Cost Information Service

⁹ Building Life Plans Component Life Manual available on line by subscription.



Discount rates used

A discount rate of 3.5%, in real terms, reflects the cost to taxpayers of a loan and is the current discount rate used by the UK Treasury.

The Life Cycle Costs study

The LCC study has been a non-test based assessment on the durability of the building components, based on BRE's own assumptions, and supported by published material where possible.

Cost items considered

The LCC study considers those costs in-use (capital costs of components + installation costs + cost of replacement parts and their installation + maintenance costs) identified by BRE.

The specification for the elements and the cost of all components are intended to represent the typical cost incurred by building owners. The values in the assessment are based on those required for a two storey detached property with a gross internal floor area of 104m².

Setting the study period

The study period is the time over which the LCC model is considered. It should be sufficiently long to ensure that a correct assessment of the long-run economic performance can be made. The study period chosen for this assessment is 50 years, which is considered a long enough time scale to assess the long term economic benefits that may be achieved. The 50 year study period does not assume that the building will be demolished at that point in time but will continue in use.

Capital replacements

If the service life of an element is less than the LCC study period a replacement of this item is necessary. The model assumes planned replacements of component parts when the life expectancy is less than the LCC study period.

Variation in discount rate

The discount rate has been varied to assess the impact on the results of different values. The results of the LCC analysis have been presented for discount rates of 0% and 5% as well as at the base case of 3.5% to show the LCC of the products should the cost of future money flows be different to that assumed. The following graph demonstrates the effect of applying different discount rates on the forecast of a typical future expenditure.

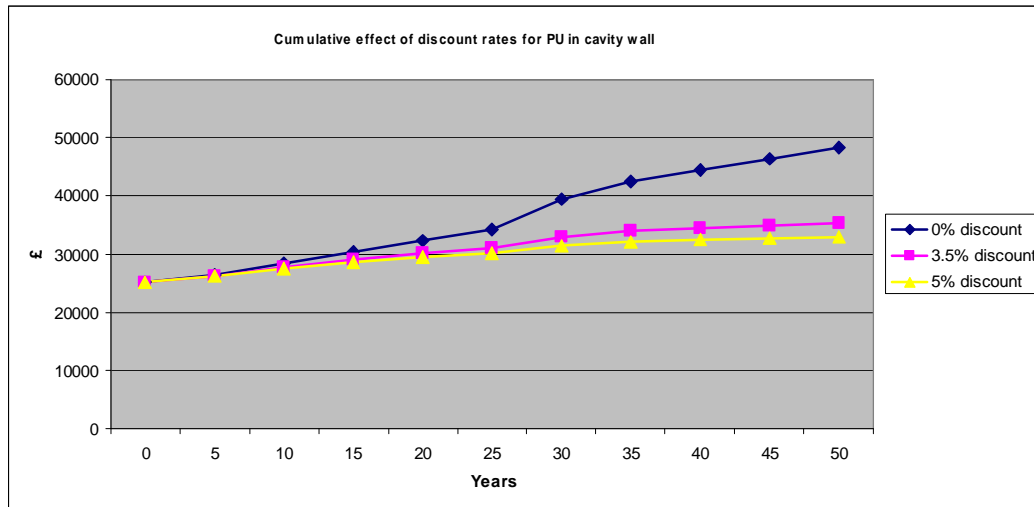


Figure 22 Cumulative effect of different discount rates for PU insulation in cavity wall for Temperate Oceanic climate zone

Initial capital costs

We have undertaken a review of published prices for the various component specifications. We have also used data obtained from Spons Architects and Builders Price book and other published price book data. Figures are based upon costs prevailing in September 2009.

Cost basis

All costs are based on rates current in September 2009 and include general preliminaries, profit and overheads but exclude fees and VAT.

All tables and graphs show the cumulative costs over the study period.

Energy Costs

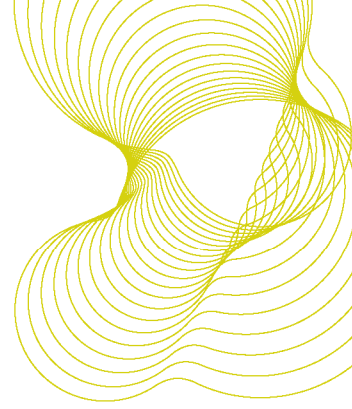
In order to be able to make a direct comparison of energy costs for all 3 climatic regions, natural gas prices in the UK have been used in order to provide consistency.

Current prices of natural gas in the UK as charged by British Gas at September 2009, are as follows:

Tier 1 (first 2680 kwh/pa) = 7.206p / kwh

Tier 2 (all subsequent kwh/pa) = 3.457p / kwh

These prices have been used throughout each climate zone.



3.2 Part 1 New build LCC

LCC New cavity wall

The new cavity wall includes half brick thick (102.5mm) outer skin of facing bricks, inner skin of 100mm thick dense blocks, 13mm lightweight plaster with 2 coats of emulsion paint. Cavity insulation materials and thicknesses vary as required in order to achieve the target U value.

In order to maintain a consistent internal floor area, different cavity insulation thicknesses that are required to achieve a common U value of $0.15 \text{ W/m}^2 \text{ K}$ will mean that the overall thickness of external wall varies and the quantity of brickwork in the outer skin will increase. This increase in material has been allowed for in the various life cycle cost analyses for each insulation type. Also, thicker external walls will mean that the total roof and foundation areas will increase and costs relating to this increase are included in each wall insulation calculation. For example, a wall with 270mm cavity insulation means that the property will have an additional 8.00sq m of roof area including soffit overhang and 7.00sq m additional foundation area when compared to a property with a 50mm cavity

Energy costs are included in this section.

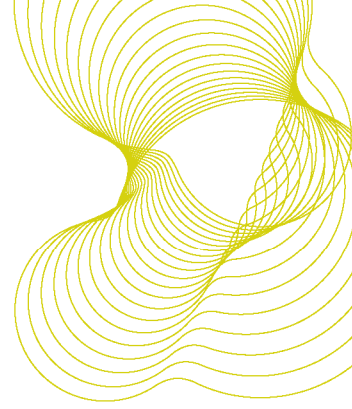
Insulation materials for the different scenarios included in this section are as follows:

180mm thick polyurethane; density 32kg/m^3 ; k-value of 0.023

270mm thick stone wool; density 39kg/m^3 ; k-value of 0.037

270mm thick glass wool; density 17kg/m^3 ; k-value of 0.037

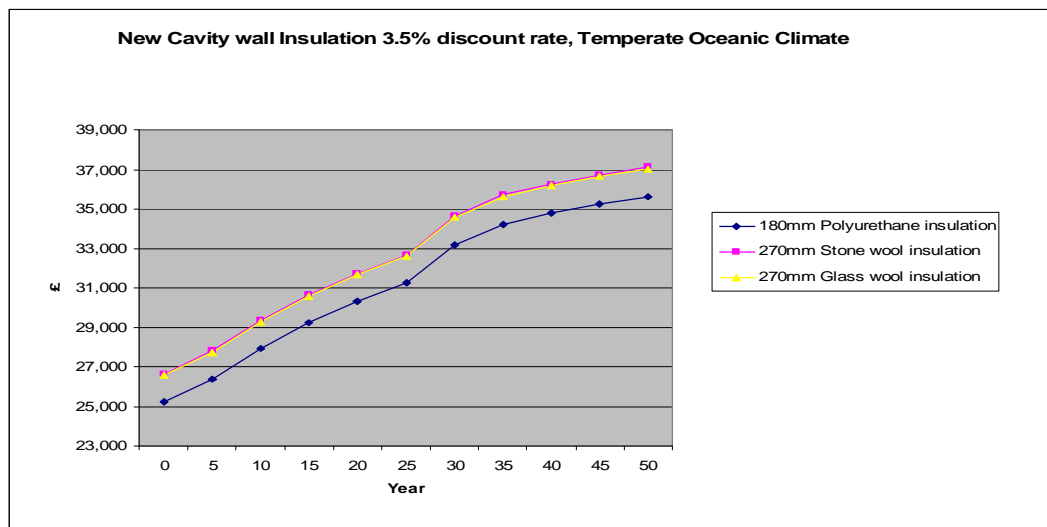
The following life cycle costs have been included - internal redecorations (5 years), replace rainwater goods and fascias and repoint brickwork (30 years) and annual energy consumed in each climatic region. (For energy calculations, see Appendix A).


Part 1 New Cavity Wall: Temperate Oceanic

Temp Ocean Discount %	year	0	5	10	15	20	25	30	35	40	45	50
	0%											
180mm Polyurethane insulation		25,211	26,515	28,493	30,470	32,448	34,426	39,725	42,873	44,850	46,828	48,806
270mm Stone wool insulation		26,636	27,940	29,918	31,895	33,873	35,850	41,238	44,416	46,393	48,371	50,348
270mm Glass wool insulation		26,567	27,871	29,849	31,826	33,804	35,781	41,169	44,346	46,324	48,302	50,279

Temp Ocean Discount %	year	0	5	10	15	20	25	30	35	40	45	50
	3.5%											
180mm Polyurethane insulation		25,211	26,389	27,928	29,224	30,316	31,234	33,192	34,246	34,794	35,256	35,645
270mm Stone wool insulation		26,636	27,814	29,353	30,649	31,740	32,659	34,648	35,712	36,261	36,722	37,111
270mm Glass wool insulation		26,567	27,744	29,284	30,580	31,671	32,590	34,579	35,643	36,192	36,653	37,042

Temp Ocean Discount %	year	0	5	10	15	20	25	30	35	40	45	50
	5%											
180mm Polyurethane insulation		25,211	26,340	27,728	28,815	29,666	30,334	31,625	32,293	32,614	32,865	33,062
270mm Stone wool insulation		26,636	27,765	29,152	30,239	31,091	31,758	33,070	33,744	34,065	34,317	34,514
270mm Glass wool insulation		26,567	27,696	29,083	30,170	31,022	31,689	33,001	33,675	33,996	34,248	34,445

Table 9 LCC new cavity wall: Temperate Mediterranean

Figure 23 LCC new Cavity wall: Temperate Oceanic

Conclusion

180mm polyurethane insulation used in the cavity has the lowest life cycle cost in the Temporary Oceanic climate zone, followed by 270mm glass wool and 270mm stone wool.

Part 1 New Cavity Wall: Temperate Mediterranean												
Temp. Med. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%	180mm Polyurethane insulation	25,211	26,368	28,199	30,029	31,860	33,690	38,843	41,843	43,674	45,504	47,335
	270mm Stone wool insulation	26,636	27,793	29,623	31,454	33,284	35,115	40,355	43,386	45,216	47,047	48,877
	270mm Glass wool insulation	26,567	27,724	29,554	31,385	33,215	35,046	40,286	43,317	45,147	46,978	48,808
3.5%	180mm Polyurethane insulation	25,211	26,256	27,683	28,885	29,897	30,750	32,650	33,657	34,166	34,594	34,955
	270mm Stone wool insulation	26,636	27,681	29,108	30,310	31,322	32,174	34,107	35,124	35,632	36,061	36,421
	270mm Glass wool insulation	26,567	27,612	29,039	30,241	31,253	32,105	34,038	35,055	35,563	35,992	36,352
5%	180mm Polyurethane insulation	25,211	26,213	27,500	28,509	29,300	29,919	31,173	31,811	32,109	32,342	32,525
	270mm Stone wool insulation	26,636	27,638	28,925	29,934	30,725	31,344	32,618	33,263	33,561	33,794	33,977
	270mm Glass wool insulation	26,567	27,569	28,856	29,865	30,655	31,275	32,549	33,194	33,492	33,725	33,908

Table 10 LCC new cavity wall: Temperate Mediterranean

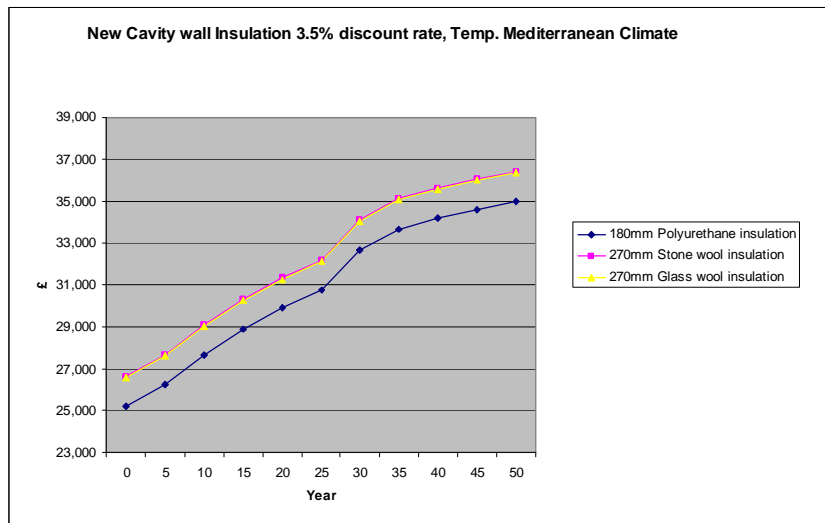
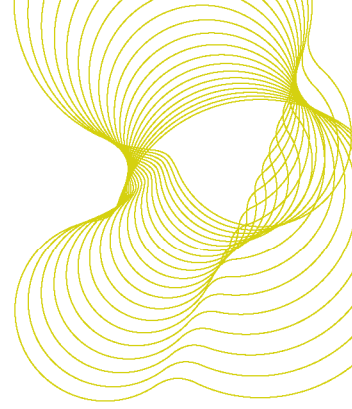


Figure 24 LCC new cavity wall: Temperate Mediterranean

Conclusion

180mm polyurethane insulation used in the cavity has the lowest life cycle cost in the Temperate Mediterranean climate zone, followed by 270mm glass wool and 270mm stone wool.



Part 1 New Cavity Wall: Cool Continental												
Cool Cont. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
180mm Polyurethane insulation		25,211	27,612	30,687	33,762	36,837	39,912	46,309	50,554	53,628	56,703	59,778
270mm Stone wool insulation		26,636	29,037	32,112	35,187	38,262	41,337	47,822	52,096	55,171	58,246	61,321
270mm Glass wool insulation		26,567	28,968	32,043	35,118	38,193	41,268	47,752	52,027	55,102	58,177	61,252
3.5%												
180mm Polyurethane insulation		25,211	27,380	29,753	31,752	33,434	34,851	37,228	38,635	39,481	40,193	40,792
270mm Stone wool insulation		26,636	28,804	31,178	33,177	34,859	36,276	38,684	40,101	40,947	41,659	42,259
270mm Glass wool insulation		26,567	28,735	31,109	33,107	34,790	36,207	38,615	40,032	40,878	41,590	42,189
5%												
180mm Polyurethane insulation		25,211	27,290	29,422	31,092	32,401	33,427	34,999	35,886	36,379	36,766	37,068
270mm Stone wool insulation		26,636	28,715	30,847	32,517	33,826	34,851	36,444	37,338	37,831	38,217	38,520
270mm Glass wool insulation		26,567	28,646	30,778	32,448	33,757	34,782	36,375	37,269	37,762	38,148	38,451

Table 11 LCC new cavity wall: Cool Continental

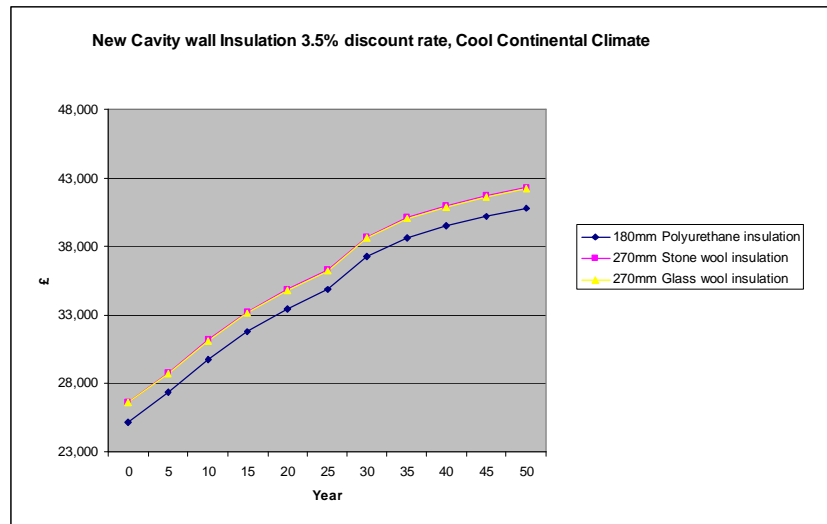
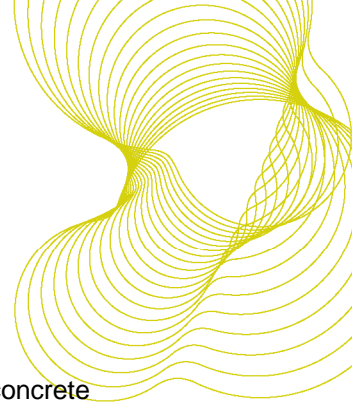


Figure 25 LCC new cavity wall: Cool Continental.

Conclusion

180mm polyurethane insulation used in the cavity has the lowest life cycle cost in the Cool Continental climate zone, followed by 270mm glass wool and 270mm stone wool.



LCC New pitched roof

The new pitched roof includes a softwood attic trussed rafter 45degree pitched roof with concrete interlocking tiles, underfelt, battens, eaves and ridges, plasterboard ceiling with 2 coats of emulsion paint. Insulation materials and thicknesses vary as required in order to achieve the target U value. Standard external walls with 50mm cavity have been assumed for all insulation types.

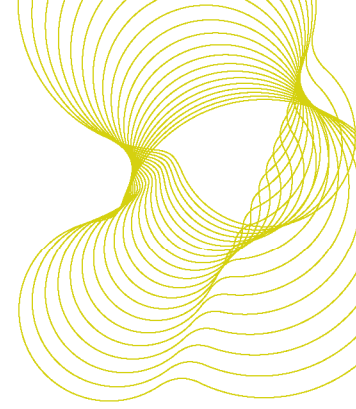
Insulation materials for the different scenarios included in this section are as follows:

190mm thick polyurethane comprising 100mm between the rafters and 90mm across the rafters; density 32kg/m³; k-value of 0.023

310mm thick stone wool comprising 220mm between the rafters and 90mm across the rafters; density 45kg/m³ between the rafters and 145kg/m³ across the rafters; k-value of 0.038

300mm thick glass wool fixed between the rafters and battens; density 17kg/m³; k-value of 0.032

The following life cycle costs have been included - internal redecorations (5 years).



Part 1 New Pitched Roof Slopes: Temperate Oceanic												
Temp Ocean	year	0	5	10	15	20	25	30	35	40	45	50
Discount %	0%											
190mm Polyurethane insulation		12,865	12,865	13,137	13,409	13,681	13,953	14,224	14,496	14,768	15,040	15,312
310mm Stone wool insulation		16,324	16,324	16,596	16,868	17,140	17,412	17,684	17,956	18,228	18,500	18,772
300mm Glass wool insulation		16,154	16,154	16,426	16,698	16,970	17,242	17,514	17,786	18,058	18,330	18,602
Temp Ocean	year	0	5	10	15	20	25	30	35	40	45	50
Discount %	3.5%											
190mm Polyurethane insulation		12,865	12,865	13,086	13,272	13,429	13,561	13,672	13,766	13,845	13,911	13,967
310mm Stone wool insulation		16,324	16,324	16,546	16,732	16,889	17,021	17,132	17,226	17,304	17,371	17,427
300mm Glass wool insulation		16,154	16,154	16,376	16,562	16,719	16,851	16,962	17,056	17,135	17,201	17,257
Temp Ocean	year	0	5	10	15	20	25	30	35	40	45	50
Discount %	5%											
190mm Polyurethane insulation		12,865	12,865	13,068	13,227	13,351	13,449	13,525	13,585	13,632	13,669	13,698
310mm Stone wool insulation		16,324	16,324	16,527	16,686	16,811	16,908	16,985	17,045	17,092	17,129	17,157
300mm Glass wool insulation		16,154	16,154	16,357	16,516	16,641	16,739	16,815	16,875	16,922	16,959	16,988

Table12 LCC pitched new roof: Temperate Oceanic

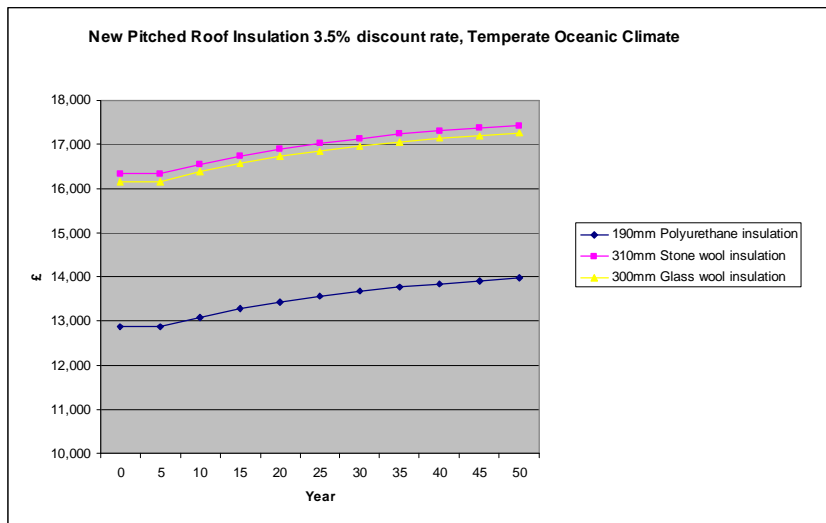
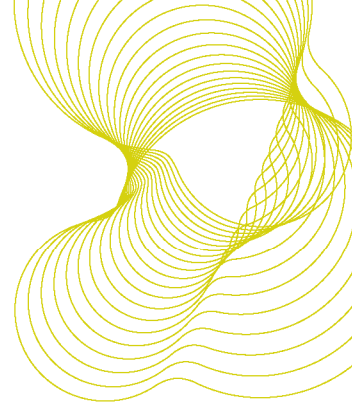


Figure 26 LCC new pitched roof: Temperate Oceanic.

Conclusion

190mm polyurethane has the lowest life cycle cost in the Temperate Oceanic climate zone, followed by 300mm glass wool insulation and 310mm stone wool.



Part 1 New Pitched Roof Slopes: Temperate Mediterranean												
Temp. Med. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
190mm Polyurethane insulation		12,865	12,865	13,137	13,409	13,681	13,953	14,224	14,496	14,768	15,040	15,312
310mm Stone wool insulation		16,324	16,324	16,596	16,868	17,140	17,412	17,684	17,956	18,228	18,500	18,772
300mm Glass wool insulation		16,154	16,154	16,426	16,698	16,970	17,242	17,514	17,786	18,058	18,330	18,602
3.5%												
190mm Polyurethane insulation		12,865	12,865	13,086	13,272	13,429	13,561	13,672	13,766	13,845	13,911	13,967
310mm Stone wool insulation		16,324	16,324	16,546	16,732	16,889	17,021	17,132	17,226	17,304	17,371	17,427
300mm Glass wool insulation		16,154	16,154	16,376	16,562	16,719	16,851	16,962	17,056	17,135	17,201	17,257
5%												
190mm Polyurethane insulation		12,865	12,865	13,068	13,227	13,351	13,449	13,525	13,585	13,632	13,669	13,698
310mm Stone wool insulation		16,324	16,324	16,527	16,686	16,811	16,908	16,985	17,045	17,092	17,129	17,157
300mm Glass wool insulation		16,154	16,154	16,357	16,516	16,641	16,739	16,815	16,875	16,922	16,959	16,988

Table 13 LCC new pitched roof: Temperate Mediterranean

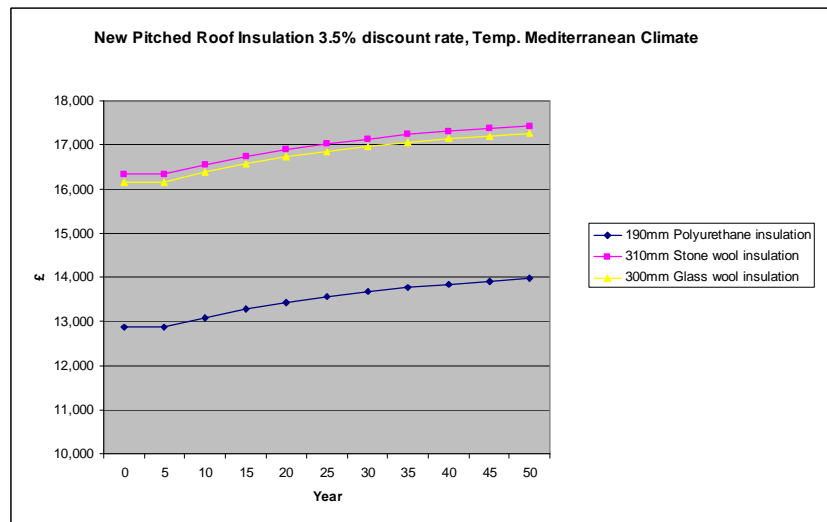


Figure 27 LCC new pitched roof: Temperate Mediterranean.

Conclusion

190mm polyurethane has the lowest life cycle cost in the Temperate Mediterranean climate zone, followed by 300mm glass wool insulation and 310mm stone wool.

Part 1 New Pitched Roof Slopes: Cool Continental												
Cool Cont. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
190mm Polyurethane insulation		12,865	12,865	13,137	13,409	13,681	13,953	14,224	14,496	14,768	15,040	15,312
310mm Stone wool insulation		16,332	16,332	16,604	16,876	17,148	17,420	17,692	17,964	18,236	18,508	18,779
300mm Glass wool insulation		16,154	16,154	16,426	16,698	16,970	17,242	17,514	17,786	18,058	18,330	18,602
3.5%												
190mm Polyurethane insulation		12,865	12,865	13,086	13,272	13,429	13,561	13,672	13,766	13,845	13,911	13,967
310mm Stone wool insulation		16,332	16,332	16,553	16,739	16,896	17,028	17,139	17,233	17,312	17,378	17,434
300mm Glass wool insulation		16,154	16,154	16,376	16,562	16,719	16,851	16,962	17,056	17,135	17,201	17,257
5%												
190mm Polyurethane insulation		12,865	12,865	13,068	13,227	13,351	13,449	13,525	13,585	13,632	13,669	13,698
310mm Stone wool insulation		16,332	16,332	16,535	16,694	16,818	16,916	16,992	17,052	17,099	17,136	17,165
300mm Glass wool insulation		16,154	16,154	16,357	16,516	16,641	16,739	16,815	16,875	16,922	16,959	16,988

Table 14 LCC new pitched roof: Cool Continental

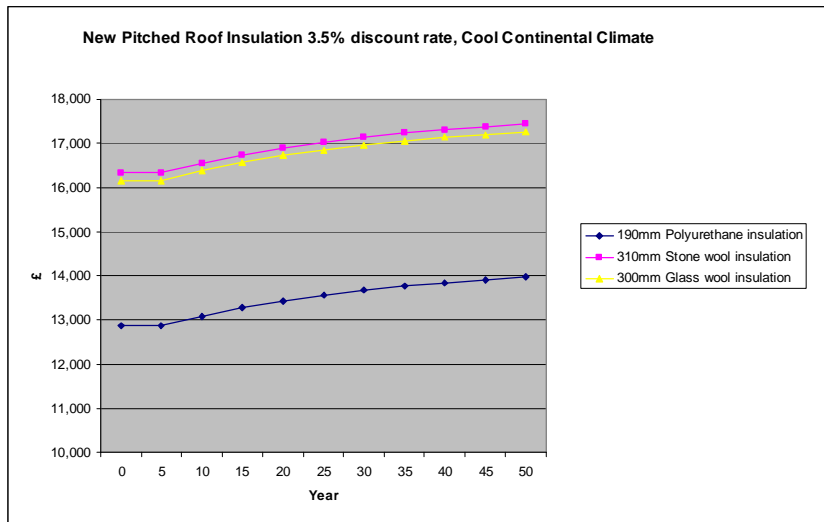
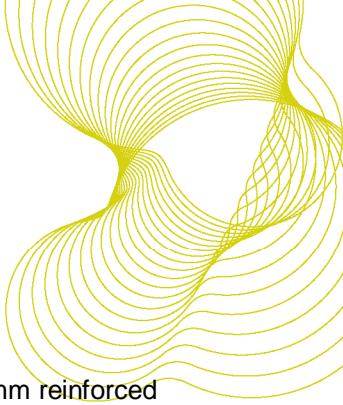


Figure 28 LCC new pitched roof: Cool Continental.

Conclusion

190mm polyurethane has the lowest life cycle cost in the Cool Continental climate zone, followed by 300mm glass wool insulation and 310mm stone wool.



LCC New ground floor

The new floor construction includes 200mm thick reinforced concrete ground slab and 50mm reinforced screed. Insulation materials and thicknesses vary as required. Standard external walls with 50mm cavity have been assumed for all insulation types.

Insulation materials for the different scenarios included in this section are as follows:

95mm thick polyurethane; density 32kg/m³; k-value of 0.023

185mm thick expanded polystyrene; density 18.5kg/m³; k-value of 0.030

Because no maintenance or replacement is anticipated during the study period, no life cycle costs are included. The determining cost is the initial installation cost.

Part 1 New Ground Floor: Temperate Oceanic												
Temp Ocean	year	0	5	10	15	20	25	30	35	40	45	50
Discount %	0%											
95mm Polyurethane insulation		6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448
185mm Expanded Polystyrene insulati		6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921

Temp Ocean	year	0	5	10	15	20	25	30	35	40	45	50
Discount %	3.5%											
95mm Polyurethane insulation		6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448
185mm Expanded Polystyrene insulati		6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921

Temp Ocean	year	0	5	10	15	20	25	30	35	40	45	50
Discount %	5%											
95mm Polyurethane insulation		6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448
185mm Expanded Polystyrene insulati		6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921

Table 15 LCC new ground floor: Temperate Oceanic

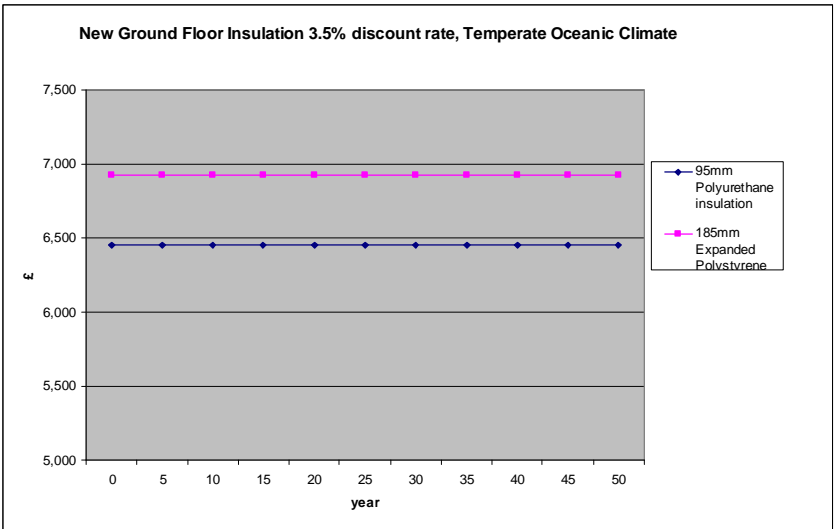
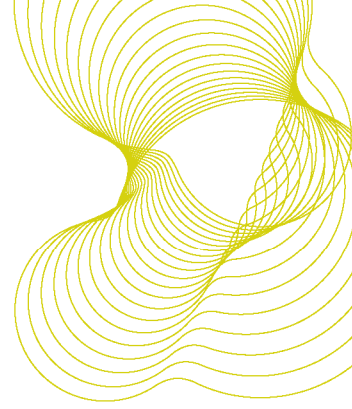


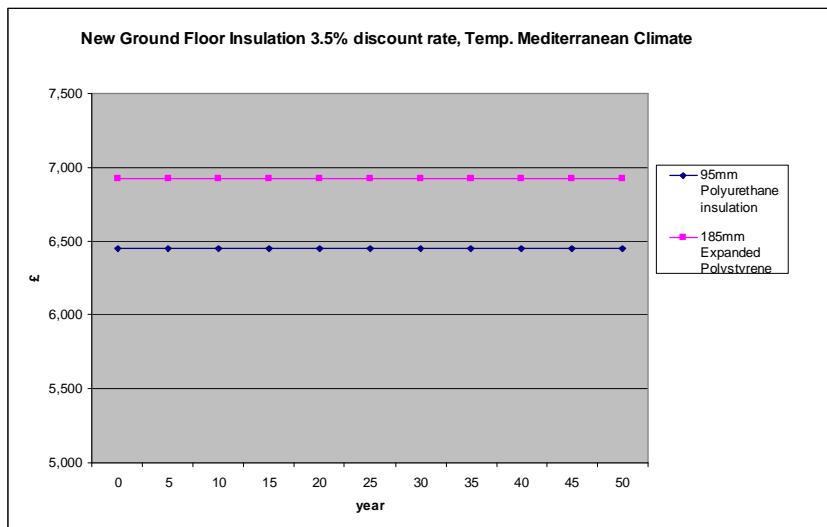
Figure 29 LCC new ground floor: Temperate Oceanic.

Conclusion

95mm polyurethane insulation has the lower life cycle cost in the Temperate Oceanic climate zone, followed by 185mm expanded polystyrene.

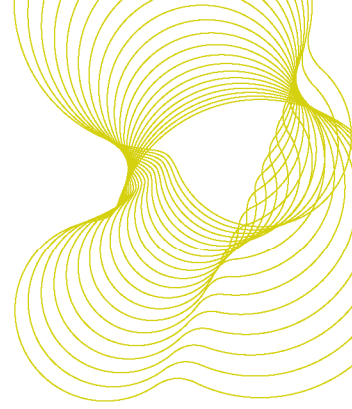

Part 1 New Ground Floor: Temperate Mediterranean

Temp. Med. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%	95mm Polyurethane insulation	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448
	185mm Expanded Polystyrene insula	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921
3.5%	95mm Polyurethane insulation	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448
	185mm Expanded Polystyrene insula	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921
5%	95mm Polyurethane insulation	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448
	185mm Expanded Polystyrene insula	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921

Table 16 LCC new ground floor: Temperate Mediterranean

Figure 30 LCC new ground floor: Temperate Mediterranean.

Conclusion

95mm polyurethane insulation has the lower life cycle cost in the Temperate Mediterranean climate zone, followed by 185mm expanded polystyrene



Part 1 New Ground Floor: Cool Continental												
Cool Cont. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
95mm Polyurethane insulation		6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448
185mm Expanded Polystyrene insu		6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921
3.5%												
95mm Polyurethane insulation		6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448
185mm Expanded Polystyrene insu		6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921
5%												
95mm Polyurethane insulation		6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448	6,448
185mm Expanded Polystyrene insu		6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921	6,921

Table 17 LCC new ground floor: Cool Continental

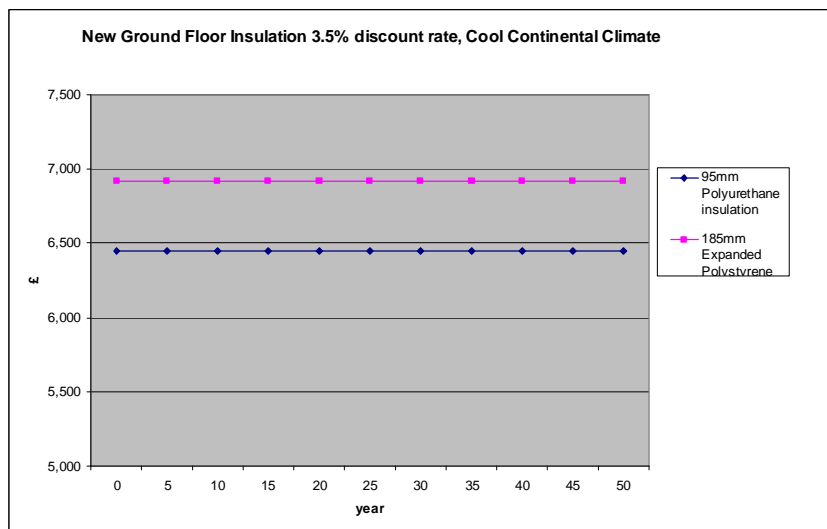
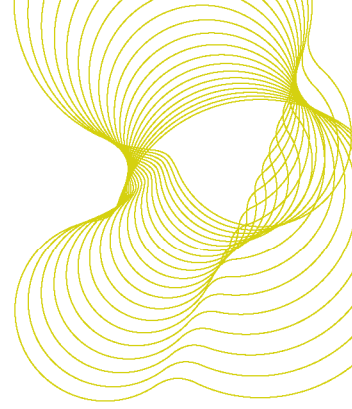


Figure 31 LCC new ground floor: Cool Continental.

Conclusion

95mm polyurethane insulation has the lower life cycle cost in the Cool Continental climate zone, followed by 185mm expanded polystyrene.



3.2.1 Affect on building footprint

The new cavity wall – different thicknesses of wall insulation lead to different quantities of materials for the wall and hence higher construction costs. An additional cost/m² for this is included with the new wall calculations.

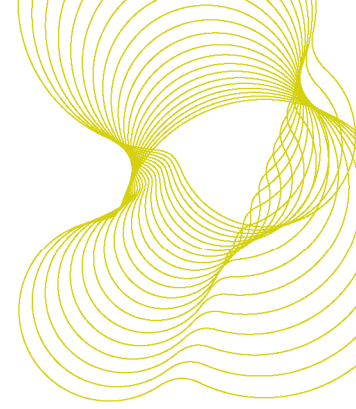
The pitched roof assumes a standard size of external wall for all insulation options.

The ground floor assumes a standard size of external wall for all insulation options.

One effect of the new cavity wall not shown in the tables is the additional footprint area required for roof and floor. On a large building site this may affect the density or number of properties that could be built on the site, e.g. in the worst case, 8.00m² extra on the roof area for each property may mean that only 9 properties could be fitted in an area that may be able to accommodate 10 if the external walls were thinner and the roof not extending over such a large area.

Coupled with this, but not included in the calculations is the possible value of the land that is unable to be utilised. Although prices vary considerably, a realistic cost of land with planning permission in an urban area in the United Kingdom, for example, is £250/m². Related to the 8.00m² area noted above, this would equate to £2,000 capital outlay on which there would be no return in the form of property.

In Part 1 New roof, the gross internal ground floor area is 52m², but the external plan area of the pitched roof is 75m² which includes for roof over the external walls with 450mm soffit overhang.



3.3 Part 2 Refurbishment: external walls LCC

LCC refurbished wall

In Part 2, an existing building is assumed with uninsulated external walls. The project requires insulation to be added, but in order to maintain internal floor areas; a restriction is imposed to allow insulation to a maximum of 50mm thick plus plasterboard finish. Materials modelled are polyurethane, stone wool, glass wool or expanded polystyrene.

Insulation is required to be added to the internal face of an existing property and it is assumed that the wall comprises half brick thick outer skin of facing bricks, 50mm thick cavity, inner skin of 100mm thick dense blocks, 12.5mm plasterboard with 2 coats of emulsion paint. 50mm thick insulation is either fixed directly to the blockwork with adhesive or between softwood framework as appropriate.

Energy costs are included in this section.

Insulation materials for the different scenarios included in this section are as follows:

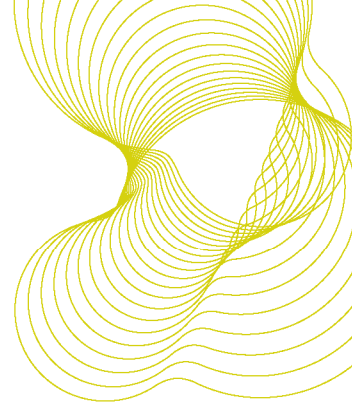
50mm thick polyurethane fixed to block wall with adhesive; density 32kg/m^3 ; k-value of 0.023

50mm thick stone wool fixed between timber studs; density 39kg/m^3 ; k-value of 0.037

50mm thick glass wool fixed between timber studs; density 24kg/m^3 ; k-value of 0.035

50mm thick expanded polystyrene fixed to block wall with adhesive; density 30kg/m^3 ; k-value of 0.034

The following life cycle costs have been included - internal redecorations (5 years), rainwater goods, renew fascias and repoint brickwork (30 years) and annual energy consumed in each location. (For energy calculations, see Appendix A)



Part 2 Internal Lining to Existing Wall: Temperate Oceanic												
Temp Ocean Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
50mm Polyurethane insulation		4,070	6,141	8,876	11,610	14,345	17,079	23,004	25,739	28,473	31,208	33,943
50mm Stone wool insulation		5,276	7,547	10,483	13,418	16,353	19,288	25,413	28,348	31,283	34,218	37,154
50mm Glass wool insulation		5,264	7,535	10,470	13,406	16,341	19,276	24,947	27,882	30,817	33,752	36,687
50mm Expanded Polystyrene insulatio		4,454	6,648	9,506	12,363	15,220	18,078	24,125	26,543	29,401	32,258	35,116
3.5%												
50mm Polyurethane insulation		4,070	5,940	8,054	9,835	11,334	12,596	14,795	15,690	16,443	17,077	17,611
50mm Stone wool insulation		5,276	7,327	9,594	11,503	13,110	14,463	16,739	17,698	18,505	19,185	19,758
50mm Glass wool insulation		5,264	7,315	9,582	11,491	13,098	14,451	16,565	17,524	18,331	19,011	19,584
50mm Expanded Polystyrene insulatio		4,454	6,435	8,643	10,502	12,067	13,385	15,631	16,434	17,220	17,882	18,440
5%												
50mm Polyurethane insulation		4,070	5,863	7,763	9,252	10,419	11,333	12,787	13,348	13,788	14,133	14,402
50mm Stone wool insulation		5,276	7,243	9,279	10,875	12,125	13,104	14,610	15,211	15,682	16,051	16,341
50mm Glass wool insulation		5,264	7,231	9,267	10,862	12,113	13,092	14,492	15,094	15,565	15,934	16,223
50mm Expanded Polystyrene insulatio		4,454	6,354	8,337	9,892	11,109	12,063	13,549	14,055	14,514	14,874	15,156

Table 18 LCC existing wall: Temperate Oceanic

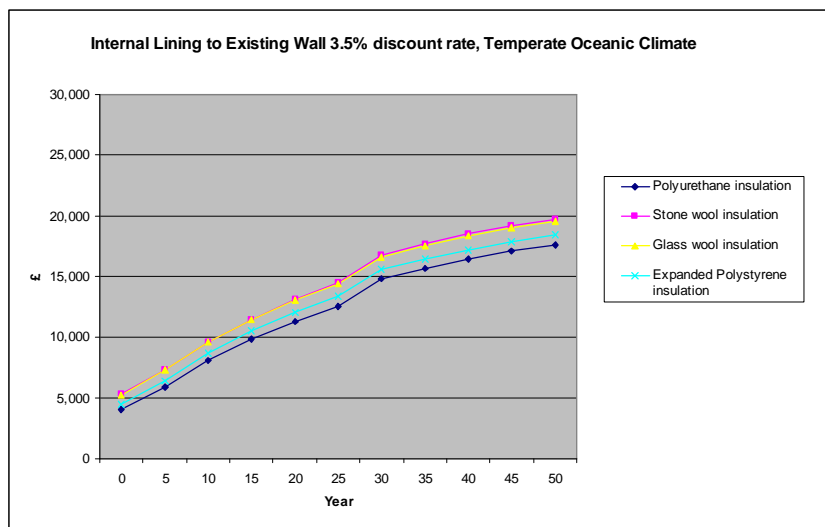
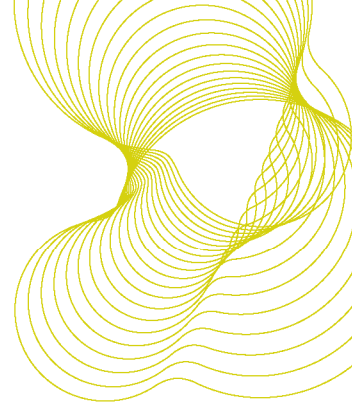


Figure 32 LCC existing wall: Temperate Oceanic.

Conclusion

Polyurethane insulation has the lowest life cycle cost, followed by expanded polystyrene, glass wool and stone wool in the Temperate Oceanic climate zone.



Part 2 Internal Lining to Existing Wall: Temperate Mediterranean												
Temp. Med. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
50mm Polyurethane insulation		4,070	5,852	8,298	10,744	13,190	15,636	21,272	23,718	26,164	28,610	31,056
50mm Stone wool insulation		5,276	7,225	9,837	12,450	15,063	17,675	23,478	26,090	28,703	31,316	33,928
50mm Glass wool insulation		5,264	7,213	9,825	12,438	15,051	17,663	23,076	25,689	28,301	30,914	33,526
50mm Expanded Polystyrene insulat		4,454	6,339	8,887	11,435	13,983	16,531	22,269	24,440	26,988	29,535	32,083
3.5%												
50mm Polyurethane insulation		4,070	5,679	7,574	9,170	10,513	11,644	13,733	14,535	15,210	15,779	16,257
50mm Stone wool insulation		5,276	7,036	9,057	10,760	12,193	13,400	15,552	16,408	17,128	17,734	18,245
50mm Glass wool insulation		5,264	7,024	9,045	10,748	12,181	13,388	15,401	16,257	16,977	17,583	18,094
50mm Expanded Polystyrene insulat		4,454	6,156	8,129	9,789	11,188	12,365	14,493	15,214	15,917	16,509	17,007
5%												
50mm Polyurethane insulation		4,070	5,613	7,318	8,653	9,699	10,519	11,900	12,403	12,797	13,106	13,349
50mm Stone wool insulation		5,276	6,963	8,781	10,205	11,321	12,195	13,618	14,155	14,575	14,905	15,163
50mm Glass wool insulation		5,264	6,951	8,769	10,193	11,309	12,183	13,516	14,052	14,473	14,802	15,061
50mm Expanded Polystyrene insulat		4,454	6,086	7,860	9,249	10,338	11,191	12,598	13,053	13,464	13,785	14,037

Table 19 LCC existing wall: Temperate Mediterranean

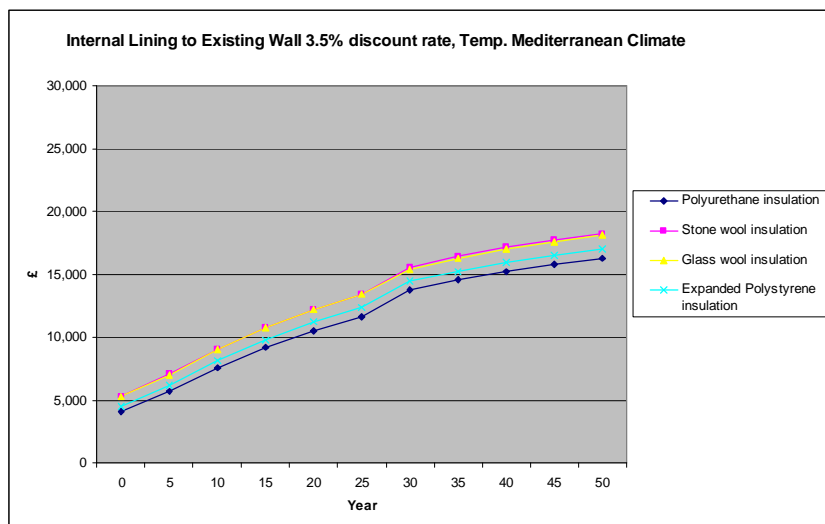
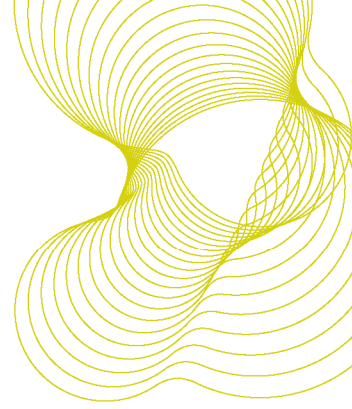


Figure 33 LCC existing wall: Temperate Mediterranean.

Conclusion

Polyurethane insulation has the lowest life cycle cost, followed by expanded polystyrene, glass wool and stone wool, when used in Temperate Mediterranean



Part 2 Internal Lining to Existing Wall: Cool Continental												
Cool Cont. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
50mm Polyurethane insulation		4,070	7,881	12,355	16,830	21,304	25,779	33,443	37,918	42,393	46,867	51,342
50mm Stone wool insulation		5,276	9,448	14,284	19,120	23,955	28,791	36,817	41,653	46,489	51,324	56,160
50mm Glass wool insulation		5,264	9,436	14,272	19,108	23,943	28,779	35,970	40,806	45,642	50,478	55,314
50mm Expanded Polystyrene insul		4,454	8,487	13,182	17,878	22,574	27,270	35,156	39,045	43,741	48,436	53,132
3.5%												
50mm Polyurethane insulation		4,070	7,511	10,948	13,843	16,279	18,331	21,195	22,650	23,874	24,905	25,774
50mm Stone wool insulation		5,276	9,043	12,755	15,881	18,512	20,728	23,730	25,301	26,623	27,737	28,674
50mm Glass wool insulation		5,264	9,031	12,743	15,869	18,500	20,716	23,421	24,991	26,314	27,427	28,365
50mm Expanded Polystyrene insul		4,454	8,096	11,701	14,737	17,293	19,445	22,394	23,677	24,962	26,043	26,954
5%												
50mm Polyurethane insulation		4,070	7,370	10,450	12,864	14,756	16,237	18,137	19,046	19,759	20,318	20,755
50mm Stone wool insulation		5,276	8,889	12,214	14,820	16,862	18,462	20,453	21,435	22,205	22,808	23,280
50mm Glass wool insulation		5,264	8,876	12,202	14,808	16,850	18,450	20,248	21,230	22,000	22,603	23,075
50mm Expanded Polystyrene insul		4,454	7,946	11,177	13,708	15,692	17,246	19,201	20,009	20,757	21,342	21,801

Table 20 LCC existing wall Cool Continental

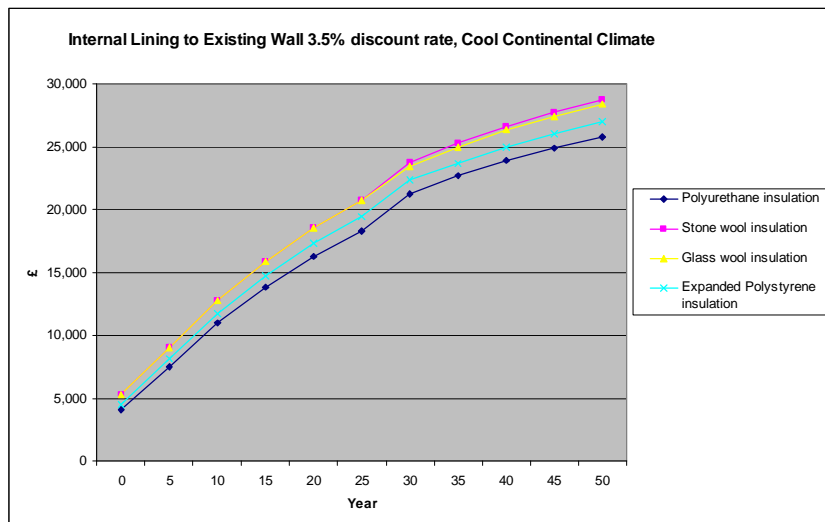
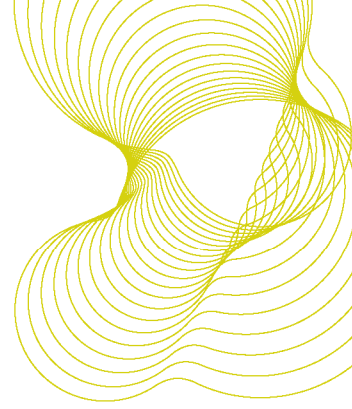


Figure 34 LCC existing wall Cool Continental.

Conclusion

Polyurethane insulation has the lowest life cycle cost, followed by expanded polystyrene, glass wool and stone wool in the Cool Continental climate zone.



3.4 Part 3 New warm deck flat roof LCC

LCC Flat roofing

In Part 3, a flat roof is considered and models the effect of polyurethane, stone wool and expanded polystyrene. The flat roof structure comprises 100mm x 50mm softwood joists, plates and strutting, 19mm OSB tongue and grooved boarding, vapour barrier and single ply membrane, plasterboard ceiling with 2 coats of emulsion paint. Insulation materials and thicknesses vary as required.

Energy costs are included in this section.

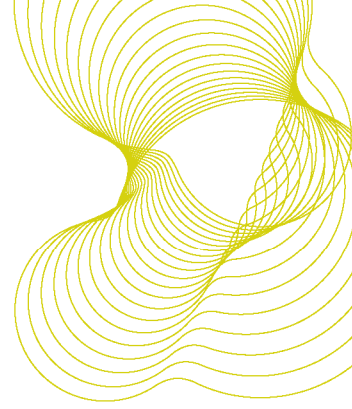
Insulation materials for the different scenarios included in this section are as follows:

150mm thick polyurethane; density 32kg/m³; k-value of 0.023

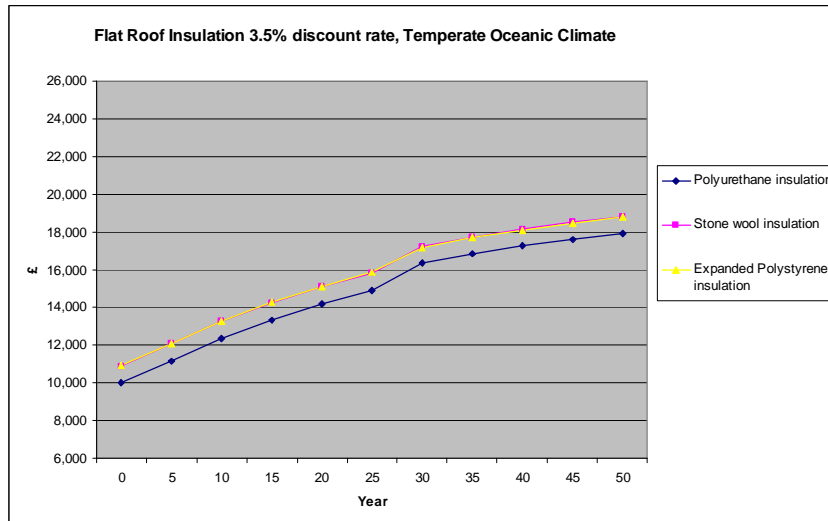
255mm thick stone wool; density 130kg/m³; k-value of 0.038

255mm thick expanded polystyrene; density 30kg/m³; k-value of 0.034

Life cycle costs allow for renewing the roof covering (25 years), redecorating the ceiling (5 years) and annual energy consumed in each location. (For energy calculations, see Appendix A).

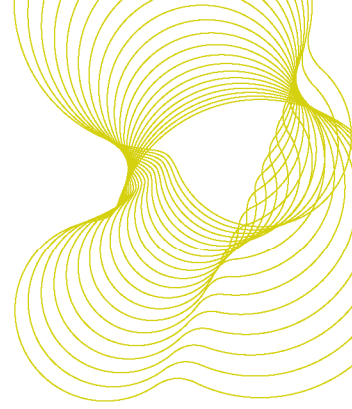

Part 3 Flat Roof Insulation: Temperate Oceanic

Temp Ocean Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
150mm Polyurethane insulation		9,999	11,273	12,819	14,365	15,911	17,457	21,051	22,598	24,144	25,690	27,236
255mm Stone wool insulation		10,897	12,171	13,718	15,264	16,810	18,356	21,950	23,496	25,042	26,588	28,134
255mm Expanded Polystyrene insula		10,941	12,216	13,762	15,308	16,854	18,400	21,739	23,285	24,832	26,378	27,924
3.5%												
150mm Polyurethane insulation		9,999	11,149	12,339	13,341	14,185	14,895	16,330	16,834	17,258	17,615	17,916
255mm Stone wool insulation		10,897	12,048	13,238	14,240	15,083	15,794	17,229	17,733	18,157	18,514	18,814
255mm Expanded Polystyrene insula		10,941	12,092	13,282	14,284	15,128	15,838	17,182	17,686	18,110	18,467	18,767
5%												
150mm Polyurethane insulation		9,999	11,102	12,169	13,006	13,661	14,174	15,153	15,468	15,715	15,908	16,060
255mm Stone wool insulation		10,897	12,001	13,068	13,904	14,560	15,073	16,051	16,366	16,613	16,807	16,959
255mm Expanded Polystyrene insula		10,941	12,045	13,112	13,948	14,604	15,117	16,036	16,352	16,599	16,792	16,944

Table 21 LCC Flat roof: Temperate Oceanic

Figure 35 LCC Flat roof: Temperate Oceanic.

Conclusion

150mm polyurethane has the lowest life cycle cost in the Temperate Oceanic climate zone, followed by 255mm expanded polystyrene and 255mm stone wool insulation.



Part 3 Flat Roof Insulation: Temperate Mediterranean												
Temp. Med. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
150mm Polyurethane insulation		9,999	11,132	12,537	13,942	15,347	16,752	20,205	21,610	23,015	24,420	25,825
255mm Stone wool insulation		10,897	12,030	13,435	14,841	16,246	17,651	21,104	22,509	23,914	25,319	26,724
255mm Expanded Polystyrene insula		10,941	12,075	13,480	14,885	16,290	17,695	20,921	22,326	23,731	25,136	26,541
3.5%												
150mm Polyurethane insulation		9,999	11,022	12,105	13,016	13,784	14,430	15,812	16,270	16,656	16,980	17,254
255mm Stone wool insulation		10,897	11,921	13,003	13,915	14,682	15,329	16,710	17,168	17,554	17,879	18,152
255mm Expanded Polystyrene insula		10,941	11,965	13,047	13,959	14,727	15,373	16,674	17,132	17,518	17,842	18,116
5%												
150mm Polyurethane insulation		9,999	10,980	11,952	12,713	13,309	13,777	14,719	15,006	15,231	15,407	15,545
255mm Stone wool insulation		10,897	11,878	12,850	13,611	14,208	14,675	15,618	15,905	16,129	16,306	16,444
255mm Expanded Polystyrene insula		10,941	11,923	12,894	13,656	14,252	14,720	15,609	15,896	16,121	16,297	16,435

Table 22 LCC Flat roof: Temperate Mediterranean

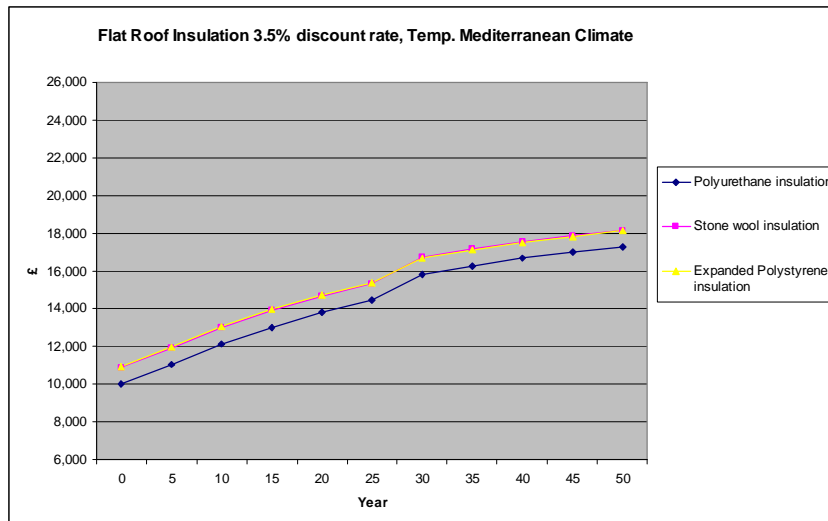


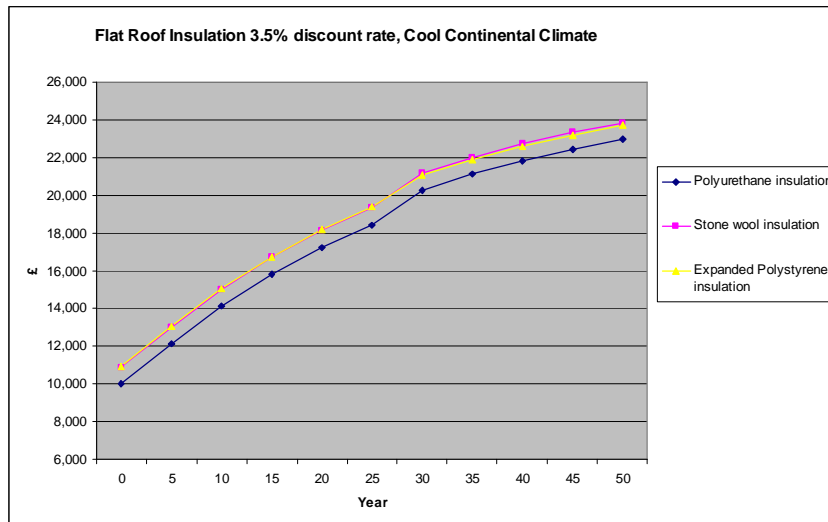
Figure 36 LCC Flat roof: Temperate Mediterranean.

Conclusion

150mm polyurethane has the lowest life cycle cost in the Temperate Mediterranean climate zone, followed by 255mm expanded polystyrene and 255mm stone wool insulation.

Part 3 Flat Roof Insulation: Cool Continental

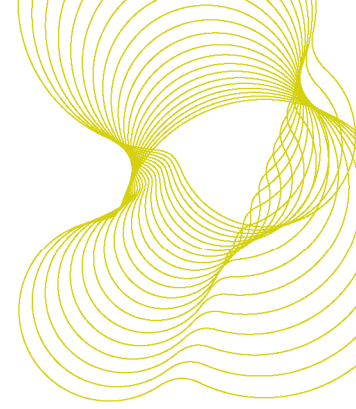
Cool Cont. Discount %	year	0	5	10	15	20	25	30	35	40	45	50
0%												
150mm Polyurethane insulation		9,999	12,344	14,961	17,578	20,194	22,811	27,476	30,093	32,710	35,327	37,944
255mm Stone wool insulation		10,897	13,242	15,859	18,476	21,093	23,710	28,375	30,992	33,609	36,226	38,842
255mm Expanded Polystyrene insu		10,941	13,286	15,903	18,520	21,137	23,754	27,950	30,567	33,184	35,801	38,418
3.5%												
150mm Polyurethane insulation		9,999	12,116	14,120	15,808	17,229	18,425	20,269	21,117	21,831	22,433	22,939
255mm Stone wool insulation		10,897	13,015	15,019	16,706	18,127	19,323	21,168	22,016	22,730	23,331	23,837
255mm Expanded Polystyrene insu		10,941	13,059	15,063	16,751	18,171	19,368	21,045	21,893	22,607	23,208	23,714
5%												
150mm Polyurethane insulation		9,999	12,029	13,823	15,229	16,330	17,193	18,445	18,975	19,390	19,715	19,970
255mm Stone wool insulation		10,897	12,928	14,722	16,127	17,229	18,091	19,343	19,873	20,288	20,613	20,868
255mm Expanded Polystyrene insu		10,941	12,972	14,766	16,171	17,273	18,136	19,279	19,809	20,224	20,549	20,804

Table 23 LCC Flat roof: Cool Continental**Figure 37** LCC Flat roof: Cool Continental.**Conclusion**

150mm polyurethane has the lowest life cycle cost in the Cool Continental climate zone, followed by 255mm expanded polystyrene and 255mm stone wool insulation.

3.4.1 Flat roof loading.

Calculations have been carried out by a structural engineer, that show that the impact of the different weights of insulation materials, owing to the different thicknesses required, have a negligible effect on the overall mass of the building and would be unlikely to incur any additional cost to the structure. If stone wool, the heaviest of the insulating materials at 130kg/m³, were to require an increase in joist size from 100mm to 150mm deep, this would cost approximately £115 extra for the whole flat roof. This would have no effect on the overall results of the life cycle costing exercise.



4 Conclusion

4.1 Environmental impacts

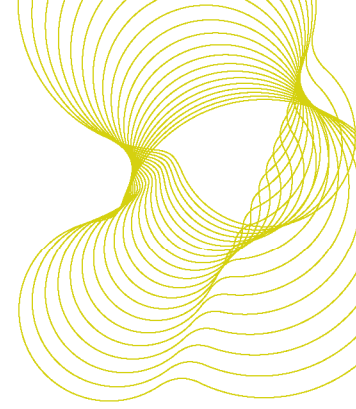
The following conclusions, based mainly on the normalised results, have been drawn from the LCA studies:

- 1) The results from Part 1 indicated that the PU designs tended to have similar or higher environmental impacts than those for the designs using alternative insulation materials at the same level of thermal performance. Part 3's results indicated that when insulations need mechanical properties in addition to their thermal performance, then solutions using PU can have environmental impacts similar to or lower than alternative insulations.
- 2) Part 1 further indicates that the materials of the modelled house accounted for around one third of the total Global Warming, and 50 to 90% of the whole house impact in Ozone Depletion, Eutrophication, Photochemical Ozone Creation and Acidification for Air and Water over 50 years for all climate zones.
- 3) The results from Part 2 show that where the amount of insulation is fixed, rather than the U-value, then the greater energy savings achieved with using PU insulation offset the higher environmental impact of the PU insulation itself.
- 4) The results from Part 2 imply that:
 - a. if the cavity is kept at the thickness needed for stone wool and glass wool in Part 1 to achieve the set U-value of $0.15 \text{ W m}^{-2}\text{K}^{-1}$ then the extra PU insulation that could be incorporated would save energy in use, which could more than offset the extra impact of the PU material and may offer greater benefits as demonstrated in Part 2.
 - b. if stone wool and glass wool were modelled at the same cavity thickness as for the PU model in this project, it is likely that stone wool and glass wool would require more energy during use, which could offset the lower environmental impacts of these insulations.

These conclusions on the relative performance of materials and energy use are influenced by the assumption that the space heating accounts for the majority of the energy consumption of using the house.

BRE Global recommends that the assessments outlined in a) and b) above are carried out with models for the specifications and energy models that are relevant to the climate zones of interest.

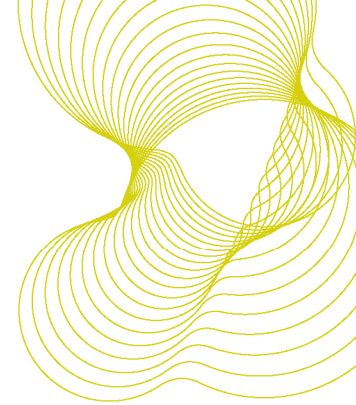
Additionally, the energy models have assumed a common airtightness and junction γ value for all models. The relevance of this assumption to the results is another further area of research.



4.2 Cost impacts

The following conclusions have been drawn from the LCC studies.

1. The results for Part 1 cavity wall infill indicates that for all regions considered, 180mm polyurethane insulation used in the cavity has the lowest life cycle cost, followed by 270mm glass wool and 270mm stone wool.
2. Greater thicknesses of wall insulation required increased quantities of materials for the wall and hence higher construction costs. An additional cost/m² for this is included with the new wall calculations. One effect of a thicker new cavity wall is the additional footprint area required for roof and floor. On a large building site this may affect the density or number of properties that could be built on the site, e.g. in the worst case, 8.00m² extra on the roof area for each property may mean that only 9 properties could be fitted in an area that may be able to accommodate 10 if the external walls were thinner and the roof smaller.
3. The results for a new pitched roof with insulation between and over the rafters to achieve a common U value indicate that 190mm polyurethane has the lowest life cycle cost when used in all regions followed by 300mm glass wool insulation and 310mm stone wool.
4. The results for the new ground floor indicates that 95mm polyurethane insulation has the lower life cycle cost when used in all regions, followed by 185mm expanded polystyrene.
5. The results for Part 2 refurbishment of an existing wall by the addition of 50mm insulation to the inside face indicates that polyurethane insulation has the lowest life cycle cost, followed by expanded polystyrene, glass wool and stone wool in all regions.
6. The results for Part 3 new warm deck flat roof indicates that 150mm polyurethane has the lowest life cycle cost when used in all regions, followed by 255mm expanded polystyrene and 255mm stone wool insulation.



Appendix 1

Thermal assessment and energy calculations

Introduction

The overall objective of the BING Project study is to quantify the PU insulation contribution on the environmental and economic performance in low-energy buildings and compare it to the use of alternative insulation materials relevant to the considered applications.

The study is in 3 parts:-

Part 1: impact of insulation in new build for total building perspective;

Part 2: impact of insulation in renovation when thickness is restricted;

Part 3: impact of insulation density with new build flat roof

For each of the three parts a specific house type and size is used, where this was selected as the small detached house from BRE Client Report "Standard Dwellings for Energy Modelling" (CR444/98) by Peter Iles. The total floor area of the two storey house is 104 m² with the heating system, lighting etc. fixed, with only the insulation of the building fabric varying.

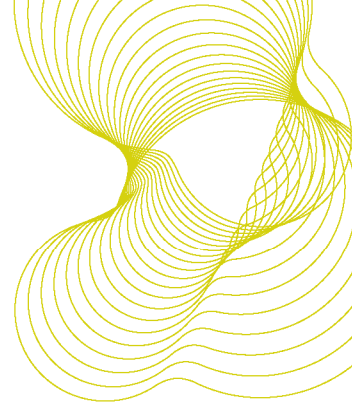
U-values and Insulation thicknesses

Part 1. New build – impact of thermal conductivity

For Part 1 where the different insulation materials are used in new build constructions, the building element constructions of wall, roof and floor have insulation thicknesses such that the same U-value is achieved for the different insulation materials. The window U-value is fixed at 2.1 W/m²K and the heat loss associated with the thermal bridging at the junctions between building elements and around openings has a y-value of 0.08 W/m²K.

Part 2. Existing build - Impact of thickness restriction

For Part 2, insulation of the walls of the dwelling is restricted to adding 50mm thickness of insulation to the inside of an uninsulated brick/cavity/block wall. This results in different U-values for the different insulation materials used in the wall. The roof is taken to be insulated between joists with 100 mm of insulation and the floor construction is taken to be uninsulated resulting in fixed U-values of 0.40 and 0.67 W/m²K for the roof and ground floor, respectively. The U-value of the windows is fixed at 2.7 W/m²K and the heat loss associated with the thermal bridging at the junctions between building elements and around openings considered to have a y-value of 0.15 W/m²K.



Part 3. New build – Flat roof

For Part 3, the roof of the dwelling is replaced with a flat roof with a U-value of 0.15 W/m²K. As for Part 1 the window U-value is fixed at 2.1 W/m²K and the heat loss associated with the thermal bridging at the junctions between building elements and around openings again has a y-value of 0.08 W/m²K.

Calculation of Energy emissions for space heating

The energy used for space heating is calculated using a version BRESAP amended for different external climates. The three climatic regions covered are Temperate Oceanic, Temperate Mediterranean and Cool Continental, where the external climate data for each being sourced from the Photovoltaic Geographical Information System (PVGIS) where the data used is the 24 hour mean monthly values of external temperature and solar radiation.

There is of course a clear difference in energy consumptions for space heating between each of the three different external climates. Using the Temperate Oceanic zone as the base consumption (bold text values), for Temperate Mediterranean the consumptions are 18% less for all builds. For Cool Continental and for the new builds (Parts 1 and 3), the consumptions are 140% higher compared to the TO zone and for the existing builds (Part2) the consumptions are about 110% more in the CC zone compared to that for the TO.

For the existing build (Part2) and for all three external climates, using the PU internal insulation as the base case (Red text values), the space heating consumption with the EPS insulation on the wall is 8% more and that for the SW/GW insulation on the wall is around 11% more.

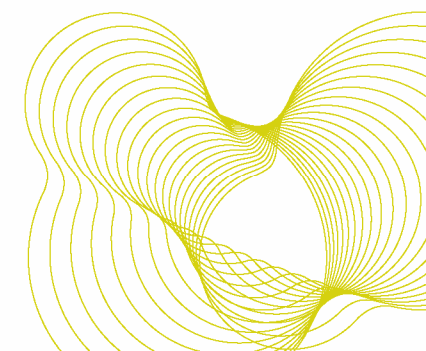
	U-values (W/m ² K)				Junctions y-value (W/m ² K)	Temperate Mediterranean (TM) Energy (kWh/yr)	Temperate Oceanic (TO) Energy (kWh/yr)	Cool Continental (CC) Energy (kWh/yr)
	Wall	Roof	Floor	Windows				
Part 1 New build								
Pitched Roof	0.15	0.13	0.18	2.1	0.08	^{-18%} 3789	4640*	^{+140%} 10988
Part 2 Existing build								
PU Composite	0.36	0.40	0.67	2.7	0.15	^{-18%} 7407 [#]	9077[#]	^{+111%} 19143 [#]
EPS Composite	0.47	0.40	0.67	2.7	0.15	^{-18%} 7997 ^{+8%}	9787^{+8%}	^{+109%} 20423 ^{+7%}
SW/GW Built-up	0.54	0.40	0.67	2.7	0.15	^{-18%} 8371 ^{+13%}	10237^{+13%}	^{+107%} 21233 ^{+11%}
Part 3 New build								
Flat Roof	0.15	0.15	0.18	2.1	0.08	^{-18%} 3649	4465	^{+139%} 10660

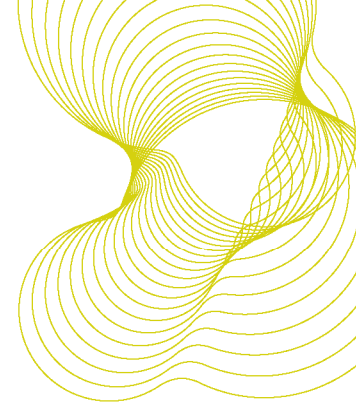
¹ Source of climate data is the Photovoltaic Geographical Information System (PVGIS) and the data used is the 24 hr mean monthly values of external temperature and solar radiation.

² Base cases in bold (UK) for comparisons of consumptions with climate variation - % values top left

[#] Base case in red (PU) for comparisons of consumptions with insulation variation - %values bottom right

Table 24 U-values summary and BRESAP Energy calculations for space heating for three different climates





Appendix 2

Outline Specifications of elements

Part 1 New Build

Cavity wall constructions (U-value = 0.15 W m⁻²K⁻¹)

Common components:

Half brick (102.5mm) thick facing brick outer skin; 100mm dense blockwork inner skin; 13mm thick lightweight plaster; mist and 2 coats emulsion paint

With *Polyurethane insulation*:

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
32	0.023

Form cavity 180mm wide with 300mm galvanised vertical twist wall ties; 180mm thick polyurethane insulation fixed in cavity.

Additional roof area for 180mm cavity over 50mm standard cavity including structure, coverings and rainwater goods

Additional foundation area for 180mm cavity over 50mm cavity including excavation, substructure and reinforced concrete slab

With *Stone Wool batt insulation*:

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
39	0.037

Form cavity 270 wide with 400mm stainless steel wall ties; 270 mm thick stone wool insulation fixed in cavity

Additional roof area for 270mm cavity over 50mm cavity including structure, coverings and rainwater goods

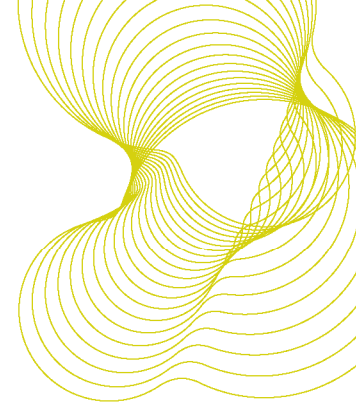
Additional foundation area for 270mm cavity over 50mm cavity including excavation, substructure and reinforced concrete slab

With *Glass Wool batt insulation*:

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
17	0.037

Form cavity 270 wide with 400mm stainless steel wall ties; 270mm thick glass wool insulation fixed in cavity

Additional roof area for 270mm cavity over 50mm cavity including structure, coverings and rainwater goods



Additional foundation area for 270mm cavity over 50mm cavity including excavation, substructure and reinforced concrete slab

Pitched roof constructions, insulated on slope (U-value = 0.13 W m⁻²K⁻¹)

Common components:

Softwood attic rafters, 100 (or 220) mm x 50mm members @600mm centres; Concrete interlocking tiles including underfelt, battens, eaves and ridges; 12.5mm plasterboard, fixed with nails, taped and filled joints for direct decoration; mist and 2 coats emulsion paint to plasterboard ceiling

With *Polyurethane insulation*:

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
32	0.023

100mm polyurethane insulation laid between rafters; 90mm polyurethane insulation laid across rafters;

With *Stone Wool insulation*: to achieve a U-value 0.13 W m⁻²K⁻¹ for any spacing or width or rafter

Density (kg m ⁻³)	Thickness (mm)
45	220mm (between rafters) λ=0.038
145	90mm (over rafters) λ=0.038

With *Glass Wool insulation*

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
17	0.032

300mm glass wool insulation laid between rafters

Ground floor constructions (U-value = 0.18 W m⁻²K⁻¹)

Common components:

200mm thick reinforced concrete ground slab; 50mm thick reinforced cement and sand screed

With *Polyurethane insulation*:

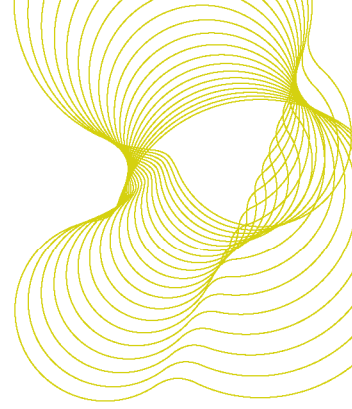
95mm thick polyurethane insulation

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
32	0.023

With *Expanded Polystyrene insulation*:

185mm thick expanded polystyrene insulation

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
18.5	0.03



Part 2 Existing Building

Lining of existing external wall constructions (fixed thickness of 50 mm insulation)

Common components:

Half brick (102.5mm) thick facing brick outer skin; form cavity 50 wide with galvanised vertical twist wall ties; 100mm dense blockwork inner skin.

With *Polyurethane insulation*: **Giving a wall U value of 0.36 W m⁻²K⁻¹**

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
32	0.023

50mm thick polyurethane insulation fixed to block wall with plaster adhesive; 12.5mm thick plasterboard; 2 coats emulsion paint.

With *Stone Wool insulation*: **Giving a wall U value of 0.54 W m⁻²K⁻¹**

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
39	0.037

50mm thick stone wool insulation fixed to block wall between studs; timber studs, 50mm x 50mm at 600ccs fixed to blockwork; 12.5mm thick plasterboard; 2 coats emulsion paint.

With *Glass Wool insulation*: **Giving a wall U value of 0.54 W m⁻²K⁻¹**

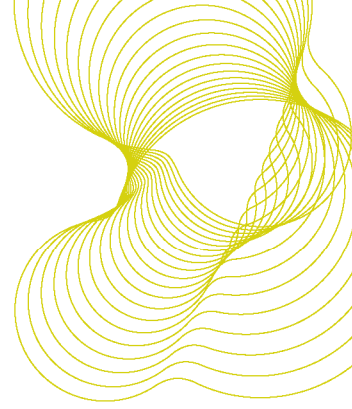
Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
24	0.035

50mm thick glass wool insulation fixed to block wall between studs; timber studs, 50mm x 50mm at 600ccs fixed to blockwork; 12.5mm thick plasterboard; 2 coats emulsion paint.

With *Expanded Polystyrene insulation*: **Giving a wall U value of 0.47 W m⁻²K⁻¹**

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
30	0.034

50mm thick expanded polystyrene insulation fixed to block wall with plaster adhesive; 12.5mm thick plasterboard; 2 coats emulsion paint.



Part 3 Flat roof constructions (U-value = 0.15 W m⁻²K⁻¹)

Common components:

Softwood flat roof structure; 100mm x 50mm joists, plates and strutting; 19mm thick OSB tongued and grooved boarding; vapour control layer; EPDM single ply roof membrane; 12.5mm plasterboard, fixed with nails, taped and filled joints for direct decoration; mist and 2 coats emulsion paint to plasterboard ceiling

150mm *polyurethane insulation*

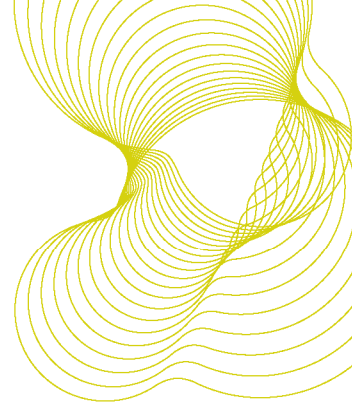
Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
32	0.023

255mm *stone wool insulation*

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
130	0.038

255mm *expanded polystyrene insulation*

Density (kg m ⁻³)	k value [thermal conductivity, λ] (W m ⁻¹ K ⁻¹)
30	0.034

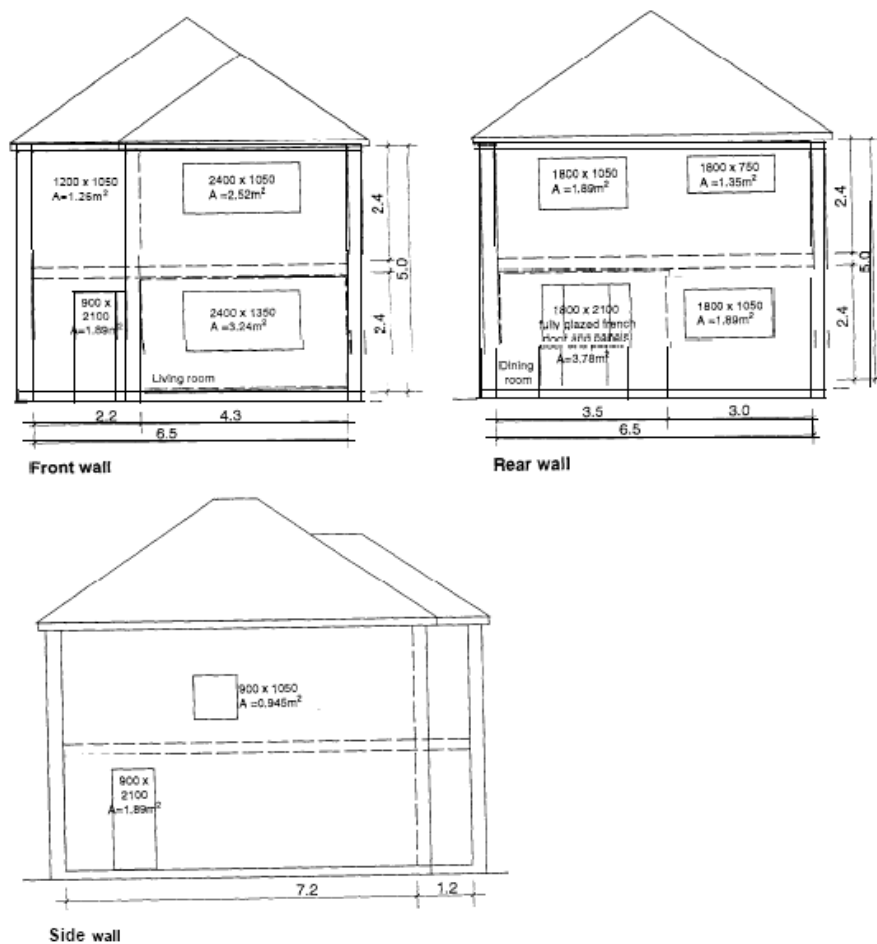


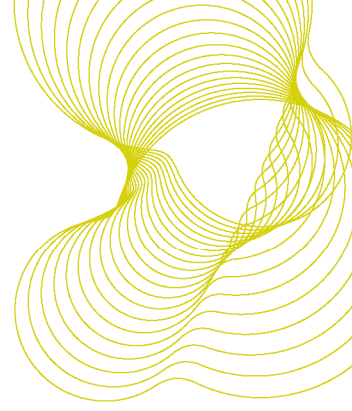
Appendix 3

Details of house model

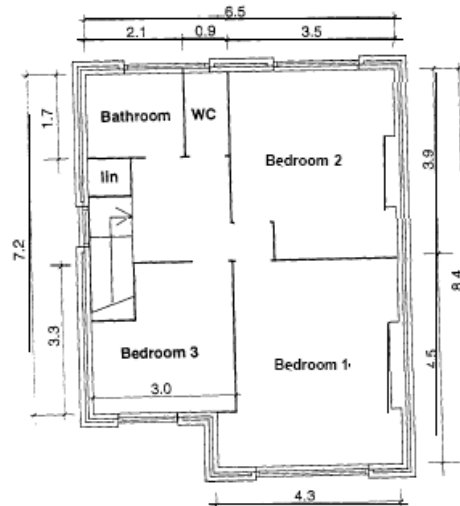
Extract from BRE Report Client Report "Standard Dwellings for Energy Modelling" (CR444/98)

SMALL DETACHED HOUSE - ELEVATIONS

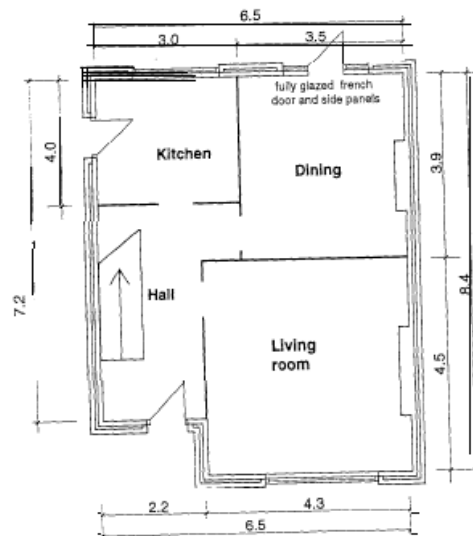




SMALL DETACHED HOUSE



First floor

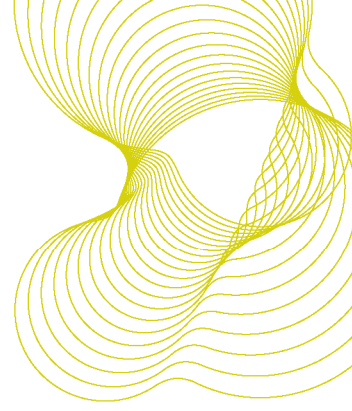


Ground floor

SMALL DETACHED HOUSE

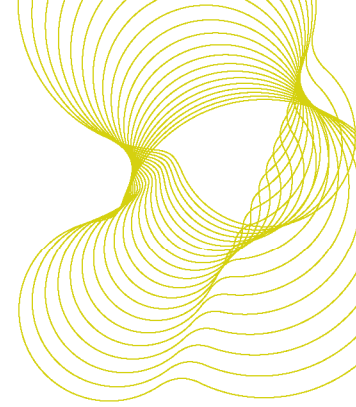
Total floor area: 104.0 m²

	Total (m ²)	Zone 1 (m ²)	Storey height (m)
Ground floor	52.0	26.0	2.4
First floor	52.0		2.6
Windows	16.9	4.2 (incl. glazed french door)	
Doors	3.8	-	
Heat loss walls excl. doors/windows	129.3	32.1	
Heat loss walls incl. doors/windows	149.0	35.3	
Perimeter	29.8 m		
Volume	260.00 m ³		
Occupants	3		



Appendix 4

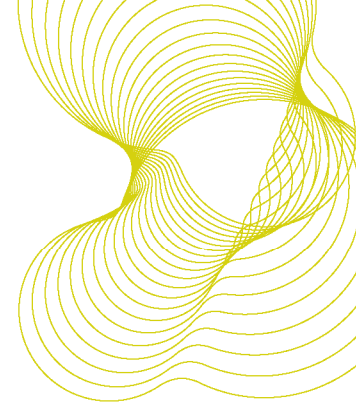
SAP Calculations



SAP 2005 WORKSHEET FOR NEW DWELLING AS DESIGNED (Version 9.82, June 2008)
CALCULATION OF DWELLING EMISSIONS FOR REGULATIONS COMPLIANCE
 Approved Document L1A, 2006 Edition

Newbuild in Temperate Oceanic (TO)

1. Overall dwelling dimensions				
	<u>Area</u>	<u>Av. storey</u>	<u>Volume</u>	
	<u>(m²)</u>	<u>height (m)</u>	<u>(m³)</u>	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q50	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	<u>Area</u>	<u>U-value</u>	<u>A × U</u>	
<u>Element</u>	<u>(m²)</u>	<u>(W/m²K)</u>	<u>(W/K)</u>	
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.10) 1.94	32.74	(27)
Ground floor	52.00	0.18	9.36	(28)
Walls	120.80	0.15	18.12	(29)
Roof	<u>52.00</u>	0.10	<u>5.20</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			76.25	(33)
Thermal bridges (0.08 × total area)			<u>19.64</u>	(34)
Total fabric heat loss			95.89	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			149.11	(37)
Heat loss parameter (HLP)			1.43	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		360	(48)
Total		3319	(49a)
Solar input		0	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

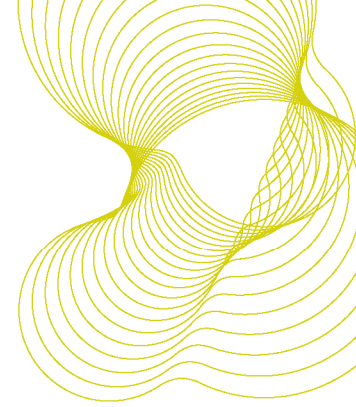
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>	<u>Gains (W)</u>
East/West	0.9 × 16.90	50	0.72	0.70	0.77	295
					total:	295
						(58)
						(65)
Total gains						1046
Gain/loss ratio						7.01
Utilisation factor						0.923
Useful gains						966
						(66)
						(67)
						(68)
						(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.88	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.50	(72)
Adjusted living area temperature		19.38	(73)
Temperature difference between zones		1.48	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		18.17	(77)

8. Degree-days

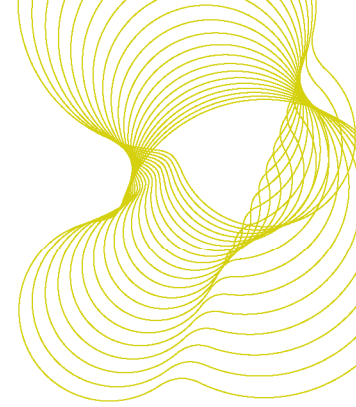
Temperature rise from gains		6.48	(78)
Base temperature		11.70	(79)
Degree-days		1281.1	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		3942	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		3942	(85)
Space heating fuel (secondary)		394	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

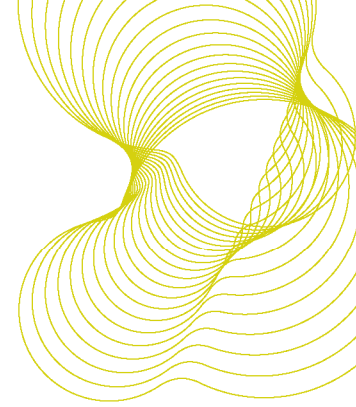
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	3942	0.194	765	(101)
Space heating, secondary - box (85a)	394	0.422	166	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			1647	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			2048	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>19.69</u>	(113)



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Newbuild in Temperate Mediterranean (TM)

1. Overall dwelling dimensions				
	Area (m ²)	Av. storey height (m)	Volume (m ³)	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q ₅₀	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)	
<u>Element</u>				
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.10) 1.94	32.74	(27)
Ground floor	52.00	0.18	9.36	(28)
Walls	120.80	0.15	18.12	(29)
Roof	<u>52.00</u>	0.10	<u>5.20</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			76.25	(33)
Thermal bridges (0.08 × total area)			<u>19.64</u>	(34)
Total fabric heat loss			95.89	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			149.11	(37)
Heat loss parameter (HLP)			1.43	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		360	(48)
Total		3319	(49a)
Solar input		0	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

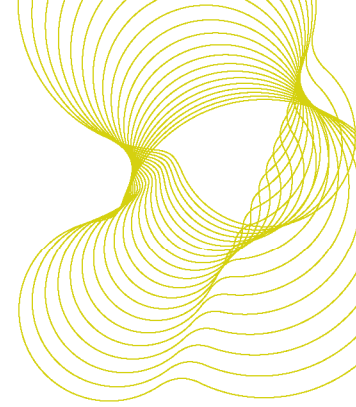
<u>Orientation</u>		<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 ×	16.90	68	0.72	0.70	0.77	401	(58)
						total:	401	(65)
Total gains							1152	(66)
Gain/loss ratio							7.73	(67)
Utilisation factor							0.903	(68)
Useful gains							1040	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.88	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.59	(72)
Adjusted living area temperature		19.47	(73)
Temperature difference between zones		1.48	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		18.27	(77)

8. Degree-days

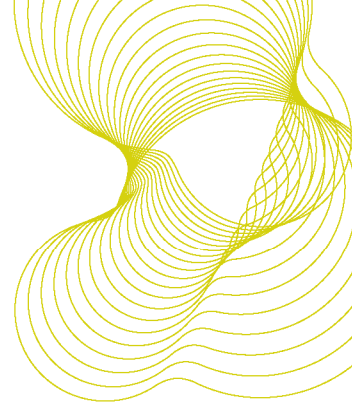
Temperature rise from gains		6.97	(78)
Base temperature		11.30	(79)
Degree-days		1199.2	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		3222	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		3222	(85)
Space heating fuel (secondary)		322	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

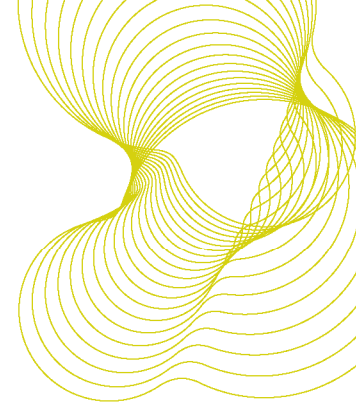
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	3222	0.194	625	(101)
Space heating, secondary - box (85a)	322	0.422	136	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			1477	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			1878	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>18.06</u>	(113)



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Newbuild in Cool Continental (CC)

1. Overall dwelling dimensions				
	Area (m ²)	Av. storey height (m)	Volume (m ³)	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q50	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)	
<u>Element</u>				
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.10) 1.94	32.74	(27)
Ground floor	52.00	0.18	9.36	(28)
Walls	120.80	0.15	18.12	(29)
Roof	<u>52.00</u>	0.10	<u>5.20</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			76.25	(33)
Thermal bridges (0.08 × total area)			<u>19.64</u>	(34)
Total fabric heat loss			95.89	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			149.11	(37)
Heat loss parameter (HLP)			1.43	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		<u>360</u>	(48)
Total		3319	(49a)
Solar input		<u>0</u>	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

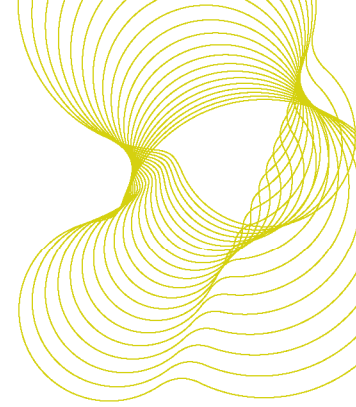
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 × 16.90	46	0.72	0.70	0.77	<u>272</u>	(58)
					total:	<u>272</u>	(65)
Total gains						1022	(66)
Gain/loss ratio						6.86	(67)
Utilisation factor						0.928	(68)
Useful gains						948	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.88	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.47	(72)
Adjusted living area temperature		19.35	(73)
Temperature difference between zones		1.48	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		18.15	(77)

8. Degree-days

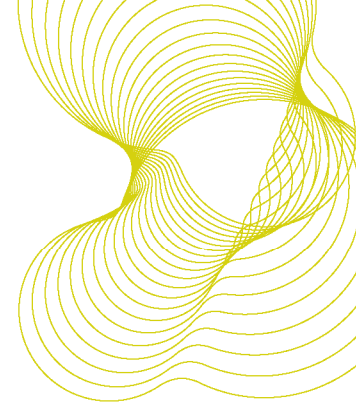
Temperature rise from gains		6.36	(78)
Base temperature		11.79	(79)
Degree-days		1300.5	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		9470	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		9470	(85)
Space heating fuel (secondary)		947	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

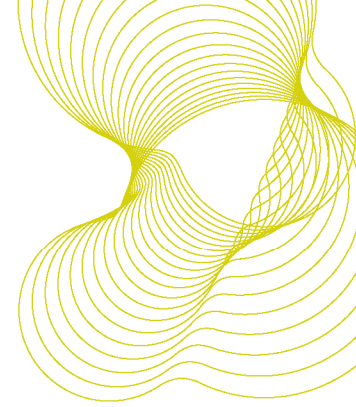
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	9470	0.194	1837	(101)
Space heating, secondary - box (85a)	947	0.422	400	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			2952	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			3354	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>kg/m²/year</u> 32.25	(113)



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Bing Part2 Existing SW_GW in Temperate Oceanic (TO)

1. Overall dwelling dimensions			
	Area (m ²)	Av. storey height (m)	Volume (m ³)
Ground floor	52.00	2.40	124.80 (1)
First floor	<u>52.00</u>	2.60	<u>135.20</u> (2)
Total floor area	104.00		(5)
Dwelling volume (m ³)			260.00 (6)
2. Ventilation rate			
		<u>m³ per hour</u>	
Number of chimneys	0 × 40	0	(7)
Number of flues	0 × 20	0	(8)
Number of fans or passive vents	2 × 10	20	(9)
Number of flueless gas fires	0 × 40	0	(9a)
		<u>ach</u>	
Infiltration due to chimneys, flues and fans		0.08	(10)
Pressure test	Yes		
Measured/design q50	10.0		
Infiltration rate		0.58	(19)
Number of sides sheltered	2		(20)
Shelter factor	0.85		(21)
Adjusted infiltration rate		0.49	(22)
Natural ventilation			
Effective air change rate		0.62	(25)
3. Heat losses and heat loss parameter			
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)
<u>Element</u>			
Doors	3.80	2.85	10.83 (26)
Windows	16.90	(2.70) 2.44	41.18 (27)
Ground floor	52.00	0.67	34.84 (28)
Walls	120.80	0.54	65.23 (29)
Roof	<u>52.00</u>	0.40	<u>20.80</u> (30)
Total area of elements	<u>245.50</u>		(32)
Fabric heat loss			172.88 (33)
Thermal bridges (0.15 × total area)			<u>36.83</u> (34)
Total fabric heat loss			209.71 (35)
Ventilation heat loss			<u>53.22</u> (36)
Heat loss coefficient			262.93 (37)
Heat loss parameter (HLP)			2.53 (38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		360	(48)
Total		3319	(49a)
Solar input		0	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

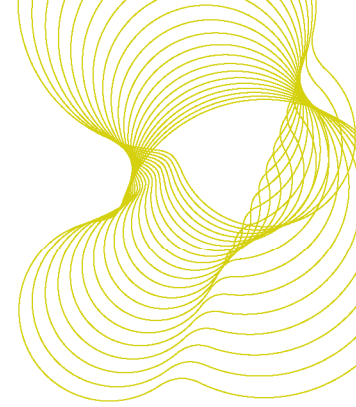
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 × 16.90	50	0.76	0.70	0.77	312	(58)
					total:	312	(65)
Total gains						1062	(66)
Gain/loss ratio						4.04	(67)
Utilisation factor						0.988	(68)
Useful gains						1050	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.81	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.00	(72)
Adjusted living area temperature		18.80	(73)
Temperature difference between zones		1.65	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		17.46	(77)

8. Degree-days

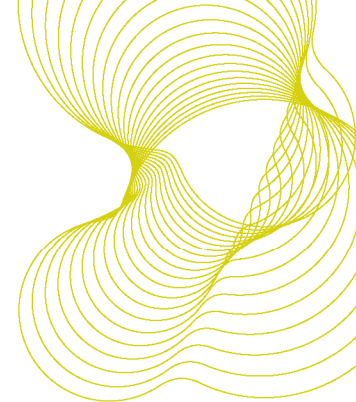
Temperature rise from gains		3.99	(78)
Base temperature		13.47	(79)
Degree-days		1662.4	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		9306	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		9306	(85)
Space heating fuel (secondary)		931	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

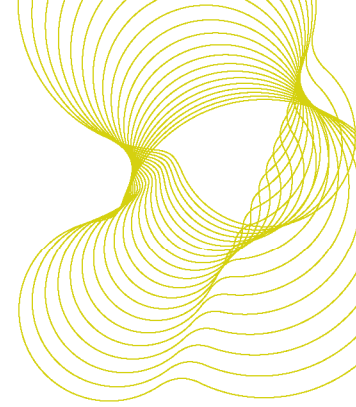
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	9306	0.194	1805	(101)
Space heating, secondary - box (85a)	931	0.422	393	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			2914	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			3315	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>31.87</u>	(113)



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Bing Part2 Existing SW_GW in Temperate Mediterranean (TM)

1. Overall dwelling dimensions			
	<u>Area</u>	<u>Av. storey</u>	<u>Volume</u>
	(m ²)	height (m)	(m ³)
Ground floor	52.00	2.40	124.80 (1)
First floor	<u>52.00</u>	2.60	<u>135.20</u> (2)
Total floor area	104.00		(5)
Dwelling volume (m ³)			260.00 (6)
2. Ventilation rate			
		<u>m³ per hour</u>	
Number of chimneys	0 × 40	0	(7)
Number of flues	0 × 20	0	(8)
Number of fans or passive vents	2 × 10	20	(9)
Number of flueless gas fires	0 × 40	0	(9a)
		<u>ach</u>	
Infiltration due to chimneys, flues and fans		0.08	(10)
Pressure test	Yes		
Measured/design q50	10.0		
Infiltration rate		0.58	(19)
Number of sides sheltered	2		(20)
Shelter factor	0.85		(21)
Adjusted infiltration rate		0.49	(22)
Natural ventilation			
Effective air change rate		0.62	(25)
3. Heat losses and heat loss parameter			
	<u>Area</u>	<u>U-value</u>	<u>A × U</u>
<u>Element</u>	(m ²)	(W/m ² K)	(W/K)
Doors	3.80	2.85	10.83 (26)
Windows	16.90	(2.70) 2.44	41.18 (27)
Ground floor	52.00	0.67	34.84 (28)
Walls	120.80	0.54	65.23 (29)
Roof	<u>52.00</u>	0.40	<u>20.80</u> (30)
Total area of elements	<u>245.50</u>		(32)
Fabric heat loss			172.88 (33)
Thermal bridges (0.15 × total area)			<u>36.83</u> (34)
Total fabric heat loss			209.71 (35)
Ventilation heat loss			<u>53.22</u> (36)
Heat loss coefficient			262.93 (37)
Heat loss parameter (HLP)			2.53 (38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		360	(48)
Total		3319	(49a)
Solar input		0	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

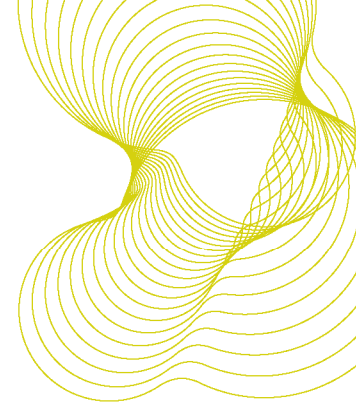
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>	<u>Gains (W)</u>
East/West	0.9 × 16.90	68	0.76	0.70	0.77	424
					total:	424
						(58)
						(65)
Total gains						1174
Gain/loss ratio						4.47
Utilisation factor						0.982
Useful gains						1154
						(66)
						(67)
						(68)
						(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.81	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.08	(72)
Adjusted living area temperature		18.88	(73)
Temperature difference between zones		1.65	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		17.54	(77)

8. Degree-days

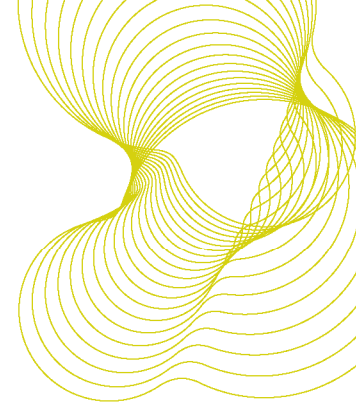
Temperature rise from gains		4.39	(78)
Base temperature		13.15	(79)
Degree-days		1593.0	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		7610	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		7610	(85)
Space heating fuel (secondary)		761	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

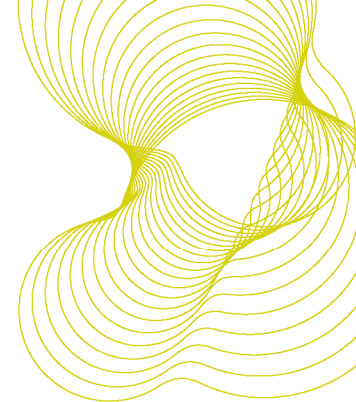
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	7610	0.194	1476	(101)
Space heating, secondary - box (85a)	761	0.422	321	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			2513	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			2914	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>kg/m²/year</u> 28.02	(113)



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Bing Part2 Existing SW_GW in Cool Continental (CC)

1. Overall dwelling dimensions			
	Area (m ²)	Av. storey height (m)	Volume (m ³)
Ground floor	52.00	2.40	124.80 (1)
First floor	<u>52.00</u>	2.60	<u>135.20</u> (2)
Total floor area	104.00		(5)
Dwelling volume (m ³)			260.00 (6)
2. Ventilation rate			
		<u>m³ per hour</u>	
Number of chimneys	0 × 40	0	(7)
Number of flues	0 × 20	0	(8)
Number of fans or passive vents	2 × 10	20	(9)
Number of flueless gas fires	0 × 40	0	(9a)
		<u>ach</u>	
Infiltration due to chimneys, flues and fans		0.08	(10)
Pressure test	Yes		
Measured/design q50	10.0		
Infiltration rate		0.58	(19)
Number of sides sheltered	2		(20)
Shelter factor	0.85		(21)
Adjusted infiltration rate		0.49	(22)
Natural ventilation			
Effective air change rate		0.62	(25)
3. Heat losses and heat loss parameter			
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)
<u>Element</u>			
Doors	3.80	2.85	10.83 (26)
Windows	16.90	(2.70) 2.44	41.18 (27)
Ground floor	52.00	0.67	34.84 (28)
Walls	120.80	0.54	65.23 (29)
Roof	<u>52.00</u>	0.40	<u>20.80</u> (30)
Total area of elements	<u>245.50</u>		(32)
Fabric heat loss			172.88 (33)
Thermal bridges (0.15 × total area)			<u>36.83</u> (34)
Total fabric heat loss			209.71 (35)
Ventilation heat loss			<u>53.22</u> (36)
Heat loss coefficient			262.93 (37)
Heat loss parameter (HLP)			2.53 (38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		360	(48)
Total		3319	(49a)
Solar input		0	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

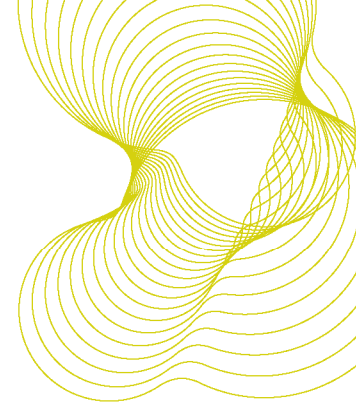
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>	<u>Gains (W)</u>
East/West	0.9 × 16.90	46	0.76	0.70	0.77	287
					total:	287
						(58)
						(65)
Total gains						1037
Gain/loss ratio						3.95
Utilisation factor						0.990
Useful gains						1027
						(66)
						(67)
						(68)
						(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.81	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		-0.02	(72)
Adjusted living area temperature		18.79	(73)
Temperature difference between zones		1.65	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		17.44	(77)

8. Degree-days

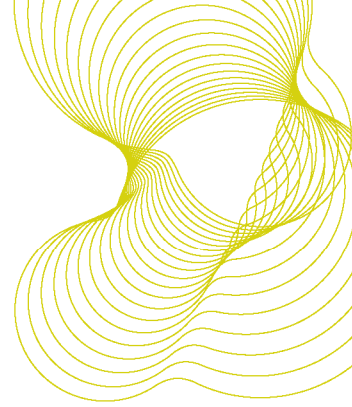
Temperature rise from gains		3.90	(78)
Base temperature		13.54	(79)
Degree-days		1678.0	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		19303	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		19303	(85)
Space heating fuel (secondary)		1930	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

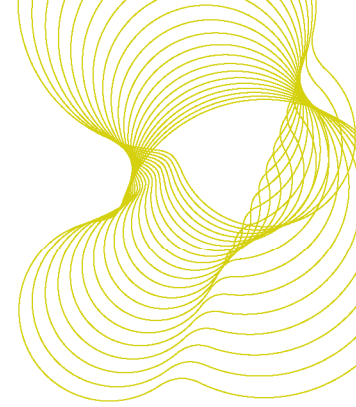
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	19303	0.194	3745	(101)
Space heating, secondary - box (85a)	1930	0.422	815	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			5275	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			5676	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>54.58</u>	(113)



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Bing Part2 Existing PU in Temperate Oceanic (TO)

1. Overall dwelling dimensions				
	Area (m ²)	Av. storey height (m)	Volume (m ³)	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q50	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)	
<u>Element</u>				
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.70) 2.44	41.18	(27)
Ground floor	52.00	0.67	34.84	(28)
Walls	120.80	0.36	43.49	(29)
Roof	<u>52.00</u>	0.40	<u>20.80</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			151.14	(33)
Thermal bridges (0.15 × total area)			<u>36.83</u>	(34)
Total fabric heat loss			187.97	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			241.18	(37)
Heat loss parameter (HLP)			2.32	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		360	(48)
Total		3319	(49a)
Solar input		0	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

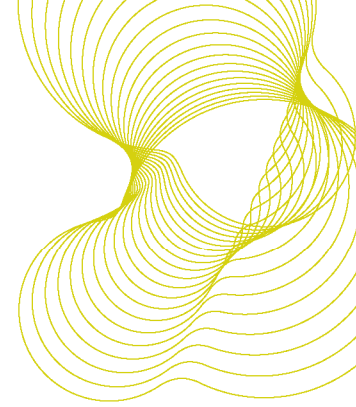
<u>Orientation</u>		<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 ×	16.90	50	0.76	0.70	0.77	312	(58)
						total:	312	(65)
Total gains							1062	(66)
Gain/loss ratio							4.40	(67)
Utilisation factor							0.983	(68)
Useful gains							1044	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.82	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.07	(72)
Adjusted living area temperature		18.89	(73)
Temperature difference between zones		1.62	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		17.57	(77)

8. Degree-days

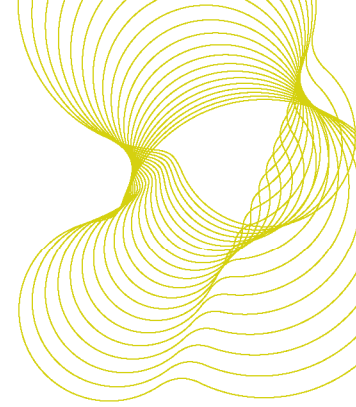
Temperature rise from gains		4.33	(78)
Base temperature		13.24	(79)
Degree-days		1612.9	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		8252	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		8252	(85)
Space heating fuel (secondary)		825	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

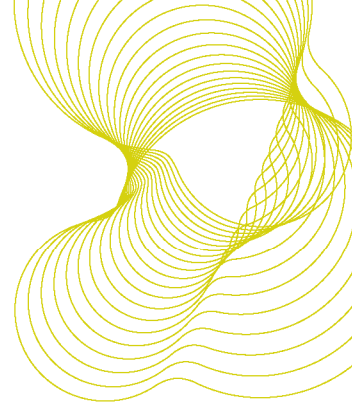
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	8252	0.194	1601	(101)
Space heating, secondary - box (85a)	825	0.422	348	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			2665	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			3066	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>29.48</u>	(113)



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Bing Part2 Existing PU in Temperate Mediterranean (TM)

1. Overall dwelling dimensions				
	Area	Av. storey	Volume	
	(m ²)	height (m)	(m ³)	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q50	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	Area	U-value	A × U	
<u>Element</u>	<u>(m²)</u>	<u>(W/m²K)</u>	<u>(W/K)</u>	
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.70) 2.44	41.18	(27)
Ground floor	52.00	0.67	34.84	(28)
Walls	120.80	0.36	43.49	(29)
Roof	<u>52.00</u>	0.40	<u>20.80</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			151.14	(33)
Thermal bridges (0.15 × total area)			<u>36.83</u>	(34)
Total fabric heat loss			187.97	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			241.18	(37)
Heat loss parameter (HLP)			2.32	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		<u>360</u>	(48)
Total		3319	(49a)
Solar input		<u>0</u>	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

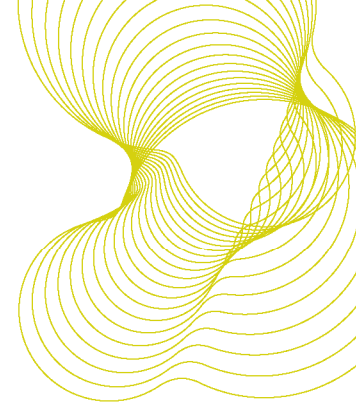
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 × 16.90	68	0.76	0.70	0.77	424	(58)
					total:	424	(65)
Total gains						1174	(66)
Gain/loss ratio						4.87	(67)
Utilisation factor						0.975	(68)
Useful gains						1145	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.82	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.15	(72)
Adjusted living area temperature		18.97	(73)
Temperature difference between zones		1.62	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		17.65	(77)

8. Degree-days

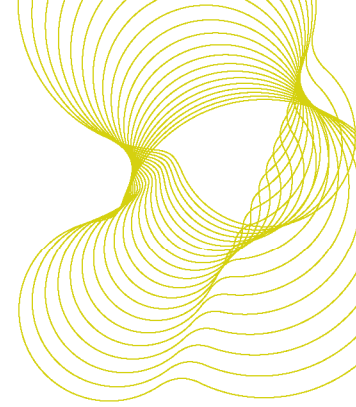
Temperature rise from gains		4.75	(78)
Base temperature		12.91	(79)
Degree-days		1539.3	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		6734	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		6734	(85)
Space heating fuel (secondary)		673	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

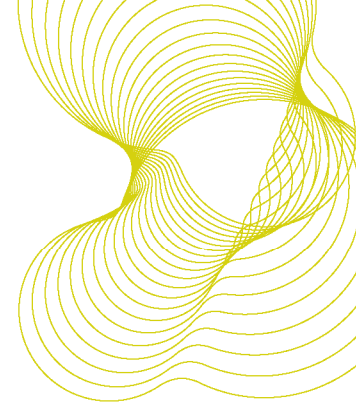
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	6734	0.194	1306	(101)
Space heating, secondary - box (85a)	673	0.422	284	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			2306	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			2707	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>kg/m²/year</u> 26.03	(113)



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Approved Document L1A, 2006 Edition

Bing Part2 Existing PU in Cool Continental (CC)

1. Overall dwelling dimensions				
	Area (m ²)	Av. storey height (m)	Volume (m ³)	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q50	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)	
<u>Element</u>				
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.70) 2.44	41.18	(27)
Ground floor	52.00	0.67	34.84	(28)
Walls	120.80	0.36	43.49	(29)
Roof	<u>52.00</u>	0.40	<u>20.80</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			151.14	(33)
Thermal bridges (0.15 × total area)			<u>36.83</u>	(34)
Total fabric heat loss			187.97	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			241.18	(37)
Heat loss parameter (HLP)			2.32	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		<u>360</u>	(48)
Total		3319	(49a)
Solar input		<u>0</u>	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

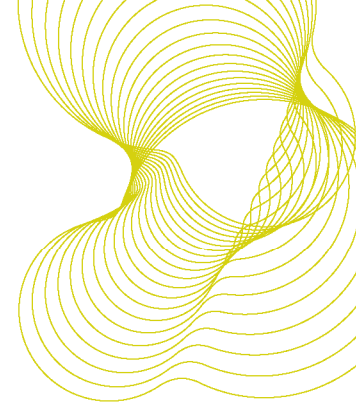
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 × 16.90	46	0.76	0.70	0.77	<u>287</u>	(58)
					total:	<u>287</u>	(65)
Total gains						1037	(66)
Gain/loss ratio						4.30	(67)
Utilisation factor						0.985	(68)
Useful gains						1022	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.82	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.05	(72)
Adjusted living area temperature		18.87	(73)
Temperature difference between zones		1.62	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		17.55	(77)

8. Degree-days

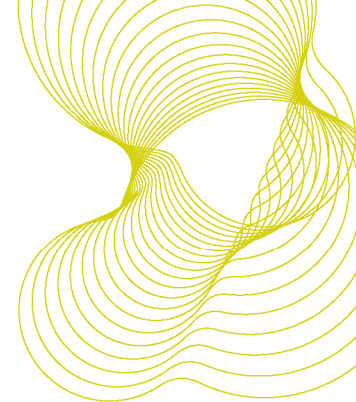
Temperature rise from gains		4.24	(78)
Base temperature		13.32	(79)
Degree-days		1629.6	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		17403	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		17403	(85)
Space heating fuel (secondary)		1740	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

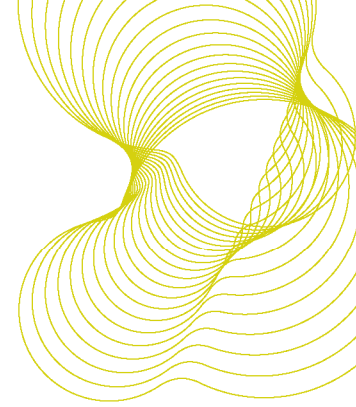
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	17403	0.194	3376	(101)
Space heating, secondary - box (85a)	1740	0.422	734	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			4826	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			5227	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>50.26</u>	(113)



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Bing Part2 Existing EPS in Temperate Oceanic (TO)

1. Overall dwelling dimensions				
	Area (m ²)	Av. storey height (m)	Volume (m ³)	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q50	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)	
<u>Element</u>				
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.70) 2.44	41.18	(27)
Ground floor	52.00	0.67	34.84	(28)
Walls	120.80	0.47	56.78	(29)
Roof	<u>52.00</u>	0.40	<u>20.80</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			164.43	(33)
Thermal bridges (0.15 × total area)			<u>36.83</u>	(34)
Total fabric heat loss			201.25	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			254.47	(37)
Heat loss parameter (HLP)			2.45	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		360	(48)
Total		3319	(49a)
Solar input		0	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

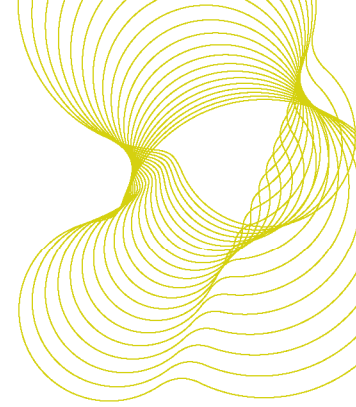
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 × 16.90	50	0.76	0.70	0.77	312	(58)
					total:	312	(65)
Total gains						1062	(66)
Gain/loss ratio						4.17	(67)
Utilisation factor						0.987	(68)
Useful gains						1048	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.81	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.02	(72)
Adjusted living area temperature		18.84	(73)
Temperature difference between zones		1.64	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		17.50	(77)

8. Degree-days

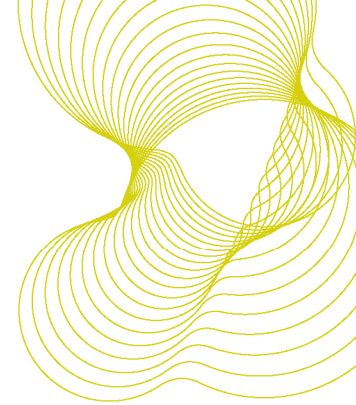
Temperature rise from gains		4.12	(78)
Base temperature		13.38	(79)
Degree-days		1644.3	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		8897	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		8897	(85)
Space heating fuel (secondary)		890	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

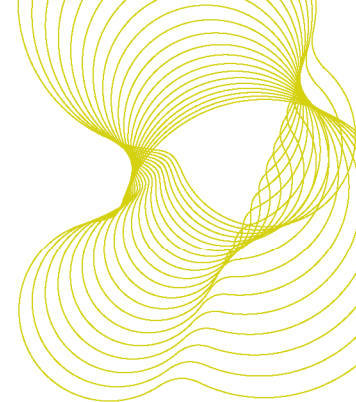
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	8897	0.194	1726	(101)
Space heating, secondary - box (85a)	890	0.422	375	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			2817	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			3218	(112)
			<u>kg/m²/year</u>	
Dwelling Carbon Dioxide Emission Rate (DER)			30.95	(113)



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Bing Part2 Existing EPS in Temperate Mediterranean (TM)

1. Overall dwelling dimensions				
	Area	Av. storey	Volume	
	(m ²)	height (m)	(m ³)	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q50	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	Area	U-value	A × U	
<u>Element</u>	<u>(m²)</u>	<u>(W/m²K)</u>	<u>(W/K)</u>	
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.70) 2.44	41.18	(27)
Ground floor	52.00	0.67	34.84	(28)
Walls	120.80	0.47	56.78	(29)
Roof	<u>52.00</u>	0.40	<u>20.80</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			164.43	(33)
Thermal bridges (0.15 × total area)			<u>36.83</u>	(34)
Total fabric heat loss			201.25	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			254.47	(37)
Heat loss parameter (HLP)			2.45	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		360	(48)
Total		3319	(49a)
Solar input		0	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

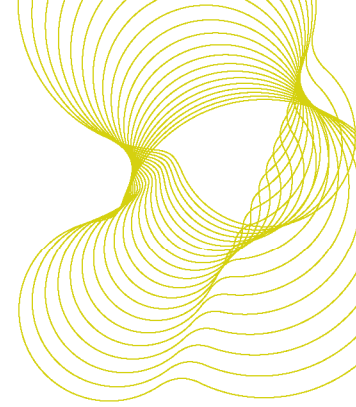
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>	<u>Gains (W)</u>
East/West	0.9 × 16.90	68	0.76	0.70	0.77	424
					total:	424
						(58)
						(65)
Total gains						1174
Gain/loss ratio						4.62
Utilisation factor						0.980
Useful gains						1151
						(66)
						(67)
						(68)
						(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.81	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.10	(72)
Adjusted living area temperature		18.92	(73)
Temperature difference between zones		1.64	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		17.58	(77)

8. Degree-days

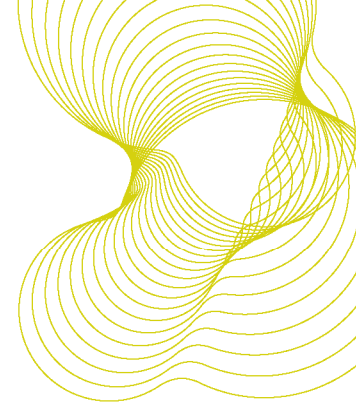
Temperature rise from gains		4.52	(78)
Base temperature		13.06	(79)
Degree-days		1573.4	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		7270	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		7270	(85)
Space heating fuel (secondary)		727	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

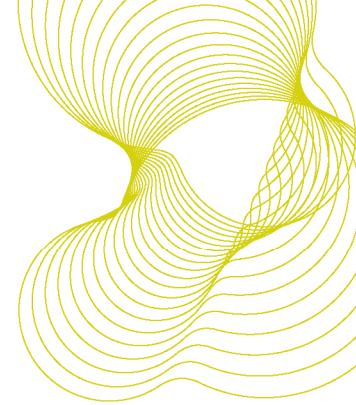
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	7270	0.194	1410	(101)
Space heating, secondary - box (85a)	727	0.422	307	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			2433	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			2834	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>27.25</u>	(113)



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Approved Document L1A, 2006 Edition

Bing Part2 Existing EPS in Cool Continental (CC)

1. Overall dwelling dimensions				
	Area (m ²)	Av. storey height (m)	Volume (m ³)	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q50	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)	
<u>Element</u>				
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.70) 2.44	41.18	(27)
Ground floor	52.00	0.67	34.84	(28)
Walls	120.80	0.47	56.78	(29)
Roof	<u>52.00</u>	0.40	<u>20.80</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			164.43	(33)
Thermal bridges (0.15 × total area)			<u>36.83</u>	(34)
Total fabric heat loss			201.25	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			254.47	(37)
Heat loss parameter (HLP)			2.45	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		<u>360</u>	(48)
Total		3319	(49a)
Solar input		<u>0</u>	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

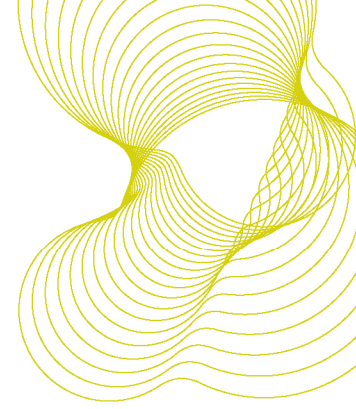
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 × 16.90	46	0.76	0.70	0.77	<u>287</u>	(58)
					total:	<u>287</u>	(65)
Total gains						1037	(66)
Gain/loss ratio						4.08	(67)
Utilisation factor						0.988	(68)
Useful gains						1025	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.81	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.01	(72)
Adjusted living area temperature		18.82	(73)
Temperature difference between zones		1.64	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		17.48	(77)

8. Degree-days

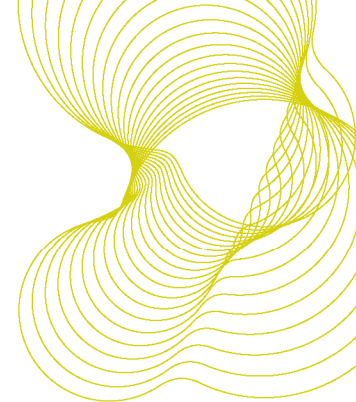
Temperature rise from gains		4.03	(78)
Base temperature		13.46	(79)
Degree-days		1660.4	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		18566	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		18566	(85)
Space heating fuel (secondary)		1857	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

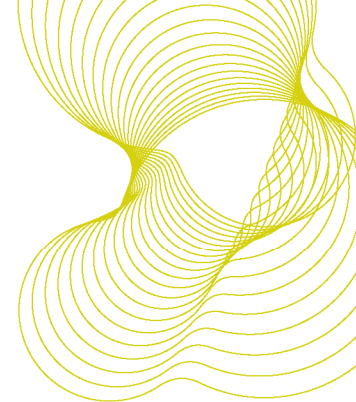
10a and 11a do not apply

12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	18566	0.194	3602	(101)
Space heating, secondary - box (85a)	1857	0.422	783	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			5101	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			5502	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>52.90</u>	(113)



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1. Overall dwelling dimensions				
	<u>Area</u> (m ²)	<u>Av. storey</u> <u>height (m)</u>	<u>Volume</u> (m ³)	
Ground floor	52.00	2.40	124.80	(1)
First floor	<u>52.00</u>	2.60	<u>135.20</u>	(2)
Total floor area	104.00			(5)
Dwelling volume (m ³)			260.00	(6)
2. Ventilation rate				
		<u>m³ per hour</u>		
Number of chimneys	0 × 40	0		(7)
Number of flues	0 × 20	0		(8)
Number of fans or passive vents	2 × 10	20		(9)
Number of flueless gas fires	0 × 40	0		(9a)
			<u>ach</u>	
Infiltration due to chimneys, flues and fans			0.08	(10)
Pressure test	Yes			
Measured/design q50	10.0			
Infiltration rate			0.58	(19)
Number of sides sheltered	2			(20)
Shelter factor	0.85			(21)
Adjusted infiltration rate			0.49	(22)
Natural ventilation				
Effective air change rate			0.62	(25)
3. Heat losses and heat loss parameter				
	<u>Area</u> (m ²)	<u>U-value</u> (W/m ² K)	<u>A × U</u> (W/K)	
<u>Element</u>				
Doors	3.80	2.85	10.83	(26)
Windows	16.90	(2.10) 1.94	32.74	(27)
Ground floor	52.00	0.18	9.36	(28)
Walls	120.80	0.15	18.12	(29)
Roof	<u>52.00</u>	0.15	<u>7.80</u>	(30)
Total area of elements	<u>245.50</u>			(32)
Fabric heat loss			78.85	(33)
Thermal bridges (0.08 × total area)			<u>19.64</u>	(34)
Total fabric heat loss			98.49	(35)
Ventilation heat loss			<u>53.22</u>	(36)
Heat loss coefficient			151.71	(37)
Heat loss parameter (HLP)			1.46	(38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		<u>360</u>	(48)
Total		3319	(49a)
Solar input		<u>0</u>	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

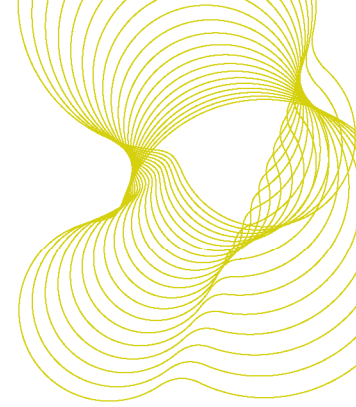
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 × 16.90	50	0.72	0.70	0.77	<u>295</u>	(58)
					total:	295	(65)
Total gains						1046	(66)
Gain/loss ratio						6.89	(67)
Utilisation factor						0.927	(68)
Useful gains						969	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.88	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.48	(72)
Adjusted living area temperature		19.36	(73)
Temperature difference between zones		1.48	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		18.15	(77)

8. Degree-days

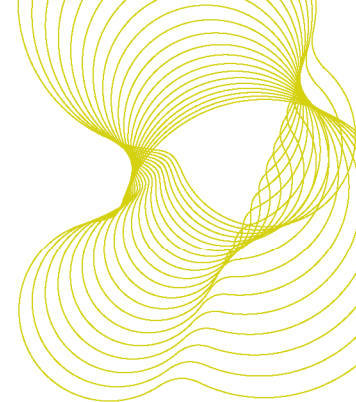
Temperature rise from gains		6.39	(78)
Base temperature		11.76	(79)
Degree-days		1295.1	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		4059	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		4059	(85)
Space heating fuel (secondary)		406	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

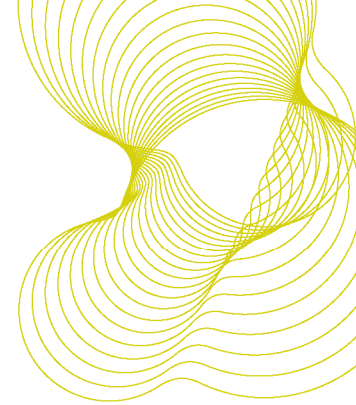
12a. <u>Carbon dioxide emissions</u>		<u>Energy</u>	<u>Emission</u>	<u>Emissions</u>	
		<u>(kWh/year)</u>	<u>factor</u>	<u>(kg/year)</u>	
Space heating, main - box (85)		4059	0.194	788	(101)
Space heating, secondary - box (85a)		406	0.422	171	(102)
Water heating - box (86a)		3688	0.194	716	(103)
Space and water heating				1674	(107)
Pumps and fans - box (87)		130	0.422	55	(108)
Electricity for lighting		821	0.422	346	(109)
Total kg/year				2076	(112)
Dwelling Carbon Dioxide Emission Rate (DER)				<u>kg/m²/year</u>	
				19.96	(113)



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Bing Part 3 - Newbuild Flat Roof in Temperate Mediterranean (TM)

1. Overall dwelling dimensions			
	Area (m ²)	Av. storey height (m)	Volume (m ³)
Ground floor	52.00	2.40	124.80 (1)
First floor	<u>52.00</u>	2.60	<u>135.20</u> (2)
Total floor area	104.00		(5)
Dwelling volume (m ³)			260.00 (6)
2. Ventilation rate			
		<u>m³ per hour</u>	
Number of chimneys	0 × 40	0	(7)
Number of flues	0 × 20	0	(8)
Number of fans or passive vents	2 × 10	20	(9)
Number of flueless gas fires	0 × 40	0	(9a)
		<u>ach</u>	
Infiltration due to chimneys, flues and fans		0.08	(10)
Pressure test	Yes		
Measured/design q50	10.0		
Infiltration rate		0.58	(19)
Number of sides sheltered	2		(20)
Shelter factor	0.85		(21)
Adjusted infiltration rate		0.49	(22)
Natural ventilation			
Effective air change rate		0.62	(25)
3. Heat losses and heat loss parameter			
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)
<u>Element</u>			
Doors	3.80	2.85	10.83 (26)
Windows	16.90	(2.10) 1.94	32.74 (27)
Ground floor	52.00	0.18	9.36 (28)
Walls	120.80	0.15	18.12 (29)
Roof	<u>52.00</u>	0.15	<u>7.80</u> (30)
Total area of elements	<u>245.50</u>		(32)
Fabric heat loss			78.85 (33)
Thermal bridges (0.08 × total area)			<u>19.64</u> (34)
Total fabric heat loss			98.49 (35)
Ventilation heat loss			<u>53.22</u> (36)
Heat loss coefficient			151.71 (37)
Heat loss parameter (HLP)			1.46 (38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		360	(48)
Total		3319	(49a)
Solar input		0	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

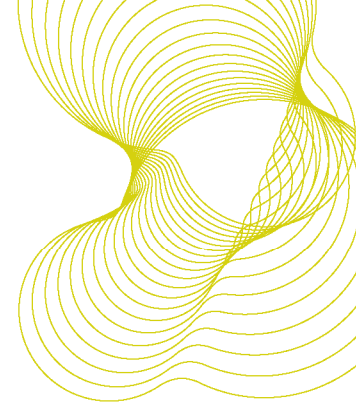
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 × 16.90	68	0.72	0.70	0.77	401	(58)
					total:	401	(65)
Total gains						1152	(66)
Gain/loss ratio						7.59	(67)
Utilisation factor						0.907	(68)
Useful gains						1044	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.88	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.58	(72)
Adjusted living area temperature		19.46	(73)
Temperature difference between zones		1.48	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		18.25	(77)

8. Degree-days

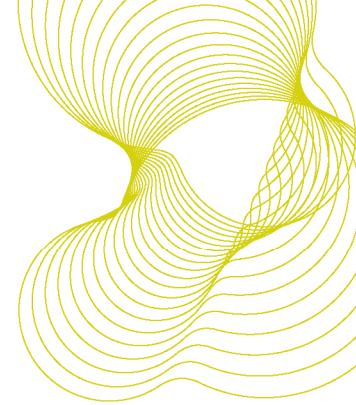
Temperature rise from gains		6.88	(78)
Base temperature		11.36	(79)
Degree-days		1213.0	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		3317	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		3317	(85)
Space heating fuel (secondary)		332	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

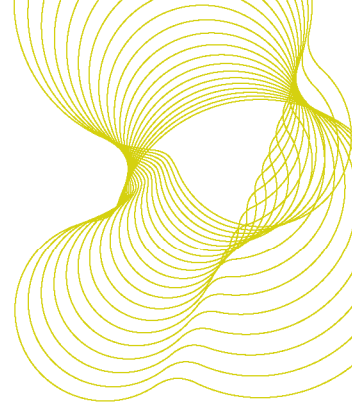
12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	3317	0.194	643	(101)
Space heating, secondary - box (85a)	332	0.422	140	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			1499	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			1900	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>18.27</u>	(113)



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1. Overall dwelling dimensions			
	Area (m ²)	Av. storey height (m)	Volume (m ³)
Ground floor	52.00	2.40	124.80 (1)
First floor	<u>52.00</u>	2.60	<u>135.20</u> (2)
Total floor area	104.00		(5)
Dwelling volume (m ³)			260.00 (6)
2. Ventilation rate			
		<u>m³ per hour</u>	
Number of chimneys	0 × 40	0	(7)
Number of flues	0 × 20	0	(8)
Number of fans or passive vents	2 × 10	20	(9)
Number of flueless gas fires	0 × 40	0	(9a)
		<u>ach</u>	
Infiltration due to chimneys, flues and fans		0.08	(10)
Pressure test	Yes		
Measured/design q50	10.0		
Infiltration rate		0.58	(19)
Number of sides sheltered	2		(20)
Shelter factor	0.85		(21)
Adjusted infiltration rate		0.49	(22)
Natural ventilation			
Effective air change rate		0.62	(25)
3. Heat losses and heat loss parameter			
	Area (m ²)	U-value (W/m ² K)	A × U (W/K)
<u>Element</u>			
Doors	3.80	2.85	10.83 (26)
Windows	16.90	(2.10) 1.94	32.74 (27)
Ground floor	52.00	0.18	9.36 (28)
Walls	120.80	0.15	18.12 (29)
Roof	<u>52.00</u>	0.15	<u>7.80</u> (30)
Total area of elements	<u>245.50</u>		(32)
Fabric heat loss			78.85 (33)
Thermal bridges (0.08 × total area)			<u>19.64</u> (34)
Total fabric heat loss			98.49 (35)
Ventilation heat loss			<u>53.22</u> (36)
Heat loss coefficient			151.71 (37)
Heat loss parameter (HLP)			1.46 (38)



4. Water heating energy requirements

		<u>kWh/year</u>	
Energy content of heated water		2152	(39)
Distribution loss		380	(40)
Cylinder volume	120		(43)
Cylinder loss factor (kWh/litre/day)	0.0181		(44)
Volume factor	1.000		(44a)
Temperature factor	0.54		(44b)
Energy lost from cylinder in kWh/year (120 litres)		428	(47)
Primary circuit loss		<u>360</u>	(48)
Total		3319	(49a)
Solar input		<u>0</u>	(50)
Output from water heater		3319	(51)
Heat gains from water heating		1472	(52)

5. Internal gains

		<u>Watts</u>	
Lights, appliances, cooking and metabolic		594	(53)
Reduction in lighting gains		-22	(53a)
Additional gains (Table 5a)		10	(53b)
Water heating		168	(54)
Total internal gains		751	(55)

6. Solar gains

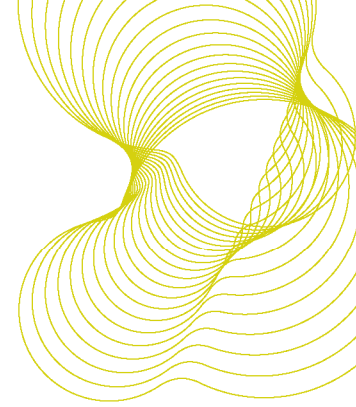
<u>Orientation</u>	<u>Area</u>	<u>Flux</u>	<u>g</u>	<u>FF</u>	<u>Shading</u>		<u>Gains (W)</u>
East/West	0.9 × 16.90	46	0.72	0.70	0.77	<u>272</u>	(58)
					total:	272	(65)
Total gains						1022	(66)
Gain/loss ratio						6.74	(67)
Utilisation factor						0.931	(68)
Useful gains						952	(69)

7. Mean internal temperature

		<u>°C</u>	
Mean temperature of the living area		18.88	(70)
Temperature adjustment from Table 4e		0.00	(71)
Adjustment for gains		0.45	(72)
Adjusted living area temperature		19.33	(73)
Temperature difference between zones		1.48	(74)
Living area fraction		0.186	(75)
Rest-of-house area fraction		0.814	(76)
Mean internal temperature		18.13	(77)

8. Degree-days

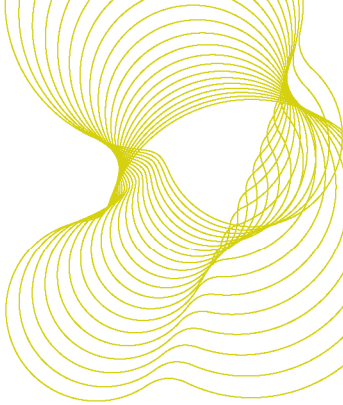
Temperature rise from gains		6.27	(78)
Base temperature		11.85	(79)
Degree-days		1314.5	(80)



9a. <u>Energy requirements</u>		<u>kWh/year</u>	
Space heating requirement (useful)		9691	(81)
Fraction of heat from secondary system (assumed for the calculation)	0.10		(82)
Efficiency of main heating system	90.0		(83)
Efficiency of secondary heating system	100		(84)
Space heating fuel (main)		9691	(85)
Space heating fuel (secondary)		969	(85a)
Water heating requirement	3319		
Efficiency of water heater	90.0		(86)
Water heating fuel		3688	(86a)
Electricity for pumps and fans		130	(87)
Electricity for lighting (30% fixed LEL)		821	(87g)

10a and 11a do not apply

12a. <u>Carbon dioxide emissions</u>	<u>Energy (kWh/year)</u>	<u>Emission factor</u>	<u>Emissions (kg/year)</u>	
Space heating, main - box (85)	9691	0.194	1880	(101)
Space heating, secondary - box (85a)	969	0.422	409	(102)
Water heating - box (86a)	3688	0.194	716	(103)
Space and water heating			3005	(107)
Pumps and fans - box (87)	130	0.422	55	(108)
Electricity for lighting	821	0.422	346	(109)
Total kg/year			3406	(112)
Dwelling Carbon Dioxide Emission Rate (DER)			<u>kg/m²/year</u> 32.75	(113)



Appendix 5

Life cycle stages impacts of PU insulation

The graphs below present the environmental impacts associated with the life cycle divided into the stages of manufacture, transport to site and disposal.

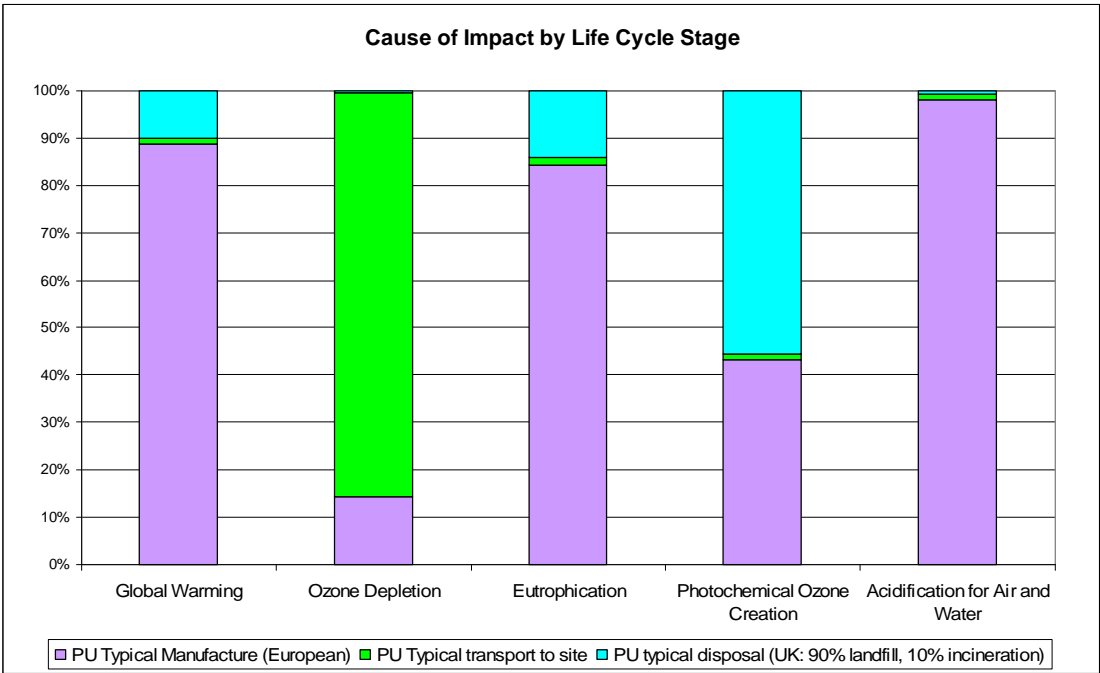


Figure (A) Characterised impact of 1 tonne of PU insulation by life cycle stage.

Figure A shows that the manufacture of the PU insulation dominates the impact categories Global Warming, Eutrophication and Acidification for Air and Water, and is also important in the Photochemical Ozone Creation category. Transport dominates the Ozone Depletion impact category.

Figure B below presents this data normalised to the annual impacts of a Western European citizen to show the relative sizes of these impact categories for each life cycle stage.

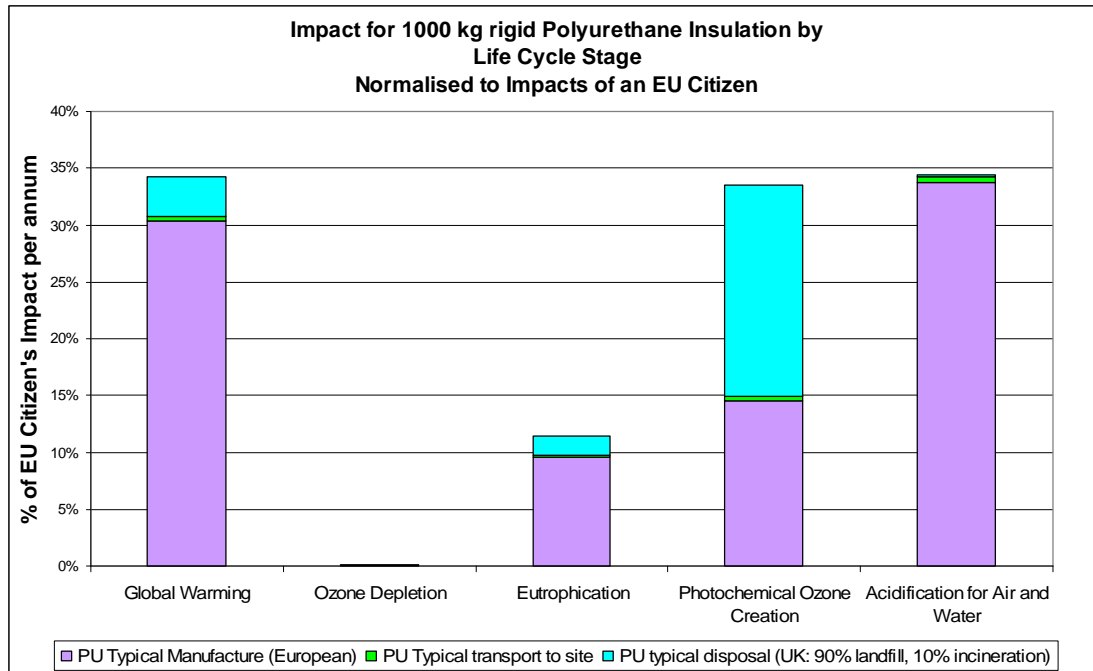
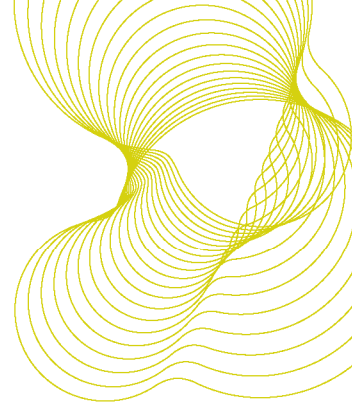


Figure (B) Normalised impact of 1 tonne of PU insulation by life cycle stage.

Figure B shows that Global Warming, Acidification for Air and Water and Photochemical Ozone Creation are the largest relative impacts, followed by Eutrophication. The impacts in Ozone Depletion are shown to be very small relative to the background level of impact in this category.