Passivhaus Options Report

Using the Passivhaus Planning Package (PHPP)

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Client	Lancaster West Neighbourhood team W11	Project Number	E2536
Status	Comment	Project Name	Lancaster West, Morland House
By	IS	Document	301 (PHPP) – Options Report
Checked	AB	Reason for Revision	Update following meeting on 20/07/2020
Revision/Date	A – 31/07/2020		

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1.0 Introduction

This report sets out several options with the aim of achieving the Passivhaus Institutes standard for existing buildings. It has been compiled using the Passivhaus Planning Package (PHPP) version 9.6. The report is split down to look at how improvements to the various elements of the building can be improved with options and then combined into a number of combinations to meet the AECB Standard, then the retrofit standard EnerPHit and finally full Passivhaus. If required these can then be upgraded to Plus or Premium if combined with enough renewable technologies.

1.1 Passivhaus Standard

A Passivhaus is designed to deliver a comfortable, healthy, high-quality building with low running costs, in any building type. Most of our time is spent indoors, therefore it is important that our buildings are healthy and happy places to be. A Passivhaus is an energy-efficient building with all year-round comfort with minimal use of space heating or cooling systems.

The primary focus whilst designing, building and retrofitting to the Passivhaus Standard is directed towards creating a thermally efficient envelope which optimises free heat gains (such as solar and heat from cooking and showering) to minimise the home's space heating requirements. A draught free, carefully detailed building, with a good form factor is essential.

To ventilate a Passivhaus a mechanical ventilation system with heat recovery (MVHR) is used, providing fresh, filtered air to the whole building. The idea is that incoming fresh air is pre-heated via a heat exchanger by outgoing warm stale air, without the fresh air mixing with the outgoing air.

To maintain high comfort levels in any building, heat losses must be replaced by heat gains. Heat losses occur through poorly insulated walls, floors, ceilings, as well as through leaky construction and poorly fitted windows and doors. Ensuring all these issues are carefully considered results in a smaller space heating system being required in a Passivhaus compared to a standard dwelling.

The energy requirements of a house built to the Passivhaus Standard are:

- Annual space heating requirement of 15 kWh/(m^{2}a) treated floor area;
- The upper limit for total primary energy demand for space and water heating, ventilation, electricity for fans and pumps, household appliances, and lighting not exceeding 135 kWh/(m^{2}a), regardless of energy source; and
- The frequency of excessive internal temperature (> 25 °C) should be limited to ≤ 10 % but a level of ≤ 5 % is recommended;
- Additionally, the air-leakage test results must not exceed 0.6 air changes per hour (ac/hr) using 50 Pascal over-pressurisation and under-pressurisation testing.

As we move towards meeting zero energy targets, new standards are needed to confirm energy efficiency and overall sustainability standards. The Passivhaus Institute has introduced two further energy targets, which require some renewable energy production in addition to the original criteria: Passivhaus Plus and Passivhaus Premium. The diagram below represents how Passivhaus Plus and Premium relate to the rebranded Passivhaus Classic in terms of energy efficiency.

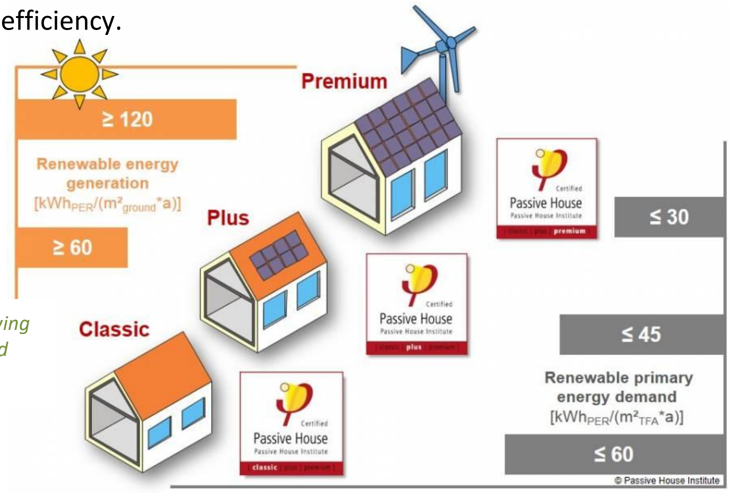


Diagram by Passivhaus Institute showing Passivhaus Standards Classic, Plus and Premium (www.passipedia.org)

1.2 Passivhaus EnerPHit Standard

It can be difficult to meet the requirements of Passivhaus for a new build and when retrofitting an existing building this can be even more complicated as the orientation and many fabric components are already set, and it may be problematic to retrospectively make some areas cold bridge free.

Certified Retrofit
Passive House Institute

Though it is possible in many circumstances to achieve the Passivhaus standard, often it may not be financially viable. A retrofit standard for existing homes has been developed by the Passivhaus Institute as an alternative option to ensure that Passivhaus principles can be effectively applied in retrofit projects, called EnerPHit.

The energy requirement of a building retrofitted to the EnerPHit Standard is:

- Annual space heating requirement of 20 kWh/(m2a) (London and
- South West England, 25 elsewhere in the UK) treated floor area;
- The upper limit for total primary energy demand for space and water heating, ventilation, electricity for fans and pumps, household appliances, and lighting not exceeding 135 kWh/(m2a), regardless of energy source; and
- The frequency of excessive internal temperature (> 25 °C) should be limited to ≤ 10 % but a level of ≤ 5 % is recommended;
- Additionally, the air-leakage test results must not exceed 1.0 air changes per hour (ac/hr) using 50 Pascal over-pressurisation and under-pressurisation testing.

1.3 EuroPHit Certification

EuroPHit aims to provide a solution to highly efficient retrofits by offering a step by step refurbishment option. Still with Passivhaus principles at its core, this certification process offers a solution to manage projects as individual steps ultimately achieving the EnerPHit standard. The energy requirements of a building retrofitted via this system are the same as the EnerPHit standard.

This process allows retrofitting to the best standard for each element or area, rather than "locking out" potential carbon savings. However, it does present additional challenges which need to be considered to avoid unintended consequences, particularly at intermediate stages. Many factors need to be considered before beginning on this process including building physics and financial implications.

1.4 AECB Building Standard

An alternative to the Passivhaus standard is the Association of Environment Conscious Builders' (AECB) Building Standard, previously called the AECB Silver Standard. It uses the same calculation methodology (PHPP), though is a 'self-certifying' scheme, allowing the certificate to be issued based on design drawings, reports and information without the need for a separate certifier.

The AECB Building Standard is aimed at those wishing to create higher-performance buildings using widely available materials. The AECB estimate that achieving the standard will reduce overall $CO2$ emissions by 70% compared to average UK regulation build. It is equally suitable for individual self-builders, large-scale residential and non-residential developers.

In additional to relying on the same calculation methodology as the Passivhaus standards the AECB system also focuses upon a fabric first methodology, making the most of passive design and technology to reduce energy demand and minimise lifecycle costs. Where the standards differ are the required targets, with the AECB building standard slightly less onerous. Also, the AECB no longer offers tiered options.

The energy requirement of a house or building built or retrofitted to the AECB Standard are:

Parameter	**Target**
Delivered heat and cooling	≤ 40kWh/(m^2.a)
Primary energy demand	135 Wh/(m^2.a)
Airtightness (n50)	≤ 1.5h-1 with MVHR ≤ 3h-1 with MEV
Thermal Bridges	$Psi_{external}$<0.01 W/m
Summer Overheating	<10% <5% recommended

2.0 Base Case Specifications

Using the survey details and, assumptions based on current and historic building regulations, and information that you have provided, a base case has been developed using the PHPP software. The development of the base case allows us to provide comparable options, which are specific to your home.

In the base case, we have assumed that the existing windows would be retained, and any new windows and doors would meet current building regulation standards.

Section 4.8 details the improvements possible with replacing the windows and improving the new specifications.

2.1 Building Elements Specification

Base Case Building Specifications used for PHPP calculations

Heat Loss Area	**U-Value** W/m²K
External Wall	1.54
Ground floor	1.70 (P/A corrected)
Flat roof	1.68
Skeiling and dormers	1.81
Doors	2.00

Windows	**U-Value** W/m²K
Single glazing	4.35

Airtightness	
At 50 Pascals	8 air changes per hour assumed

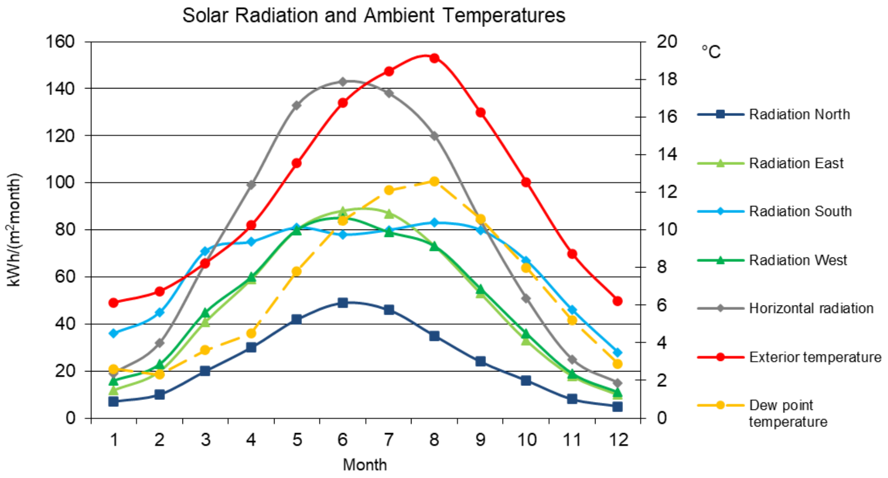
Ventilation
Natural ventilation via opening windows assumed

Thermal bridges	**Psi Value** W/mK
Foundation Wall junction	0.40
Balcony and Intermediate floor/external wall	0.40
Internal walls/ground floor	-0.02
Internal walls/external walls	0.51
Door threshold and jamb/head	0.25
SVP	0.632

2.2 Climate

The regional climate is set as Zone 01 - London (Warm-Temperate) (area 1 on map to the right), with the altitude of the site as 12m above sea level (6m lower than the climate data station).

The graph below demonstrates the solar radiation and ambient temperature of the regional climate. This information allows analysis of your homes heat loss and solar gain based on average monthly temperatures and hours of direct sunlight.



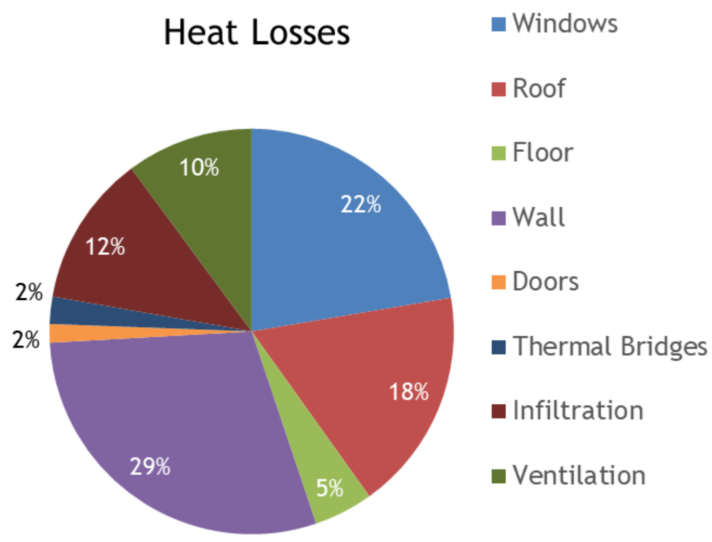
PHPP Climate Data, taken from the PHPP software, PHI

PHPP Regional Climates, taken from www.passivhaus.org.uk

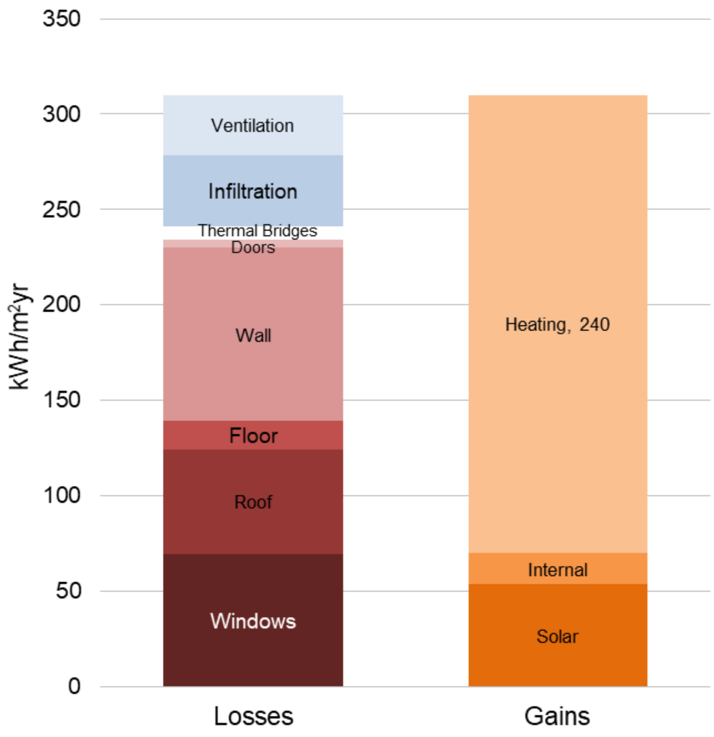
3.0 Base Case Results

These base case results have been produced assuming that the building will be heated to 20°C throughout the heating season, so this can be compared with the improved cases. In this building we would not expect this to be the case and so actual fuel usage is likely to be less.

We have currently assumed that none of the flats have been renovated and there is no insulation in the walls, roof and floor and the windows are single glazed.



No.	Option	Treated Floor Area	Space Heat Demand	Heating Load	Overheating Risk
		m^2	$kWh/(m^2a)$	W/m^2	%
1	**Base Case**	665.2	240.2	87.6	0.0%



3.1 Form Factor

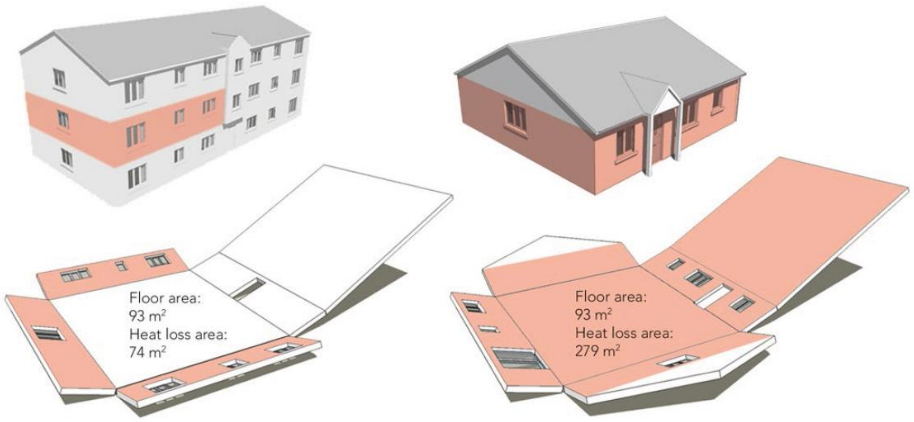
Form Factor describes the relationship between the external surface area and the internal Treated Floor Area (TFA). As heat is lost through every metre square of external fabric, reducing this area greatly increases performance.

Achieving a heat loss form factor of ≤ 3 is a useful benchmark guide when designing smaller Passivhaus buildings. In retrofit projects the form factor is usually fixed. To balance this, an increased thickness of insulation can be used.

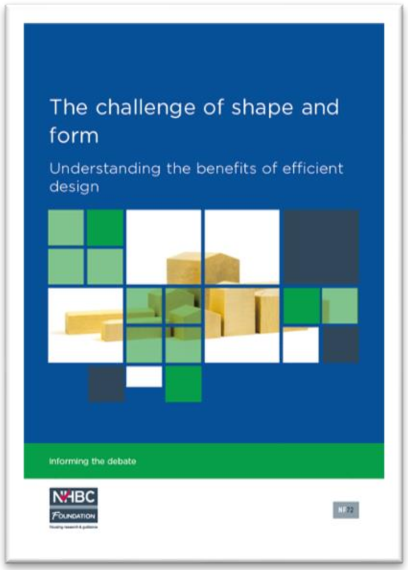
Morland House has a form factor of 1.78 which is very good.

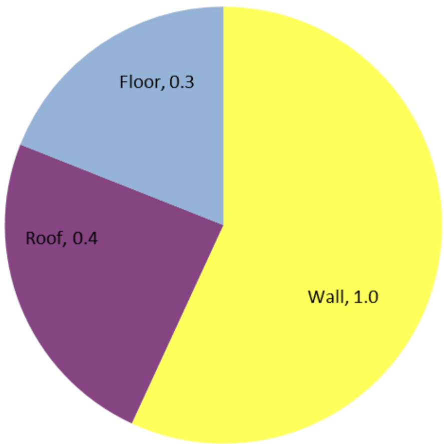
Further information on this can be found in the NHBC foundation document "NF72 The Challenge of Shape and Form", co-authored by Eco Design Consultants and downloadable from www.nhbcfoundation.org.

Increases in the surface area of a building can increase heat loss, and therefore to achieve the same energy efficiency would require additional insulation and cost.



The bungalow above has a poor form factor compared to the flat and uses more than double the energy





Heat loss form factor	
Wall	1.0
Roof	0.4
Floor	0.3
Total	1.7

3.2 Glazing

Glazing has a remarkable impact on the comfort of a building. Where there is a temperature differential of more than 4^0C between ambient room temperature and the inner pane of glass a down draft is created. Originating at the surface of the glass, cold air then pools on the floor in front of the window and travels across the floor. You feel this as a draft from the window, even before taking into account air leaks.

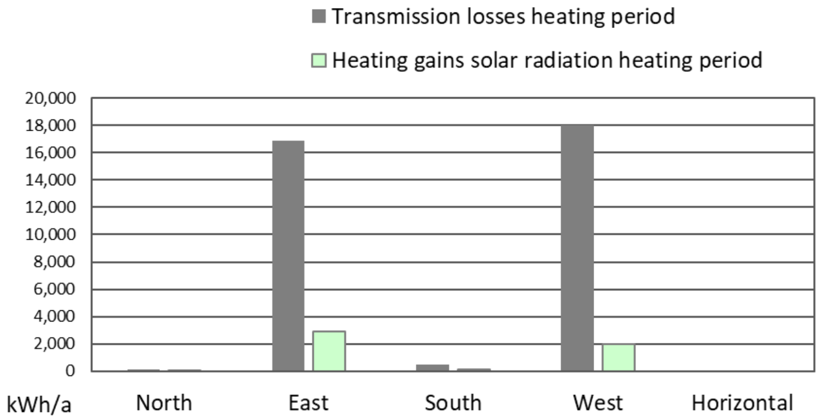
Window type, size and orientation should all be considered to balance passive solar heat gain against heat losses, minimise overheating risks and optimise architectural /aesthetic requirements.

The table on this page demonstrates the balance of passive solar heat gain and heat losses of the windows on each façade of your building.

They demonstrate that all windows currently lose more energy than they gain suggesting that the performance of the building would be improved if they were replaced or reduced in size. However, daylighting is important and should not be sacrificed to improve thermal performance beyond a minimal amount.

Window breakdown

	Losses kWh/a	**Heat gains** kWh/a	**Balance** kWh/a	**area m²** **(% of wall)**
North	97	4	-93	0.4 (0% of N. wall)
East	16899	2880	-14020	67.2 (29% of E. wall)
South	508	115	-393	2.2 (2% of S. wall)
West	18022	1984	-16037	71.7 (29% of W. wall)
Horizontal	0	0	0	0.00
Total	**35527**	**4983**	**-30543**	**141.4 (14% of wall+roof)**



3.3 Primary Energy

Primary energy is the source energy requirement. This is not to be confused with the energy delivered and metered but is the energy at source that includes the delivery and production losses. The requirement includes heating, hot water, lighting, controls, white goods, and allowances for cooking, and appliances. To achieve Passivhaus or EnerPHit standard the dwellings need to achieve less than 135kWh/m2yr.

Currently this has not been calculated. We would recommend that you have the primary energy calculated when you have agreed the heating strategy and energy demands.

4.0 Potential Improvements

This section identifies the potential options for improving the energy efficiency and performance of the proposed building, looking at each element in turn, and how this changes the buildings overall performance.

We will look at the following areas:

Wall Insulation

Floor Insulation

Roof Insulation

Skeilings and Dormers Insulation

Soffit Floor Insulation

Windows

Airtightness and Ventilation

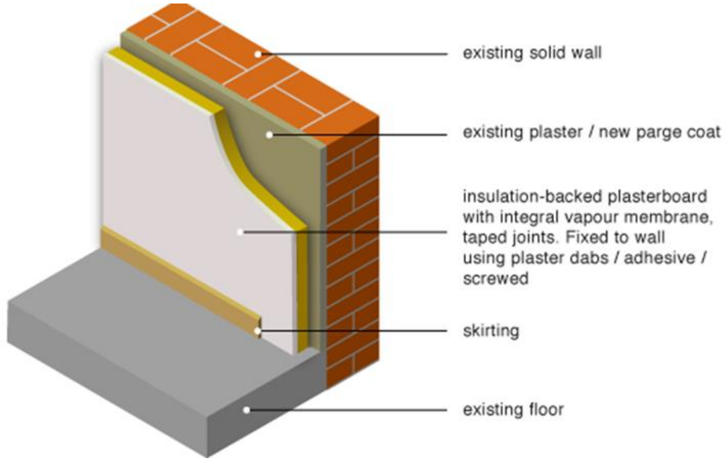
4.1 Improvement 1a – Internal Wall Insulation

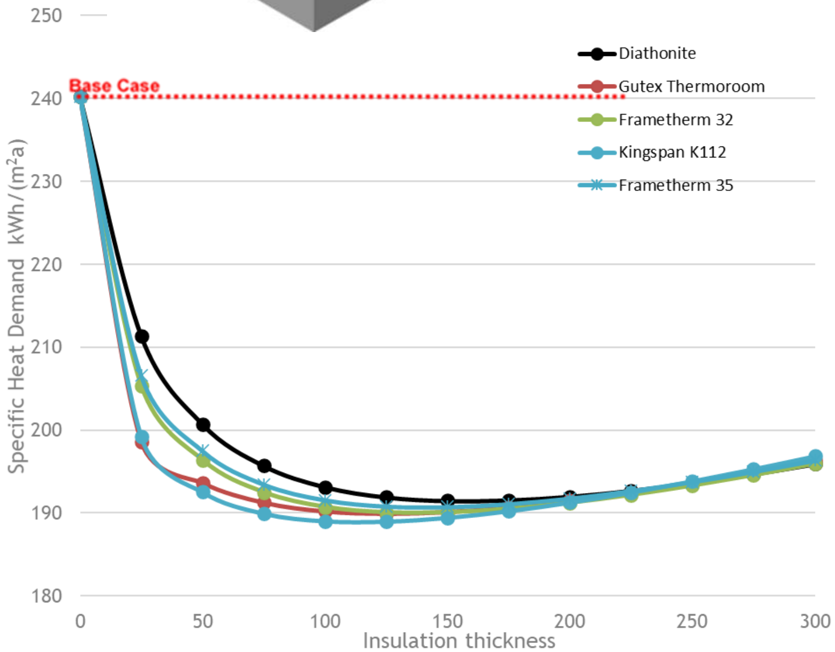
The solid brick external wall in this building is a large heat loss area (42% of the surface area), so here large improvements are possible. We have modelled two options, one with internal and the other one with external insulation.

In this section we investigate the use of internal insulation. This has the advantage of preserving the external appearance of the building, however this needs particular attention to avoid interstitial condensation. Moreover, the installation of internal insulation reduces the floor area. Interstitial condensation can be minimised by using wood fibre insulation like Thermoroom (wood fibre), Diathonite (lime plaster with cork) or a combination of the two. The below table shows that by using 100mm of Diathonite, savings up to 20.1% can be achieved, or with 80mm of Thermoroom 20.9% Where a high-performance insulation is chosen, a thinner layer can be used, however this would need a void space to prevent condensation. An example is Kingspan K112 which, with a thickness of 70mm gives savings up to 21.9%, but this would reduce the treated floor area and may not perform as well in reality due to thermal bypass.

No.	Option	Treated Floor Area m²	Space Heat Demand kWh/(m²a)	Heating Load W/m²	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**90mm Frametherm 32**	640.7	191.3	73.6	0.0%	20.4%
3	**90mm Frametherm 35**	640.7	192.1	73.9	0.0%	20.0%
3	**100mm Diathonite**	643.9	191.9	73.7	0.0%	20.1%
4	**80mm Thermoroom**	642.8	190.0	73.2	0.0%	20.9%
5	**70mm Kingspan K112**	635.8	187.5	72.6	0.0%	21.9%

Another option would be 90mm of mineral wool insulation. Here we modelled two types, Frametherm 32 and 35, which respectively can reach improvements of 20.4% or 20.0%. This has the advantage to be relatively easy to install as well as being is non-combustible and cost effective.

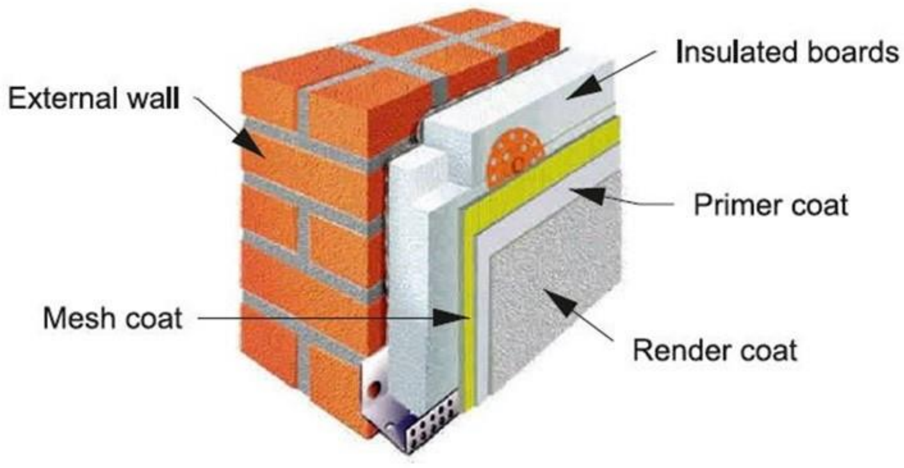




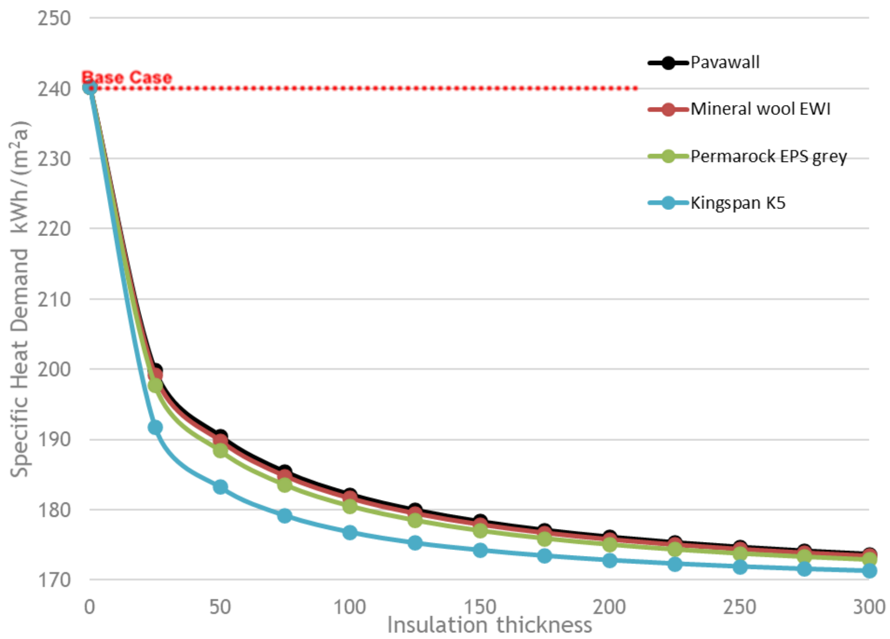
4.2 Improvement 1b – External Wall Insulation

External insulation has the advantage of maintaining the existing TFA and helps avoid thermal bridges between internal floors, walls and the thermal envelope.

In this option we have assessed the use of two different insulation types, a mineral wool and a phenolic insulation. 150mm of the first one can allow savings up to 25.9%, while with 100mm of the second one, specifically Kingspan K5, it is possible to achieve 26.5%. Both options offer good fire resistance, however the rockwool solution is completely fire resistant.

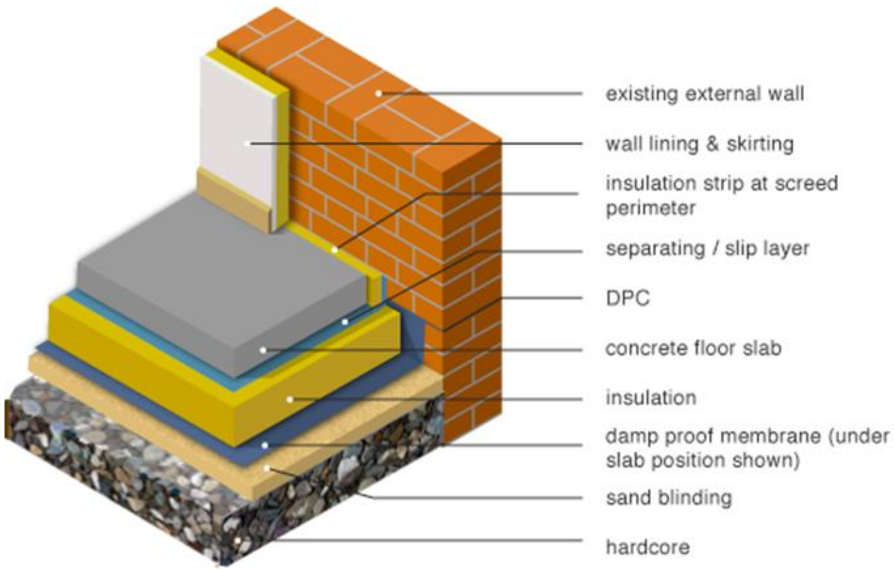


No.	Option	Treated Floor Area m²	Space Heat Demand kWh/(m²a)	Heating Load W/m²	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**150mm Mineral wool**	665.2	177.9	69.2	0.0%	25.9%
3	**100mm Kingspan K5**	665.2	176.9	68.9	0.0%	26.4%



4.3 Improvement 2a – Solid Floor Insulation

We have assumed the existing solid floor is uninsulated. There are different options for this to be more efficient. We can either insulate the existing floor by replacing the existing screed with a layer of insulation or dig up the existing floor and replace this with insulation under and concrete on top. The second option should be more efficient; however, this would entail major works. The image on the right shows the second type.

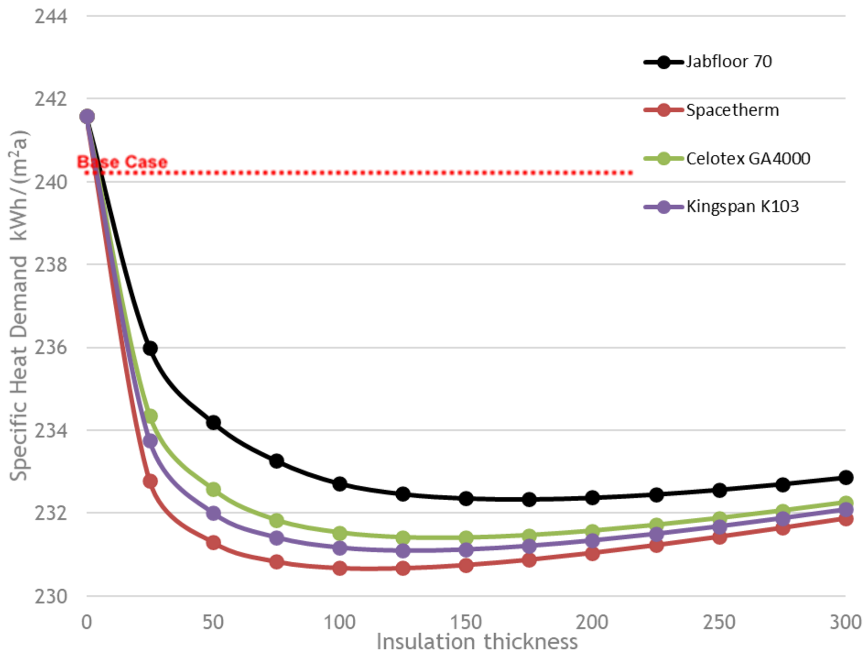


The graph and table indicate a few different insulation types that have been modelled across the entire floor area with the abovementioned approaches.

By using 60mm of Kingspan K103 insulation above, savings of up to 3.5% over the base case can be made. Another option would be the installation of a thin layer, 20mm, of high-performing aerogel Spacetherm. This would lead to an improvement of 2.8% and would reduce work disruptions.

With the second method, by replacing the old solid concrete floor with new concrete and insulating under with 200mm of Jabfloor 70 XPS, slightly lower savings, 3.3%, can be granted. Alternatively, 150mm of Celotex GA4000 could be used which also gives a 3.7% improvement.

No.	Option	Treated Floor Area m^2	Space Heat Demand $kWh/(m^2a)$	Heating Load W/m^2	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**Floor above - 60mm Kingspan**	665.2	231.7	85.9	0.0%	3.5%
3	**Floor below - 200mm XPS**	665.2	232.4	86.2	0.0%	3.3%
4	**Floor below - 150mm Celotex**	665.2	231.4	86.0	0.0%	3.7%
5	**Floor above - 20mm Spacetherm**	665.2	233.4	86.2	0.0%	2.8%

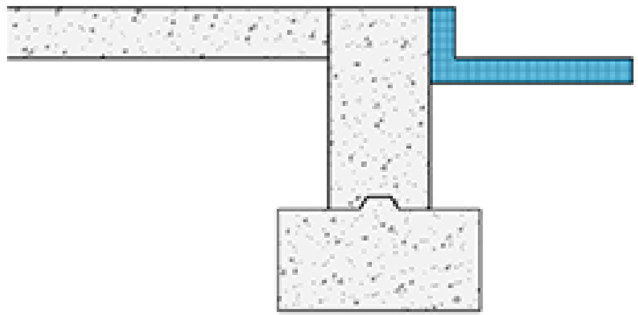


4.4 Improvement 2b – Ground Floor Insulation

Another option that can be pursued to improve the performance of the ground floor would be perimeter insulation. This could either be done by extending the external wall insulation below ground, or by insulating the perimeter of the house horizontally. We modelled both options and, in your building, the vertical option would not achieve adequate levels of insulation, however the horizontal option might be considered.

The below table shows the improvement that can be achieved by installing 150mm of insulation around the external perimeter of the house, with a width of 2.4m. This could achieve savings up to 2.2%.

This system can be used when there is no intention to carry out internal works.

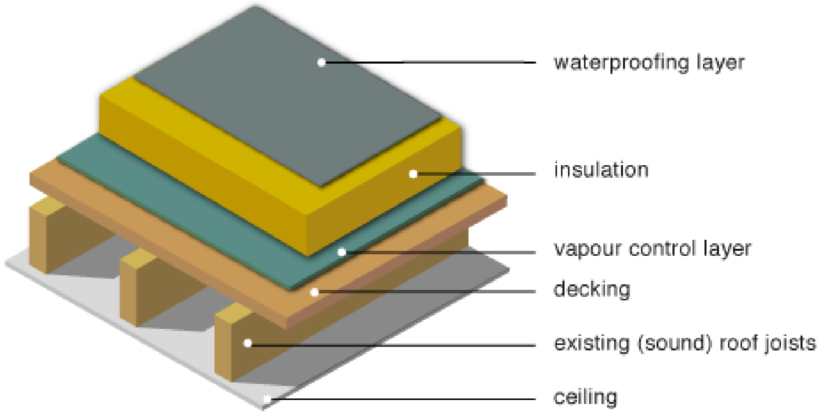


No.	Option	Treated Floor Area m^2	Space Heat Demand $kWh/(m^2a)$	Heating Load W/m^2	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**Perimeter insulation 2.4m width, 150mm thickness, λ=0.036 W/mK**	665.2	235.0	86.5	0.0%	2.2%

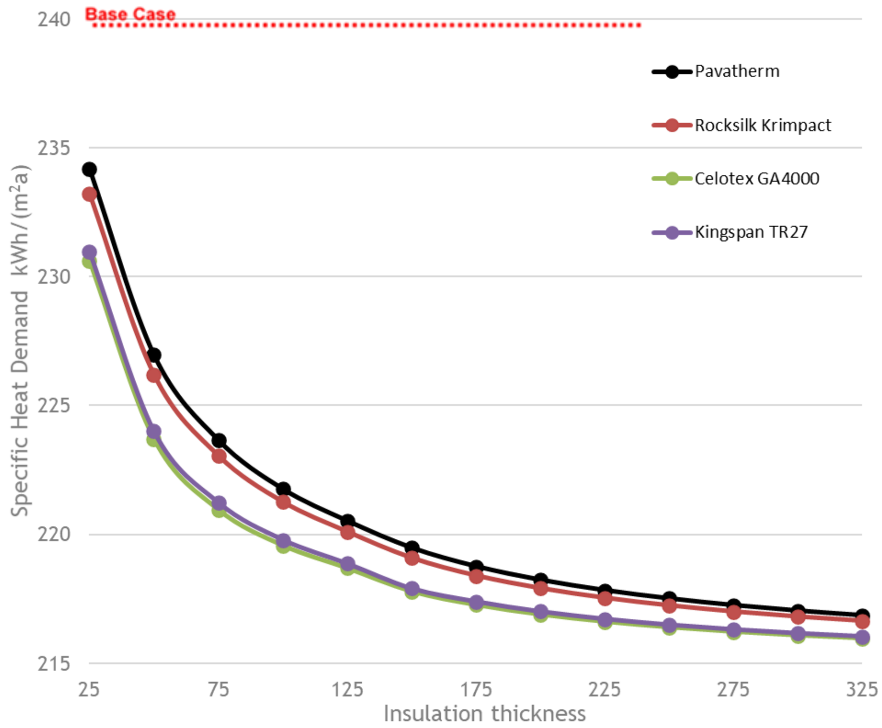
4.5 Improvement 3 – Roof Insulation

Insulation of the roof space can have a significant impact on heat loss due to its large surface area. In this case, the total roof area, including flat roof and skeilings/dormers is 24%. The flat roof area on its own equals to 13% of the total thermal envelope.

The following table shows the results of adding insulation over the rafters either 200mm of rock mineral wool or 150mm of high performing PIR insulation. In both cases it would be possible to grant savings up to 9.3%. Please note that it may be possible to add some insulation between the rafters but this would be limited and require a specialist one way vapour membrane and careful calculation to ensure the risk of interstitial condensation does not cause a problem.



No.	Option	Treated Floor Area m²	Space Heat Demand kWh/(m²a)	Heating Load W/m²	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	200mm Rocksilk Krimpact	665.2	217.9	81.1	0.0%	9.3%
3	150mm Kingspan TR27	665.2	217.9	81.1	0.0%	9.3%

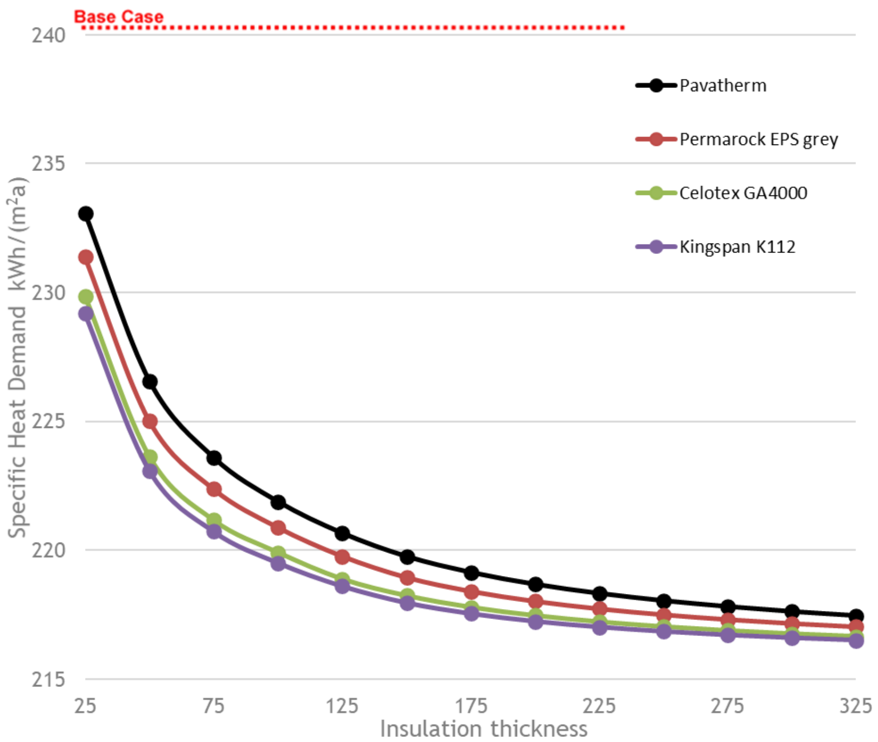


4.6 Improvement 4 – Skeilings and Dormers Insulation

The Skeilings and Dormers together are the equivalent of 11% of the total heat loss area, and currently we believe them to be uninsulated and so a large heat loss.

Skeilings and dormers will be insulated between the rafters and on the outside. As shown in the table below, over 9% improvement can be achieved where insulating with either 200mm of grey EPS or 150mm of high-performing PIR (Kingspan K112). For the final solution we would suggest using a compressible insulation such as mineral wool between the studs, and a ridged board outside to minimise thermal bypass through tiny gaps.

No.	Option	Treated Floor Area m^2	Space Heat Demand $kWh/(m^2a)$	Heating Load W/m^2	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**200mm Permarock Grey EPS**	665.2	218.0	81.1	0.0%	9.2%
3	**150mm Kingspan K112**	665.2	218.0	81.0	0.0%	9.3%

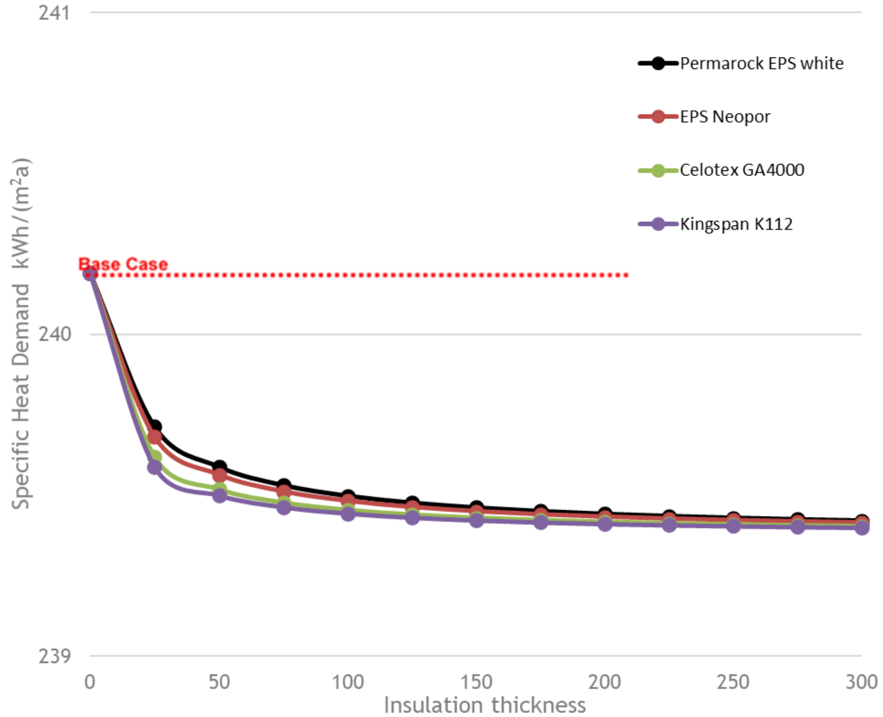


4.7 Improvement 5 – Soffit Floor Insulation

Soffit floor, in this report, refers to the small portion of floor, on the second level, that sits above the balcony/gallery/walkway on the first floor, at the entrance of the flats on the south and north side, exposed to the outside air. This is only a small area in the building, 0.3%, however it needs to be considered carefully in order to avoid thermal bridges and a large heat loss. This will be insulated below.

As mentioned, the improvement would not be significant, given the small area being considered. The table shows that with 100mm of either grey Neopor EPS or, a better performing, PIR insulation such as Kingspan K112, up to 0.3% savings can be achieved over the base case scenario.

No.	Option	Treated Floor Area m²	Space Heat Demand kWh/(m²a)	Heating Load W/m²	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**100mm EPS Neopor**	665.2	239.4	87.4	0.0%	0.3%
3	**100mm Kingspan K112**	665.2	239.4	87.4	0.0%	0.3%



4.8 Improvement 6 – Windows

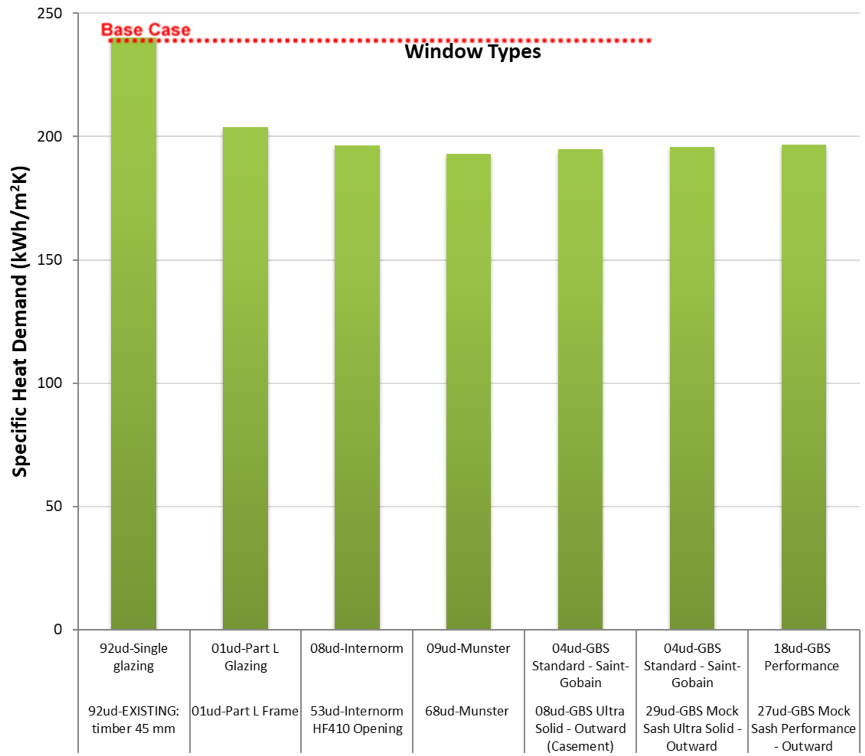
As previously discussed, glazing is an important part of a low-energy building. In the base case, heat loss through the existing timber frame single glazed windows is 22%, therefore, your choice of windows has a considerable impact on the performance of the building.

Upgrading the windows to good triple-glazed windows can improve the performance of the building by up to 18.9%.

The windows below are just a small selection of those available and most can have the glazing modified to make further improvements. Further modifications can be made with different frames and adjusting the glass specification.

Reducing the frame percentage of the window also has a big influence, hence windows with a thin profile perform well.

No.	Option	Treated Floor Area m²	Space Heat Demand kWh/(m²a)	Heating Load W/m²	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**Part L**	665.2	203.8	77.2	0.0%	15.2%
3	**GBS Ultra Solid Outward**	665.2	194.8	74.3	0.0%	18.9%
4	**GBS Mock Sash Ultra Outward**	665.2	195.7	74.5	0.0%	18.5%
5	**GBS Mock Sash Performance Outward**	665.2	196.7	74.9	0.0%	18.1%



4.9 Improvement 5 – Airtightness & Ventilation

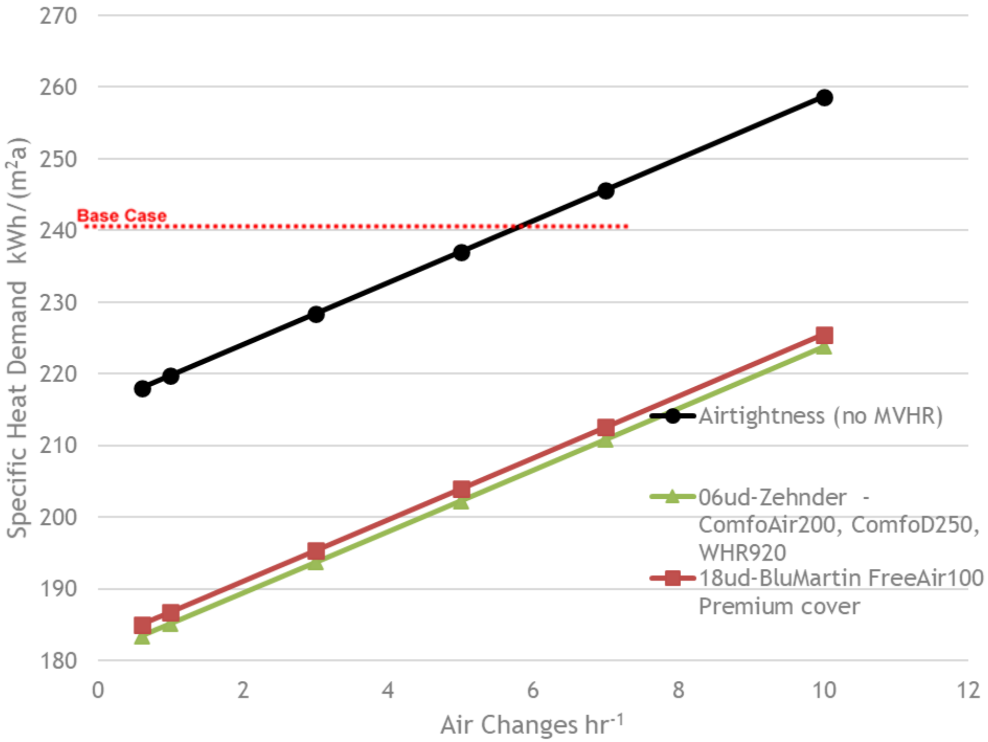
Airtightness contributes significantly to the efficiency of buildings. As demonstrated in the graph below, over 13.3% savings can be made if your buildings airtightness is improved from the current assumed level.

Airtightness improvements can be made using of specialist air tightness tapes, please see image on the right, and intelligent membranes for a continuous air permeability barrier, along with wet plaster and concrete slabs. Even if trickle vents are used to ventilate the property, and there is no MVHR, with a continuous air permeability barrier the losses can be reduced considerably.

All buildings with air permeability below 3 air changes per hour would benefit from a form of mechanical ventilation, so we would always recommend a mechanical, ventilation and heat recovery (MVHR) system, as this is most efficient. An MVHR unit will ensure the supply of fresh air at an optimal rate. It will use the warmth of stale air as it is removed to preheat incoming air. MVHR units will need to be specifically designed for your building to maximise its benefits, removing stale air from bathrooms and kitchens, and introducing the fresh air to living rooms and bedrooms, we currently assume one per dwelling.

No.	Option	Treated Floor Area m2	Space Heat Demand kWh/(m2a)	Heating Load W/m2	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**ACH 0.6 no MVHR**	665.2	208.3	66.1	0.0%	13.3%
3	**ACH 0.6 - Zehnder - ComfoAir200, ComfoD250**	665.2	183.4	59.3	0.0%	23.6%
4	**ACH 0.6 - BluMartin FreeAir100 Premium cover**	665.2	185.0	59.8	0.0%	23.0%

The specification of the MVHR unit can make a 1.6kWh/m^{2}a difference to the heat load. This is the difference between a highly efficient unit, such as the Zehnder ComfoAir200, and a slightly less efficient unit, such as a BluMartin FreeAir100 Premium Cover. However, the second one is fully demand controlled, therefore can have significant savings, which are not considered in this report. Moreover, the positioning and design of the unit will affect the overall efficiency of the system, so placement of the unit and duct lengths should be optimised through discussions with the MVHR supplier. Short duct lengths to the external envelope and well-insulated, ideally rigid metal spiral ducting are recommended.



4.10 Overheating

Most people have experienced overheating in building at some point in the summer months. On a hot day uncontrolled solar heat gains can rapidly warm a space to uncomfortable temperatures. Overheating is not unique to low energy buildings, we have all been in buildings which are cold in winter and too hot in the summer, but overheating is perceived to be more of an issue in well insulated buildings.

Raised internal temperatures are associated with raised mortality rates and increased exacerbation of chronic diseases, especially amongst the frail and vulnerable. Quality of sleep is impaired, and the sense of general wellbeing is decreased.

Both the Passivhaus and AECB building standards defines overheating as when indoor temperatures exceed 25^{0}C. They set a maximum limit of 10% of annual hours to achieve certification. It is generally considered that an upper limit of 5% of hours is more appropriate, and particularly important when considering climate change when many places will get warmer.

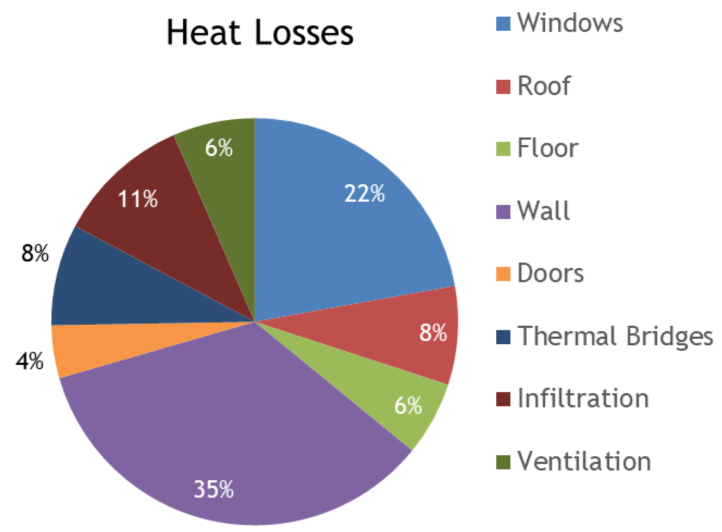
All of the above options have been tested against the requirements to ensure comfort is maintained, including the limit to temperatures above 25˚C. In this building, we believe, there is no risk of overheating.

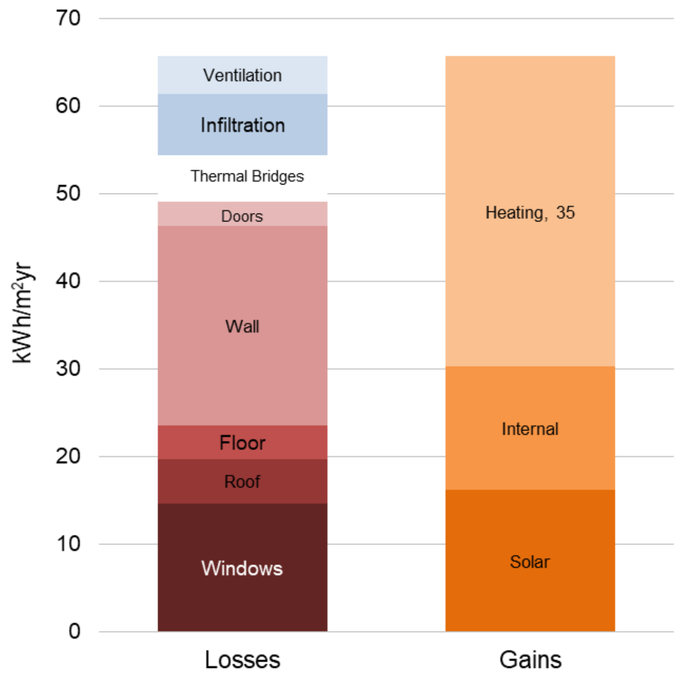
5.0 Combined Option AECB Standard

To achieve the AECB Standard at 40kWh/m^2 per annum we have combined the following:

- Improve U-value of existing walls by introducing 80mm Pavadry wood fibre (λ = 0.043 W/mK) internal wall insulation
- Improve U-value of existing solid ground floor by replacing the screed with 80mm Kingspan Kingspan K103 (λ = 0.018 W/mK) and cement board.
- Improve U-value of existing flat roof by insulating over with roof 150mm of Celotex (λ = 0.022 W/mK)
- Improve the U-value of skeiling and dormers by insulating over with 80mm of Celotex (λ = 0.022 W/mK) and between rafters with 114mm mineral wool such as Rocksilk Krimpact (λ = 0.038 W/mK)
- Improve U-value of the soffit floor by adding 100mm of Celotex insulation (λ = 0.022 W/mK)
- Improve all thermal bridge details to below 0.3W/mK with insulation returning on internal floors, ceilings and internal walls.
- Replace all existing windows with GBS Ultra Solid and triple-glazing (Ug=0.53, g=0.53)
- Replace doors with low U-value of 1.2W/mK or better
- Airtightness of 1.5ach @ 50pa or better
- Passivhaus certified MVHR unit – Zehnder - ComfoAir200, ComfoD250, with a calculated efficiency of 92%

No.	Option	Treated Floor Area m^2	Space Heat Demand kWh/(m^{2}a)	Heating Load W/m^2	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**AECB Silver**	642.8	35.5	17.4	0.0%	85.2%





5.1 Combined Option EnerPHit by Component

To achieve the EnerPHit by Component, where we need to achieve minimum efficiencies on different elements, we have upgraded the following items from AECB:

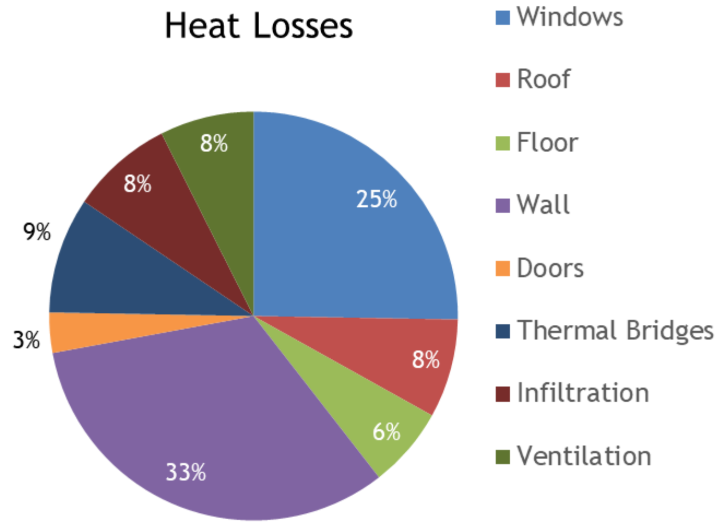
- Improve U-value of existing walls by introducing 90mm of Frametherm 32 mineral wool (λ = 0.032 W/mK) internal wall insulation.
- Improve U-value of roofs by increasing the insulation over to 160mm of Celotex (λ = 0.022 W/mK).
- Improve the U-value of skeiling and dormers by increasing the insulation over to 100mm of Celotex (λ = 0.022 W/mK).
- Improve U-value of the soffit floor by increasing the insulation to 160mm of Celotex insulation (λ = 0.022 W/mK).
- Airtightness of 1.0ach @ 50pa or better.
- Replace doors with low U-value of 0.8W/mK or better.

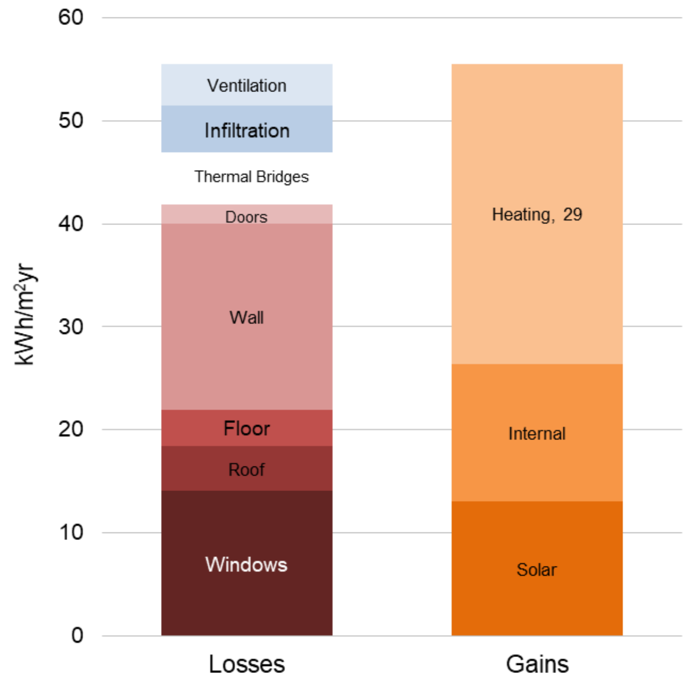
EnerPHit (retrofit): Component characteristics

Building envelope to exterior air[1] (U-value)	W/(m²K)	0.21	≤	0.3	yes
Building envelope to ground[1] (U-value)	W/(m²K)	0.28	≤	0.3	yes
Wall w/int. insulation in contact w/exterior air (U-value)	W/(m²K)	0.29	≤	0.5	yes
Wall w/interior insulation in contact w/ground (U-value)	W/(m²K)	-	≤	0.56	-
Flat roof (SRI)	-	19	≥	-	-
Inclined and vertical external surface (SRI)	-	19	≥	-	-
Windows/Entrance doors ($U_{W/D,installed}$)	W/(m²K)	0.92	≤	1.12	yes
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	1.17	-
Windows ($U_{W,installed}$)	W/(m²K)	-	≤	1.27	-
Glazing (g-value)	-	0.53	≥	0.19	yes
Glazing/sun protection (max. solar load)	kWh/(m²a)	124	≤	-	-
Ventilation (effective heat recovery efficiency)	%	86	≥	75	yes
Ventilation (humidity recovery efficiency)	%	0	≥	-	-

[1] Without windows, doors and external walls with interior insulation
[2] Empty field: Data missing; '-': No requirement

No.	Option	Treated Floor Area m²	Space Heat Demand kWh/(m²a)	Heating Load W/m²	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	
2	**EnerPhit by Component**	640.7	29.2	14.5	0.0%	87.9%

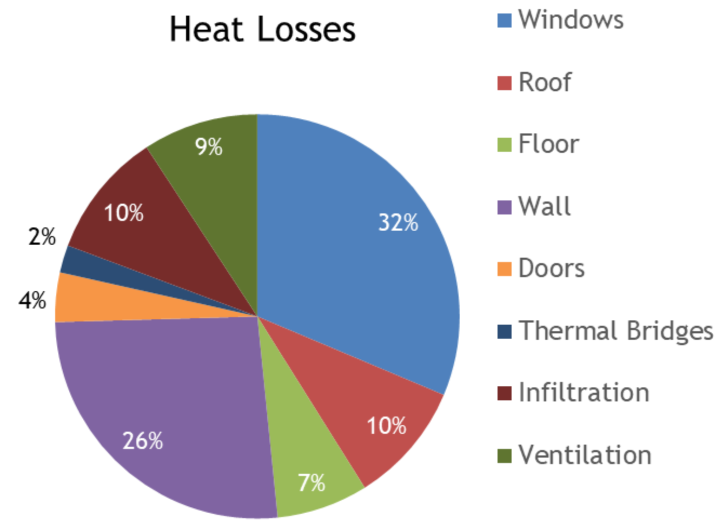


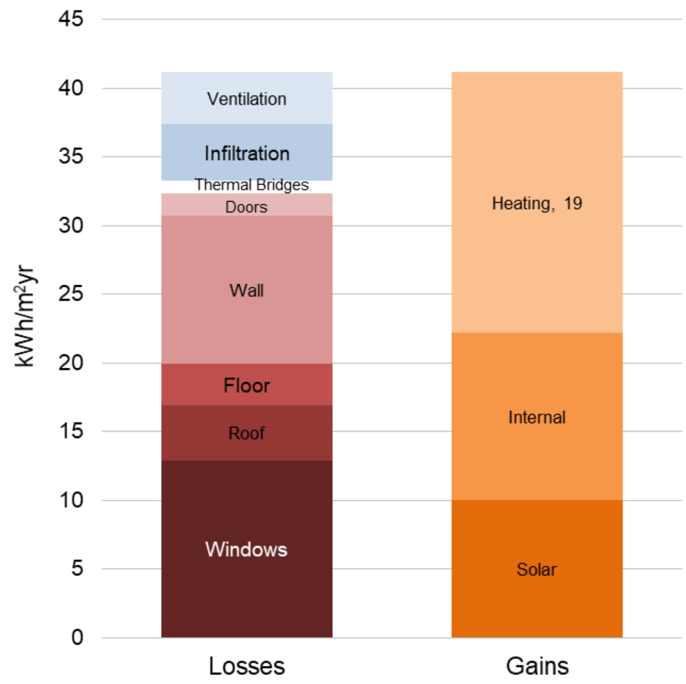


5.2 Combined Option EnerPHit by Heat demand

To achieve the EnerPHit level at 20kWh/m2 per annum, (London and South West England) we have upgraded the following items from EnerPHit by Component:

- Improve U-value of existing walls by introducing 150mm mineral wool external wall insulation (λ = 0.036 W/mK) instead of internal wall insulation.
- Improve all thermal bridge details to below 0.2W/mK with extra attention to junctions with balconies. It should be noted that with External insulation the thermal bridges with internal walls and intermediate floors will be removed.



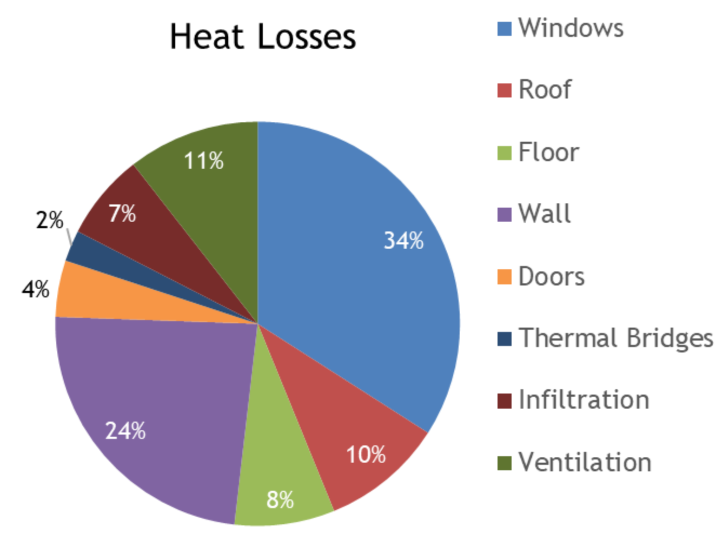


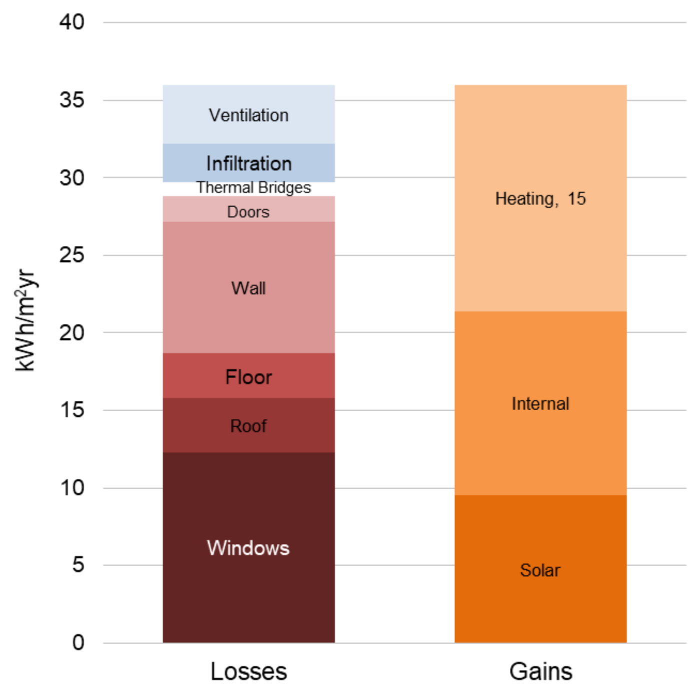
No.	Option	Treated Floor Area m²	Space Heat Demand kWh/(m²a)	Heating Load W/m²	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	
2	**EnerPHit by Heat demand**	665.2	19.0	11.2	0.0%	92.1%

5.3 Combined Option Passivhaus Standard

To achieve the Passivhaus level at 15kWh/m2 per annum we have upgraded the following items from the EnerPhit by Heat demand:

- Improve U-value of existing walls by increasing the external wall insulation to 200mm mineral wool (λ = 0.036 W/mK)
- Increase the insulation over the flat roof to 200mm of Celotex (λ = 0.022 W/mK)
- Replace all windows with GBS Ultra with insulated frames and triple-glazing (Ug=0.53, g=0.53)





No.	Option	Treated Floor Area m²	Space Heat Demand kWh/(m²a)	Heating Load W/m²	Overheating risk %	Improvement over base case %
1	**Base Case**	665.2	240.2	87.6	0.0%	-
2	**Passivhaus**	665.2	14.6	9.0	0.0%	93.9%

5.4 Recommendations

We believe that it is possible for your building to achieve full Passivhaus, however the EnerPHit by Component standard with internal wall insulation may be more appropriate. The design combinations for EnerPHit by component detailed in this report at section 5.1. represent an improvement of 87.5% above the assumed current level.

The building has a form factor of 1.78, which is great and well below the recommended maximum of 3. Insulating the thermal envelope, for example the external walls internally, the ground floor and roof, would give a great opportunity for improvement over the current level. The external wall is 42% of the total thermal envelope. Our suggestion is to improve its performance with 90mm internal wall insulation such as Frametherm 32 mineral wool, which would allow up to 20.4% savings to be achieved. Attention to the thermal bridging is however required around windows and by adding insulation to internal walls and internal floors where they abut the external walls.

Another big area of improvement are the windows. The greatest impact on the reduction of heat loss from windows would be the installation of highly efficient triple glazed window units, where a 18.9% improvement over the base case can be achieved.

Moreover, improving the airtightness to 1.0ach/hour and installing a Passivhaus certified MVHR unit Zehnder - ComfoAir200, ComfoD250, could enable savings up to 22.9%.

It should be noted that we have also suggested improving all the thermal bridges to less than 0.3 or better and this includes removing the losses from the SVP.

We have exceeded the minimum requirements to allow some room for manoeuvre as your thermal upgrade strategy develops.

5.5 Recommended Specification

Heat Loss Area	**U-Value** W/m^{2}K
External Wall	0.32
Ground floor solid	0.16
Flat roof	0.14
Skeilings/dormers	0.15
Doors	0.80

Windows	**Glass g** Transmission	**Glass Ug** W/(m^{2}K)	**Frame** W/(m^{2}K)	**Spacer** W/(mK)
GBS Ultra Solid and triple-glazing	0.53	0.53	1.04	0.023

Airtightness	
At 50 Pascals	1.0 air changes / hour assumed

Ventilation	
MVHR	Zehnder - ComfoAir200, ComfoD250

Thermal bridges	**Psi Value** W/mK
Foundation Wall junction	0.01
Intermediate floor/external wall	0.25
Balcony	0.30
Internal walls/ground floor	0.12
Internal walls/external walls	0.19
Door threshold	0.10
Door jamb/head	0.04
SVP	0.00

5.6 Summary

A summary of the findings is detailed in the table below:

No.	Option	Treated Floor Area	Space Heating Demand	Heating Load	Risk of Overheating	Improvement over base case	Form Factor
		m²	kWh/m²Ka	W/m²a	%	%	
0	**Base Case**	665.2	240.2	87.6	0.0%	7.1%	1.78
1	**Wall IWI – 90mm Frametherm 32**	640.7	191.3	73.6	0.0%	20.4%	1.85
2	**Wall IWI – 90mm Frametherm 35**	640.7	192.1	73.9	0.0%	20.0%	1.85
3	**Wall IWI - 100mm Diathonite**	643.9	191.9	73.7	0.0%	20.1%	1.84
4	**Wall IWI - 80mm Thermoroom**	642.8	190.0	73.2	0.0%	20.9%	1.84
5	**Wall IWI - 70mm Kingspan K112**	635.8	187.5	72.6	0.0%	21.9%	1.86
6	**Wall EWI - 100mm Kingspan K5**	665.2	176.9	68.9	0.0%	26.4%	1.78
7	**Wall EWI - 150mm Mineral wool**	665.2	177.9	69.2	0.0%	25.9%	1.78
8	**Floor above – 20mm Spacetherm aerogel**	665.2	233.4	86.2	0.0%	2.8%	1.78
9	**Floor above - 60mm Kingspan**	665.2	231.7	85.9	0.0%	3.5%	1.78
10	**Floor below - 200mm XPS**	665.2	232.4	86.2	0.0%	3.3%	1.80
11	**Floor below - 150mm Celotex**	665.2	231.4	86.0	0.0%	3.7%	1.79
12	**Perimeter insulation**	665.2	235.0	86.5	0.0%	2.2%	1.78
13	**Roof - 200mm Rocksilk Krimpact**	665.2	217.9	81.1	0.0%	9.3%	1.78
14	**Roof - 150mm Kingspan TR27**	665.2	217.9	81.1	0.0%	9.3%	1.78
15	**Skeiling - 200mm Grey EPS**	665.2	218.0	81.1	0.0%	9.2%	1.78
16	**Skeiling - 150mm Kingspan K112**	665.2	218.0	81.0	0.0%	9.3%	1.78
17	**Soffit - 100mm EPS**	665.2	239.4	87.4	0.0%	0.3%	1.78
18	**Soffit - 100mm Kingspan**	665.2	239.4	87.4	0.0%	0.3%	1.78
19	**Windows - Part L compliant**	665.2	203.8	77.2	0.0%	15.2%	1.78
20	**Windows - GBS Ultra Solid Outward**	665.2	194.8	74.3	0.0%	18.9%	1.78
21	**Windows - GBS Mock Sash Ultra Outward**	665.2	195.7	74.5	0.0%	18.5%	1.78
22	**Windows - GBS Mock Sash Performance Outward**	665.2	196.7	74.9	0.0%	18.1%	1.78
23	**ACH 0.6 no MVHR**	665.2	208.3	66.1	0.0%	13.3%	1.78
24	**ACH 0.6 - Zehnder - ComfoAir200**	665.2	183.4	59.3	0.0%	23.6%	1.78
25	**ACH 0.6 - BluMartin FreeAir100 Premium cover**	665.2	185.0	59.8	0.0%	23.0%	1.78

26	**AECB**	642.8	35.5	17.4	0.0%	85.2%	1.84
27	**EnerPHit by Component**	640.7	29.2	14.5	0.0%	87.9%	1.85
28	**EnerPHit by Heat demand**	665.2	19.0	11.2	0.0%	92.1%	1.78
29	**PassivHaus**	665.2	14.6	9.0	0.0%	93.9%	1.78