The Scottish Government

Directorate for the Built Environment
Building Standards Division

ESRU, University of Strathclyde

Benchmarking Scottish energy standards: Passive House and CarbonLite Standards: A comparison of space heating energy demand using SAP, SBEM, and PHPP methodologies

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Contents

Abbreviations

The following abbreviations have been used in this report.

BRE	Building Research Establishment
CHP	Combined heat and power
CO_2	Carbon dioxide
GSHP	Ground source heat pump
MVHR	Mechanical ventilation with heat recovery
PHPP	Passive House Planning Package
PV	Photovoltaics
SBEM	Simplified Building Energy Model
SAP	Standard Assessment Procedure

Definition of terms

The following terms are used in the report.

Useful space heating requirement / heating load	The quantity of heat that must be supplied by heating equipment in addition to solar and internal heat gains to keep the indoor air at the desired temperature. The heating load in a building is the result of the temperature settings for space heating, external temperatures, heat losses through the external fabric, solar gains and internal heat gains. If the temperature settings for space heating and usage profile is maintained, the space heating load can be reduced by improved insulation, reduction of air permeability, and retention of heat by the building fabric.
Useful energy	Energy demand for provision of space heating, water heating, cooling or lighting.
Delivered energy	Energy necessary to fulfil the useful energy demand, taking into account the inefficiency of equipment but less any energy produced by renewable sources on-site, for instance a solar thermal system that heats water, or photovoltaics, wind turbines, or a CHP system that generate electricity as a by-product of space and water heating.
Internal heat gains	Heat gain within the building that is derived from anything within the building that generates heat, and thus increases the indoor air temperature, including occupants, lighting, mechanical or electrical equipment and electric appliances.
Heat losses	Heat losses through the external fabric comprise heat lost through the external envelope (roof, external walls, ground floor, doors, windows, rooflights), ventilation and air infiltration.

Executive Summary

The Scottish Government has commissioned various research projects to investigate the impact of the adoption of the recommendations of the Sullivan report. This study analyses the useful energy requirement for space heating for a selection of domestic and non-domestic buildings designed to the energy standards of the Technical Handbooks 2007 and also with three levels of further energy efficiency measures applied (basic, intermediate and advanced improvement packages). Results are then compared to the EU Passive House standard[1] and the AECB CarbonLite Silver and Gold standards[2].

The EU Passive House standard and the AECB CarbonLite Silver and Gold standards are based on Passive House principles. Criteria for compliance with these standards are calculated using the Passive House Planning Package (PHPP) which differs from the UK national calculation methods i.e. the Standard Assessment Procedure (SAP) and the Simplified Building Energy Model (SBEM).

In this study, Davis Langdon modelled a wide range of buildings designed to meet 2007 building regulations and with the further improvement packages applied using SAP and SBEM. ESRU then calculated the space heating performance for three of the buildings (detached house, mid-floor flat, city centre office), and the same range of building standards and improvement packages, using the PHPP and compared results against Passive House and CarbonLite standards.

One important observation is that the PHPP assumes lower internal gains than SAP (2.1 W/m^2 vs. 6.7 W/m^2 and 7.7 W/m^2 for the 2007 detached house and mid-floor flat respectively) and therefore gives a higher space heating energy demand. Other differences between PHPP and SAP include the use of local climates and the treatment of air permeability and thermal bridges. When SAP was used, the baseline mid-floor flat (designed to Technical Handbooks 2007) was calculated to have a useful space heating energy demand of 33kWh/m^2 p.a. but when PHPP was used the calculated useful space heating energy demand was 73 kWh/m^2 p.a., more than double. SAP as it stands can not be used to make valid comparisons with the Passive House or CarbonLite standards.

For the dwellings (detached house and mid-floor flat), none of the upgrade packages achieved the Passive House or CarbonLite Gold standard, only the advanced improvement package achieved the criterion for CarbonLite Silver.

The differences in the calculated useful space heating energy demand between the PHPP and SBEM when applied to the city centre office are less marked than between PHPP and SAP for the dwellings. For the city centre office, none of the improvement packages achieved the Passive House standard.[3]

The detached house, mid-floor flat and city centre office were then modelled with further improvements applied so that the Passive House / CarbonLite Gold standards for space heating energy demand were achieved. These further improvements included Passive House details for thermal bridges and air permeability and, for the office case, improved ventilation heat recovery efficiency. The detached house required the specification of

[1] Passive House Standards. www.passivehouse.com

[2] AECB CarbonLite Standards. www.carbonlite.org.uk

[3] The AECB criteria for non-domestic buildings are defined in terms of the % primary energy or % carbon emissions reductions rather than space heating demands and a comparison was not practicable.

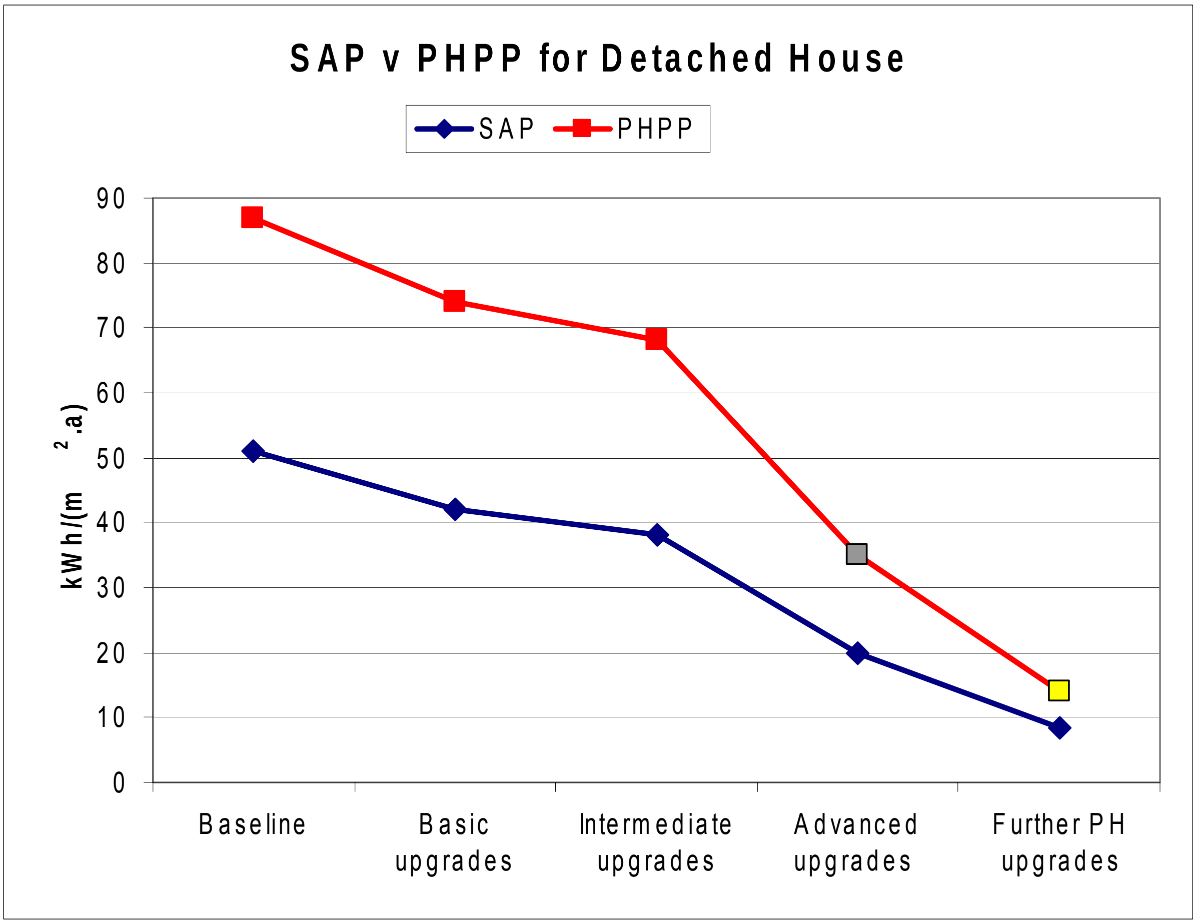
Passive House glazing (higher performance glazing than in the advanced package) but this could be avoided if orientation of the windows was optimised. It was possible to meet the Passive House standard without affecting the form or general appearance of the buildings however optimising window orientation may allow reduced specifications elsewhere.

It should be noted that the addition of low carbon equipment, such as wind turbines, solar water heating, photovoltaics etc. has no impact on the useful energy requirement for space heating, which is only reduced by energy efficiency improvements.

The results are summarised in the following three figures.

Figure 1 describes the space heating energy demand (kWh/m^2 p.a.) for the baseline detached house (Technical Handbooks 2007) and the three possible upgrades beyond the 2007 standards (Basic, Intermediate and Advanced) calculated using PHPP and SAP. A further upgrade to Passive House construction details is also shown. The criterion for the Passive House and the CarbonLite Gold standards is < 15 kWh/m^2 p.a. (gold data-point) and the criterion for the CarbonLite Silver standard is < 40 kWh/m^2 p.a. (silver data-point) as calculated using the PHPP.

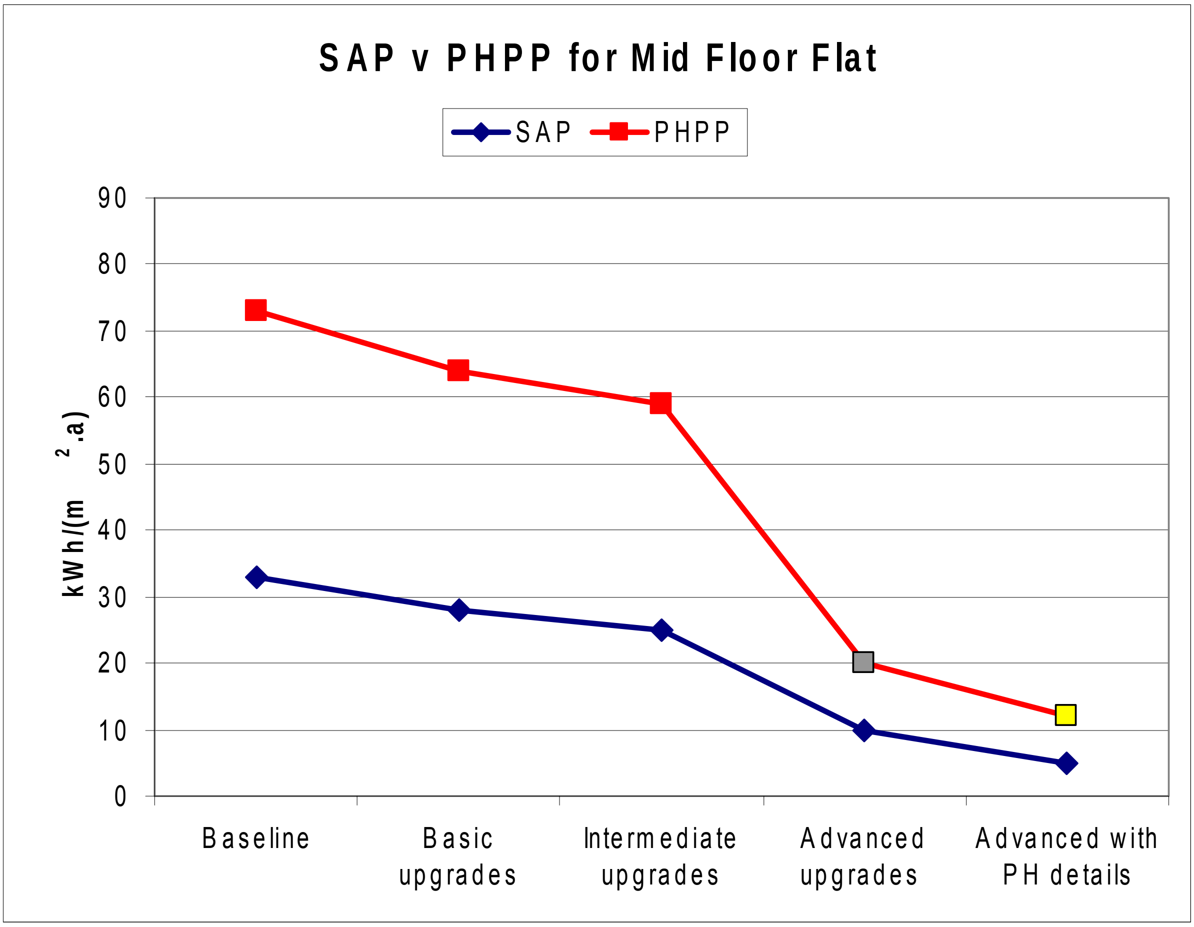
Figure 1: Detached house: space heating energy demand



Upgrade / Heat demand kWh/m2pa	SAP	PHPP
Baseline	51	87
Basic upgrades	42	74
Intermediate upgrades	38	68
Advanced upgrades	20	35
Further PH upgrades	8	14

Figure 2 describes the space heating energy demand (kWh/m^2 p.a.) for the baseline mid floor flat (Technical Handbooks 2007) and the three possible upgrades beyond the 2007 standards (Basic, Intermediate and Advanced), calculated using PHPP and SAP. A further upgrade to Passive House construction details is also shown. The criterion for Passive House and CarbonLite Gold standards is < 15 kWh/m^2 p.a. (Gold data-point) and the criterion for CarbonLite Silver standard is < 40 kWh/m^2 p.a. (Silver data-point) calculated using PHPP.

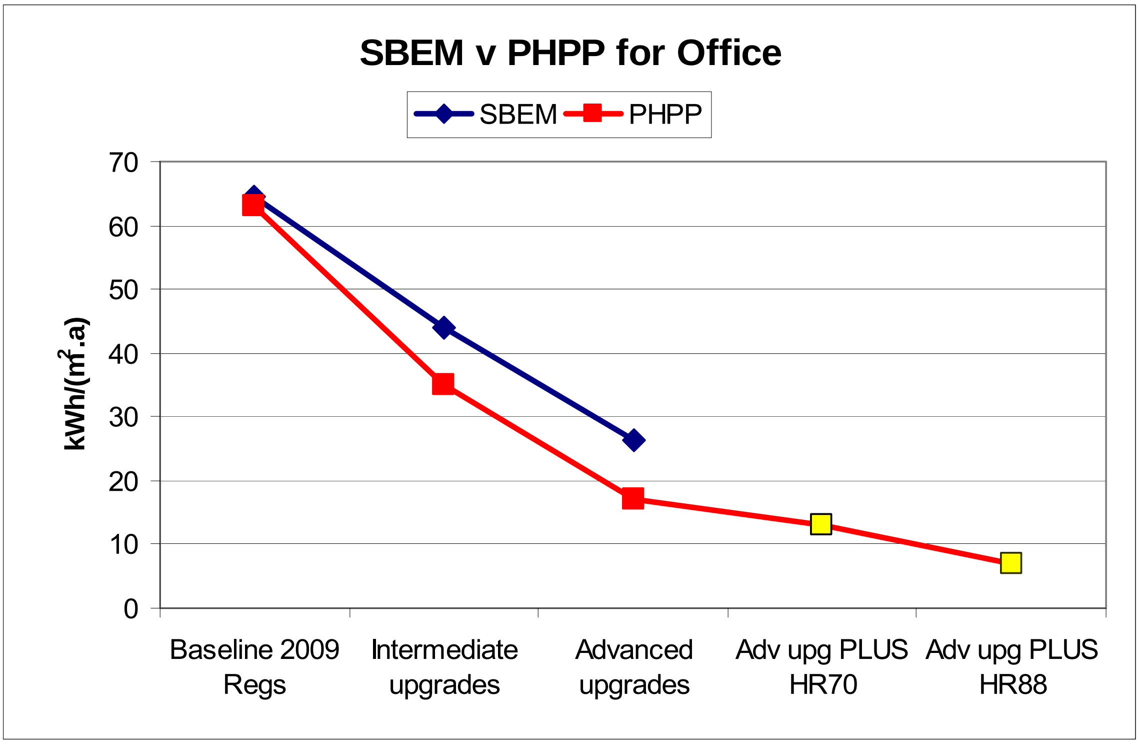
Figure 2: Mid Floor Flat: Space Heating energy demand



Upgrade / Heat demand kWh/m2pa	SAP	PHPP
Baseline	33	73
Basic upgrades	28	64
Intermediate upgrades	25	59
Advanced upgrades	10	20
Advanced with PH details	5	12

Figure 3 describes the space heating energy demand (kWh/m^2 p.a.) for the baseline city centre office (2007 building regulations) and the two possible upgrades beyond the 2007 non-domestic standards (Intermediate and Advanced) calculated using PHPP and SBEM. A further upgrade to Passive House construction details is also shown in combination with two further improvements to ventilation system heat recovery efficiency (70% and 80%). The criterion for Passive House is < 15 kWh/m^2 p.a. (Gold data-points). The criterion for CarbonLite standards for non-domestic buildings is based on primary energy or carbon emissions and not space heating energy and is beyond the scope of this study.

Figure 3: City Centre Office: Space Heating energy demand



Upgrade / Heat demand kWh/m2pa	SBEM	PHPP
Baseline 2009 Regs	65	63
Intermediate upgrades	44	35
Advanced upgrades (HR60)	26	17
Adv upg PLUS HR70		13
Adv upg PLUS HR88		7

1 Introduction

In 2007 Scottish Ministers convened an international expert panel to advise on a low carbon building standards strategy for Scotland, which published its findings in December 2007. In addition to recommendations for raising energy standards to deliver further carbon dioxide savings (30% domestic buildings, 50% non-domestic), the 'Sullivan report' includes a recommendation "That the carbon dioxide emissions standard be modified to take account of energy consumption."

Scottish Ministers are now considering the impact of the adoption of the recommendations of the Sullivan report. A range of research is already underway and further studies will be undertaken in future. This is one of two studies which attempt to relate various levels of improvement in energy standards to recognised benchmarks based on energy consumption (rather than delivered energy or CO_2 emissions). The buildings and improvement scenarios in this study are drawn from two studies by Davis Langdon on the cost impacts of possible changes to the energy standards in 2010, for domestic and non-domestic buildings.[4, 5]

This study was commissioned in order to benchmark current and potential energy standards in Scotland against other recognised standards for energy performance, and also to understand differences in the calculation methodologies used:

- the UK national calculation methodologies: the Standard Assessment Procedure (SAP) and the Simplified Building Energy Model (SBEM), for domestic and non-domestic buildings respectively;
- the Passive House Planning Package (PHPP).

Various standards for low energy buildings, such as those published by the Association for Environment Conscious Building (AECB) or the Passive House Institute, are written in terms of useful energy, whereas the research undertaken on the cost impacts addresses delivered energy. Useful energy is the demand for energy in order to provide heat, cooling or lighting, while delivered energy is that energy necessary to fulfill that demand, adjusted for the efficiency of equipment and less any energy produced by renewable sources on site. For example a 90% efficient boiler consumes 100 kWh (delivered energy) of natural gas to provide 90 kWh (useful energy) of heat.

The EU Passive House standard[6] and the AECB CarbonLite Silver and Gold standards[7] are based on Passive House principles. Criteria for compliance with these standards are calculated using the PHPP. The EU Passive House criteria[1] are intended to ensure the building does not require a conventional heating system, the remaining space heating demand is capable of being satisfied by pre-heating the ventilation air if or when required. Eliminating the cost of a standard heating system is intended to offset the cost of the Passive House construction and ventilation system and make the Passive House economic. The AECB Gold criterion for dwellings is the same as the Passive House criterion in terms of

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4 Davis Langdon (2008) Assessing the costs of changes to domestic energy standards in 2010. Building Standards Division, Scottish Government http://www.sbsa.gov.uk/research/summ_dom_energ_2010.htm

5 Davis Langdon (2008) Assessing the costs of changes to non-domestic energy standards in 2010. Building Standards Division, Scottish Government http://www.sbsa.gov.uk/research/summ_nd_energ_2010.htm

6 Passive House Standards. www.passivehouse.com

7 AECB CarbonLite Standards. www.carbonlite.org.uk

space heating energy demand. Table 1 gives the useful space heating criteria for the Passive House and CarbonLite standards.

Table 1: Useful space heating requirements for AECB and Passive House ratings

Standard	**Annual useful space heating requirement**
	(kWh/m^{2}yr)
AECB Silver (domestic)	≤ 40
AECB Gold (domestic)	≤ 15
Passive House (domestic and non-domestic)	≤ 15

As well as useful space heating criteria, both AECB and Passive House standards set levels to limit primary energy consumption, the scope of the primary energy criteria extends beyond the current UK regulated uses of energy (Passive House standards include appliances, UK regulations do not). The Passive House and CarbonLite primary energy criteria are beyond the scope of this current report.

This study has taken place in two stages:

- Davis Langdon used SAP and SBEM to assess demand for useful energy for space heating for a selection of the buildings used in their earlier research. They also assessed the impact of energy efficiency improvements on the demand for useful energy for space heating.
- ESRU repeated the exercise using the PPHP and compared the results against the Passive House standard and AECB CarbonLite standards. They then investigated further options for improvements that would meet these standards, and also provided insights into the differences between the calculation methodologies.

For reasons of simplicity, the Davis Langdon part of the study is included at Appendix A, with the ESRU findings drawing on those results within the main text.

2 Baseline buildings and improvements

The research reported here examines three example buildings (detached house, mid floor flat and city centre office) built to the 2007 standards and also to improved standards using the EU Passive House Planning Package (PHPP) to calculate energy performance. The results of these calculations are compared to the criteria for Passive House and CarbonLite standards. The results for energy use from the PHPP calculations are also compared to those generated using SAP and SBEM (see Appendix A).

Tables 1 and 2 below give a summary of the parameters applied for the baseline buildings and the improvement scenarios cases for the dwellings and for the office building. In some cases further upgrades beyond those given here were applied in order to illustrate what further measures would be required to achieve the Passive House or CarbonLite standards.

Table 1: Energy efficiency measures in baseline dwellings and improvement packages

	Baseline	**Improvement levels**		
U-values	**(W/m^2K)**	**Basic (W/m^2K)**	**Intermediate (W/m^2K)**	**Advanced (W/m^2K)**
Walls: houses	0.23 & 0.25	0.19 & 0.21	0.15 & 0.17	0.10 & 0.12
Walls: flats	0.25	0.19	0.15	0.10
Ground Floors	0.21	0.15	0.15	0.10
Roofs	0.16	0.13	0.13	0.10
Openings	1.80	1.50	1.30	1.10
Max permeability $m^3/h.m^2$@50Pa	10	7	7	3
MVHR efficiency	-	-	-	90%

Table 2: Baseline buildings & energy efficiency scenarios for the office building

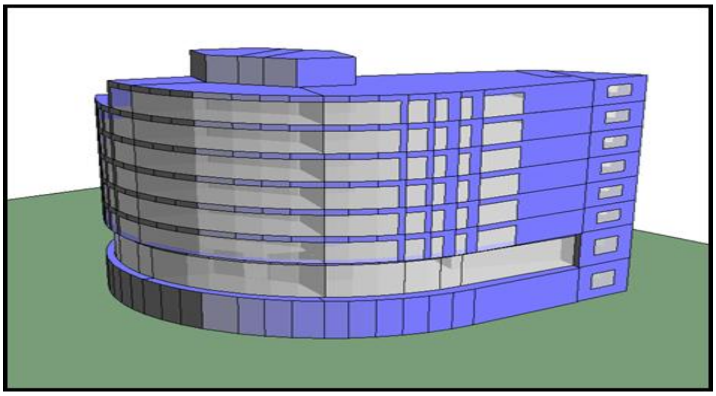
U-values	**Baseline (W/m^2K)**	**Intermediate (W/m^2K)**	**Advanced (W/m^2K)**
Roof	0.25	0.15	0.1
Wall	0.3	0.25	0.15
Floor	0.25	0.2	0.1
Windows, doors, rooflights	2.2	1.6	1.2
Air permeability ($m^3/(h.m^2)$ @ 50Pa)	10	7	3
MVHR efficiency (%) *	0%	40%	60%

* The MVHR efficiency assumed was from an Excel sheet used to compile the Davis Langdon report.

The buildings used in this study were a 4 bedroom detached house and 2 bedroom flat (dwelling types H and J in the earlier Davis Langdon domestic study) and the City Centre office building from the Davis Langdon non-domestic study.

The PHPP modeling inputs were derived from the data sheets used by Davis Langdon.

Figure 4: City centre office



3 Detached house

3.1 Detached House: Results

SAP has a more optimistic view of internal gains than PHPP (6.7 W/m^2 v. 2.1 W/m^2) and therefore predicts lower demand for useful space heating energy than PHPP. SAP should not be used to make comparisons with Passive House or CarbonLite standards. The gains assumed in the PHPP are said to be based on monitored and calculated data from Passive Houses and include the effects of evaporation losses.[8]

Of the three upgrade scenarios (basic, intermediate, advanced), only the advanced package meets the AECB CarbonLite Silver standard of < 40kWh/m^2 p.a. None of these upgrade scenarios met the Passive House or CarbonLite Gold standards for the detached house.

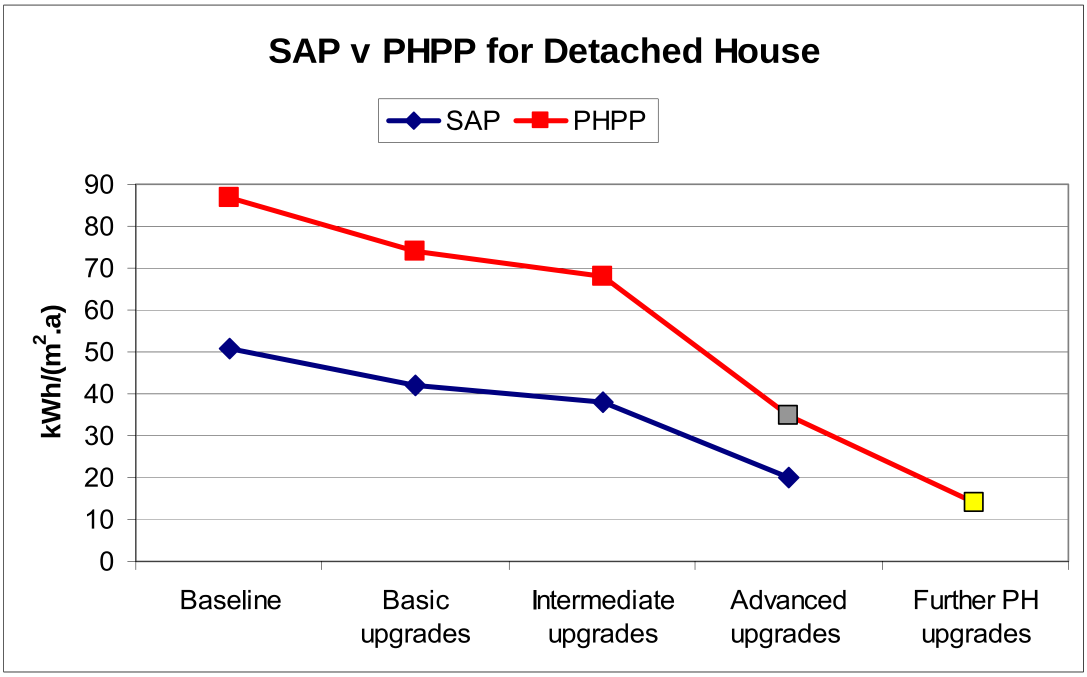
The upgrade scenarios all assumed current accredited construction details for thermal bridges. If the intermediate and advanced upgrade packages are improved to meet even the CarbonLite Silver details for thermal bridges then the useful energy demand for space heating, as calculated using PHPP, is reduced by 13% and 25% respectively.

If the advanced upgrade package is improved by adopting the CarbonLite Silver thermal bridge values, decreasing air permeability to PH standard (0.6 ac/h at 50Pa) and moving some of the glazing from the default East/West orientation to include some glazing on the South façade then the Passive House and CarbonLite Gold heating energy demand criterion is met (<15kWh/m^2 p.a.). As an alternative to changing window orientation it would be possible to specify a higher performing glazing (from the PHPP database) to allow the standard to be met without changing the building form. (Note: The East / West glazing orientation in this case represents the SAP default rather than the actual glazing orientation but this does serve to illustrate the trade-off between fabric performance and solar gains).

The PHPP analysis showed that the selected mechanical heat recovery ventilation (HRV) of Passive House standard provided no space heating benefit for this building with building air permeability of 10 m^3/m^2 at 50Pa but provided a very significant benefit at improved air permeability levels.

[8] It is stated in the PHPP that the energy consumed in the evaporation of a moisture e.g. drying of used to towels, drying of shower surfaces etc. is represented by a reduction in the internal heat gains, this evaporation is not currently considered in SAP.

Figure 1: Detached house: space heating energy demand



3.2 Detached House: Data tables

Table 3.1: Space heat demand, SAP v PHPP calculations

Upgrade / Heat demand kWh/m2pa	SAP	PHPP
Baseline	51	87
Basic upgrades	42	74
Intermediate upgrades	38	68
Advanced upgrades	20	35
Further PH upgrades		14

Table 3.2: Space heat demand (PHPP), 'Accredited' v 'AECB Silver' thermal bridges

Upgrade / Heat demand kWh/m2pa	PHPP Accred. details	PHPP CL Silver details
Baseline	87	
Basic upgrades	74	
Intermediate upgrades	68	59
Advanced upgrades	35	26
Further PH upgrades		14

Table 3.3: Space heat demand (PHPP), impact of heat recovery ventilation (HRV) compared with natural ventilation (NV)

Upgrade / Heat demand kWh/m2pa	PHPP Accred. details NV	PHPP Accred. details HRV	PHPP CL Silver details NV	PHPP CL Silver details HRV
Baseline	87	89		
Basic upgrades	74			
Intermediate upgrades	68		59	
Advanced upgrades	54	35	45	26
Further PH upgrades				14

Table 3.4: Passive House Heat Recovery, ventilation fan energy use comparison

PH HRV 0.3 ac/h electricity kWh pa	PH HRV 0.3 ac/h electricity kWh/m^2 pa
190	1.6

equivalent 1.5W/l/s

3.3 Detached house: Notes and assumptions

The inputs to the PHPP were extracted from the SAP datasheet used in Davis Langdon's analysis rather than being derived from plans. This has the benefit of allowing direct comparison with SAP but requires some assumptions to be made. The assumptions are stated below.

i. The PHPP requires externally measured dimensions for the heat loss areas. We have followed this convention and derived the external dimensions by adding the appropriate thicknesses to the internal dimensions from the SAP sheet.

ii. The SAP data sheet does not require individual window sizes and framing, which are required inputs to PHPP, although some SAP-based software allows individual inputs. In this study we assumed that the $5.95m^2$ on the East and also on the West façade is made up of 3 windows of 1.6m width by 1.24m depth with a centre vertical frame (i.e. each window made up two panes 0.8m wide by 1.24m depth).

iii. The PHPP requires thermal bridge Psi values (ψ) and lengths to be entered. In this study we used the ψ values given in SAP for the use of accredited details for the base and then also investigate the impact of the CarbonLite Silver details.

iv. The SAP ψ values are for internally measured dimensions, the PHPP uses external dimensions. We used the embedded PHPP tool for the required translation of internal to external dimensions for PHPP.

v. The highest ψ value thermal bridges in the current construction details are for lintels above doors and windows and at gable ends. We have assumed the detached house has gable at two sides and eaves at two sides.

vi. The PHPP requires input of the thermal bridge ψ values for the glazing spacer and also the glazing installation. The spacer is to reflect the glazing panel edge bridge which should be included in the UK full frame U-value, the installation ψ is to reflect the thermal bridge (lintel, sill, jamb). In this study we used values representing the current regulations and also investigate the CarbonLite details.

vii. The PHPP requires local climate to be considered. The only Scottish climate file provided is for Glasgow and we used this in the study. SAP uses Sheffield weather data throughout the UK.

viii. The PHPP can be used as a design tool or in certification mode. The design tool allows different occupancy types and associated gains to be selected etc. In this study we used the PHPP in certification mode.

ix. The PHPP definition of treated floor area is slightly different to SAP in its treatment of stairs, for consistency we used the SAP definitions.

x. The PHPP ventilation section requires mechanical systems to be specified and also infiltration rates. For natural ventilation we set the mechanical systems' operating hours to zero and set the air pressurisation test result in ac/h to give the appropriate level of air permeability in m^3/m^2. The level of infiltration takes account of sheltering in PHPP similarly to SAP. We set the PHPP air change rates for natural ventilation based on similar assumptions to those made in SAP i.e. for $10m^3/m^2$ permeability ac/h = 0.65, for $7m^3/m^2$ ac/h = 0.61 and for $3m^3/m^2$

ac/h = 0.54. The Passive House specification for permeability of 0.6ac/h at 50Pa is represented by 0.5 ac/h. The ventilation rates for natural ventilation in SAP are intended to represent an average occupant behaviour i.e. window and vent opening, local extract fan use etc.

xi. SAP uses a constant scaling factor between air pressurisation test result and ac/h. This is arithmetically incorrect. See also comments on this in section on the mid-floor flat.

xii. The PHPP states that where heat recovery systems are not accredited by the Passive House Institute (PHI) then 12% should be subtracted from the stated HR efficiency. Here we have used a PHI accredited system from the PHPP embedded database with 88% HR efficiency.

xiii. The thermal bridge details are given below:

Table 3.5: Thermal bridges comparison - summary tables

Openings thermal bridges	SAP Accredited details		CarbonLite Silver		PH (Gold) spacer install	
	Psi		Psi		Psi	
wind/door lintel (H)	0.4	(0.3 to 0.5)	0.03			
window sill (S)	0.04		0.03			
wind/door jamb (L,R)	0.05		0.03			
	spacer	install	spacer	install	spacer	install
	0.00	L,R,S,H	0.00	L,R,S,H		

Envelope thermal bridges	SAP Accredited details		CarbonLite Silver		PH (Gold)	
	Int Psi	Ext Psi	Int Psi	Ext Psi	Int Psi	Ext Psi
wall to floor jn	0.16	0.02	0.03	-0.11		<0.01
eaves	0.06	-0.06	0.03	-0.09		<0.01
gable	0.24	0.12	0.03	-0.09		<0.01
wall to wall jn	0.09	-0.05	0.06	-0.08		<0.01
int floor jn	0.07	0.07	0.00	0.00		<0.01

3.4 Detached house: PHPP output summary sheets

The following PHPP output summary sheets are appended at Appendix B, section B.1:

- Baseline
- Baseline with HRV
- Basic upgrade
- Intermediate upgrade
- Advanced upgrades (NV)
- Advanced upgrades including HRV
- Intermediate upgrades plus CL Silver Details for thermal bridges
- Advanced upgrades (NV) plus CL Silver Details for thermal bridges
- Advanced upgrades including HRV plus CL Silver Details for thermal bridges
- Advanced upgrades, HRV, CL Silver Details, 0.6ac/h at 50Pa, South glazing.
- Advanced upgrades, HRV, CL Silver Details, 0.6ac/h at 50Pa, EW glazing, PH windows.

4 Mid floor flat

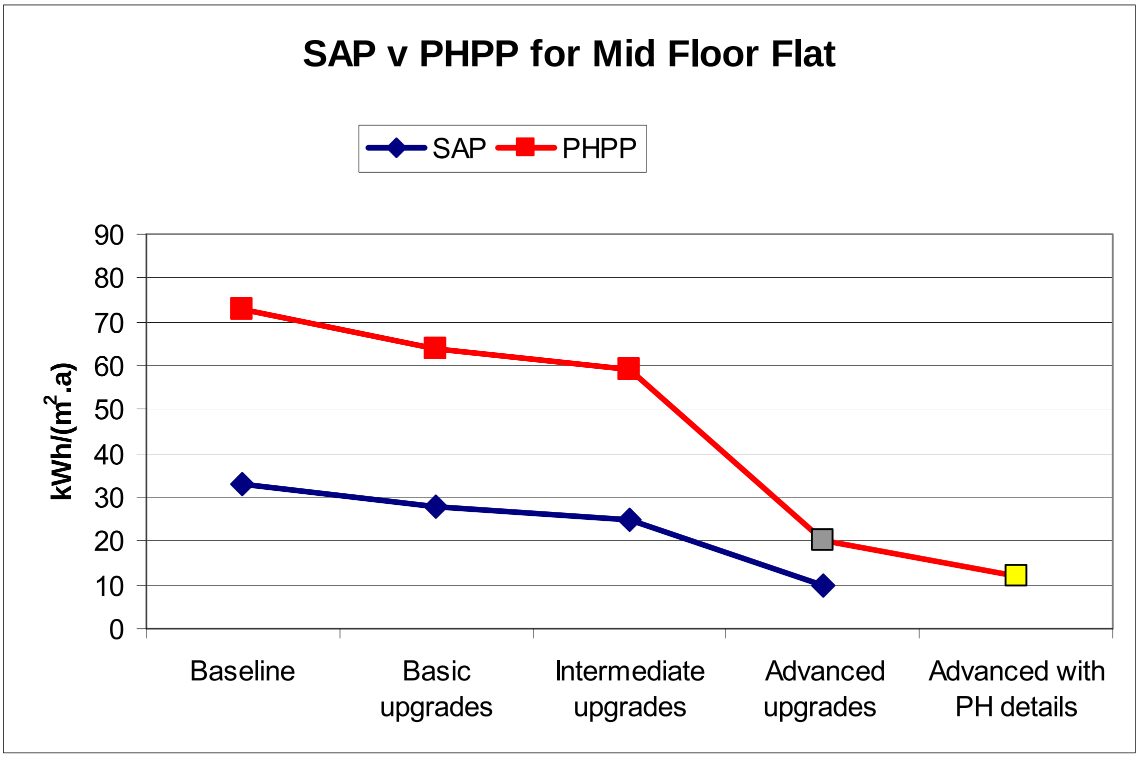
4.1 Mid Floor Flat - brief summary of results

SAP has a more optimistic view of internal gains than PHPP (7.7 W/m^2 v. 2.1 W/m^2) and therefore predicts lower demand for useful space heating energy than PHPP. SAP should not be used to make comparisons with Passive House standards. The AECB CarbonLite Silver standard for useful space heating energy demand is 40kWh/m^2 p.a. When SAP was used, the baseline flat and upgrade scenarios all appeared to be 40kWh/m^2 p.a. or less. However, when PHPP is used to calculate, only the advanced package meets the AECB CarbonLite Silver standard.

The upgrade packages all assume current accredited construction details for thermal bridges. If the advanced upgrade package is improved by adopting the CarbonLite Silver thermal bridge values and increasing air permeability to PH standard (0.6 ac/h at 50Pa) then the Passive House and CarbonLite Gold heating energy demand criterion is met (<15kWh/m^2 p.a.).

In contrast to the detached house, the PHPP analysis showed that mechanical heat recovery ventilation (HRV) of Passive House standard provides a significant space heating benefit for this building even with building air permeability of 10 m^3/m^2 at 50Pa and an even larger benefit at improved air permeability levels. This partly reflects the smaller exposed fabric area i.e. no external ground floor or roof and a party wall, which gives a lower air change rate than the detached house, due to less air infiltration, even with the same air permeability. SAP applies a constant scaling factor to translate air permeability to air change rate and does not explicitly take the exposed surface area into account.

Figure 2: Mid Floor Flat: Space Heating energy demand



4.2 Mid Floor Flat – Data Tables

Table 4.1: Space Heat Demand, SAP v PHPP calculations

Upgrade / Heat demand kWh/m2pa	SAP	PHPP
Baseline	33	73
Basic upgrades	28	64
Intermediate upgrades	25	59
Advanced upgrades	10	20
Advanced with PH details		12

Table 4.2: Space Heat demand (PHPP), 'Accredited' v 'AECB Silver' thermal bridges

Upgrade / Heat demand kWh/m2pa	PHPP Accred. details	PHPP CL Silver tbr details
Baseline	73	
Basic upgrades	64	
Intermediate upgrades	59	
Advanced upgrades	20	15
Advanced with PH details		12

Table 4.3: Space Heat demand (PHPP), impact of heat recovery ventilation (HRV) compared with natural ventilation (NV)

Upgrade / Heat demand kWh/m2pa	PHPP Accred. details NV	PHPP Accred. details HRV	PHPP CL Silver tbr details HRV
Baseline	73	53	
Basic upgrades	64		
Intermediate upgrades	59		
Advanced upgrades	48	20	15
Advanced with PH details			12

4.3 Mid Floor Flat – Notes and Assumptions

The inputs to the PHPP were generally extracted from the SAP datasheet provided rather than being derived from plans, this has the benefit of allowing direct comparison with SAP but requires some assumptions to be made, the assumptions are stated below.

i. The PHPP requires externally measured dimensions for the heat loss area, we have followed this convention and derived the external dimensions by adding the appropriate thicknesses to the internal dimensions from the SAP sheet.

ii. The SAP data sheet does not require details of individual window sizes and framing which is a required input to PHPP, although some SAP-based software allows individual inputs. In this study we estimated the individual glazing element sizes based on existing plans for a similar dwelling.

iii. The PHPP requires thermal bridge ψ values and lengths to be entered. In this study we used the values given in SAP for the use of accredited details for the base and then also investigate the impact of the CarbonLite Silver details.

iv. The SAP ψ values are for internally measured dimensions, the PHPP uses external dimensions. We used the embedded PHPP tool for the required translation of internal to external for PHPP.

v. The PHPP requires input of the thermal bridge ψ values for the glazing spacer and also the glazing installation. The spacer is to reflect the glazing panel edge bridge which should be included in the UK full frame U-value, the installation ψ is to reflect the thermal bridge (lintel, sill, jamb). In this study we used values representing the current regulations and also investigate the CarbonLite details.

vi. The PHPP requires local climate to be considered. The only Scottish climate file provided is for Glasgow and we used this in the study. SAP uses Sheffield weather data throughout the UK.

vii. The PHPP can be used as a design tool or in certification mode. The design tool allows different occupancy types and associated gains to be selected etc. In this study we used the PHPP in certification mode.

viii. The PHPP ventilation section requires mechanical systems to be specified and also infiltration rates. For natural ventilation we set the mechanical systems' operating hours to zero and set the air pressurisation test result in ac/h to give the appropriate level of air permeability in m^3/m^2. The level of infiltration takes account of sheltering in PHPP similarly to SAP. We have set the PHPP air change rates for natural ventilation to be the same as in SAP i.e. for $10m^3/m^2$ permeability ac/h = 0.65, for $7m^3/m^2$ ac/h = 0.61 and for $3m^3/m^2$ ac/h = 0.54. The Passive House specification for permeability of 0.6ac/h at 50Pa is represented in SAP for natural ventilation by 0.5 ac/h. The ventilation rates for natural ventilation represent average occupant behaviour i.e. window and vent opening, local extract fan use etc.

ix. The PHPP states that where heat recovery systems are not accredited by the Passive House Institute (PHI) then 12% should be subtracted from the stated HR efficiency. Here we have used a PHI accredited system from the PHPP embedded database with 88% HR efficiency.

4.2 Midfloor flat: PHPP output summary sheets

The following PHPP output summary sheets are appended at Appendix B, section B.2:

- Baseline
- Baseline with HRV
- Basic upgrade
- Intermediate upgrade
- Advanced upgrades (NV)
- Advanced upgrades including HRV
- Advanced upgrades, PH details.

5 City centre office

5.1 City centre office - brief summary of results

The differences between PHPP and SBEM results are less marked.

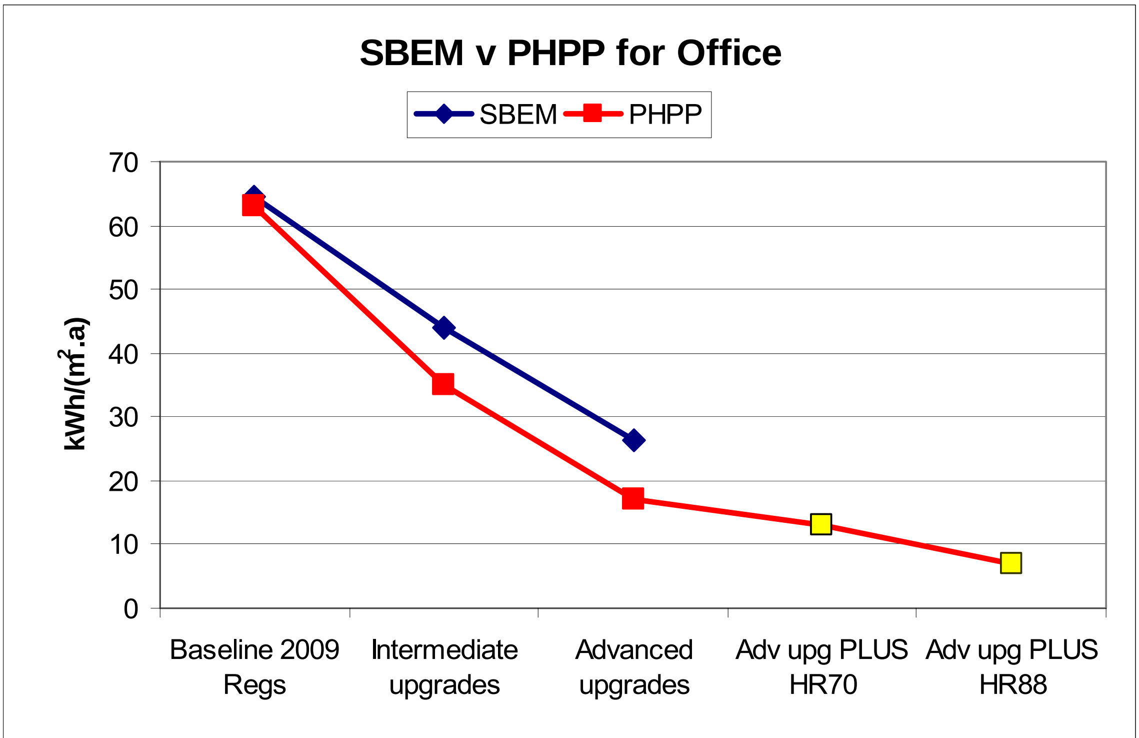
Neither of the upgrade scenarios achieved the Passive House standard.

The heat recovery efficiency specified in the upgrade scenarios were 40% and 60% respectively. If higher heat recovery efficiencies were adopted then the Passive House standard could be met. Heat recovery would have high impact on space heating energy use due to the high ventilation rates applied in the office.

Although the CarbonLite Silver criterion for domestic space heating energy demand would have been met by both upgrade packages, this criterion is not applicable to non-domestic buildings. The CarbonLite criteria for non domestic buildings is based on primary energy and carbon emissions rather than space heating energy demand and is beyond the scope of this study.

The Passive House criteria includes the energy demand for cooling unless it is demonstrated that cooling is not required. For this building the calculated overheating frequency was 5.1% of hours > 25ºC which is less than the limit in PHPP of 10%, however the PHPP recommends that for non-domestic buildings the calculated overheating frequency should be much less than 10% and states that where there are high internal heat gains that are concentrated in space or time (which would be the case for this building due solar gains through the highly glazed façade), a dynamic simulation should be used. Here we assumed that cooling was not required as a more complete study was out-with the scope of this study.

Figure 3: City Centre Office: Space Heating energy demand



5.2 City centre office – data table

Table 5.1: Space Heat Demand, SBEM v PHPP calculations

The 'PHPP No HR' column shows the impact of the ventilation Heat Recovery on the heat demand for the Intermediate and the Advanced upgrade packages which have 40% and 60% ventilation heat recovery included. HR70 and HR80 refer to further improved ventilation Heat Recovery systems with 70% and 80% efficiencies respectively. With these further improvements to the Advanced upgrade package then the Passive House criteria (< 15 kWh/m^2 p.a. would be met.

Upgrade / Heat demand kWh/m2pa	SBEM	PHPP	PHPP No HR
Baseline 2009 Regs	65	63	
Intermediate upgrades	44	35	51
Advanced upgrades	26	17	41
Advanced upgrades PLUS HR70		13	
Advanced upgrades PLUS HR88		7	

5.3 City centre office – notes and assumptions

The inputs to the PHPP were extracted from the Excel datasheet used in Davis Langdon's SBEM analysis rather than being derived from plans. This has the benefit of allowing direct comparison with SBEM but required some assumptions to be made. The assumptions are stated below.

Notes on the Excel spreadsheet and Davis Langdon's analysis that serve as a baseline for comparison:

i. The calculation of the heating energy in the spreadsheet are based on the SBEM outputs which give the delivered energy used to supply the heat rather than the space heating energy demand as specified in the Passive House and CarbonLite standards. To convert from the SBEM values supplied to the space heating energy demand we multiplied by the heating system efficiency (for the baseline 83.6%, the Intermediate upgrade case 85.5% and the Advanced upgrade case 87.4%) as shown in the table below.

Scenario	SBEM Heating Energy kWh/m^2 p.a.	Heating System Efficiency %	Space Heating Energy Demand kWh/m^2 p.a.
Baseline building	77	83.6	65
Intermediate upgrade	51	85.5	44
Advanced upgrade	30	87.4	26

Notes on inputs for PHPP:

ii. The PHPP requires local climate to be considered. The only Scottish climate file provided is for Glasgow and we used this in the study. SAP uses Sheffield weather data; in SBEM, Glasgow weather data are used for Scotland.

iii. The PHPP can be used as a design tool or in certification mode. The design tool allows different occupancy types and associated gains to be selected etc. In this study we used the PHPP in certification mode.

iv. The SBEM input spreadsheet does not specify the details of individual window and framing sizes and orientations or specify storey heights etc. For PHPP, where required dimensions were not given these were estimated from the given dimensions and with reference to the picture of the building. The orientations of windows were assigned arbitrarily but a study was carried out with differing orientations and the impact found to be small.

v. The PHPP requires the number of occupants to be entered. We have used a density of 1 person per 15m^2 (same as 'open office' space from the PHPP building use database) which gives an occupancy of 700 people. Note: SBEM allocates an occupant density and occupation period based on the specified activity for each area of the building as defined in the NCM. More detailed investigation of differences between the NCM and the PHPP occupancy assumptions was not done.

vi. The PHPP ventilation section requires mechanical systems to be specified and also infiltration. For infiltration we set the air pressurisation test result in ac/h to give the appropriate level of air permeability in m^3/m^2. In PHPP, the level of infiltration takes account of sheltering and here we have chosen the defaults representing an urban environment.

vii. 7 kitchens, 28 WCs and 4 shower rooms were assumed.

viii. The PHPP ventilation rates are set based on the occupancy of the building in a similar fashion to SBEM, PHPP uses 30m^3/h/p, similar to CIBSE 8l/s/p, added to the ventilation for wet rooms. The operating hours for the system were set as 'max' for 70% and 'basic' for 30% of the time as specified in the PHPP for an 'administration' building use pattern. As stated above, more detailed investigation of the differences between NCM and PHPP occupancy assumptions was not carried out.

ix. The thermal bridge ψ values required for PHPP must be explicitly entered in PHPP rather than using an area weighted factor. The ψ values from the SAP accredited details were used in this analysis. More detailed analysis of the impact of thermal bridging for non-domestic buildings could be undertaken in future.

x. Summer overheating calculations were carried out using the PHPP and the overheating frequency (T > 2^{o}C) calculated as 5.1% which is within the Passive House guideline of < 10%. The PHPP recommends that for non-domestic buildings calculated overheating frequency should be much less than 10% and states that where there are high internal heat gains that are concentrated in space or time, a dynamic simulation should be used. For this study it was assumed that the building achieves comfortable summer temperatures without cooling and no further investigation was carried out.

5.4 City centre office: PHPP output summary sheets

The following PHPP output summary sheets are appended at Appendix B, section B.3:

- Baseline
- Intermediate upgrade
- Intermediate upgrade but NV
- Advanced upgrades
- Advanced upgrades but NV
- Advanced upgrades but HRV improved to 70%
- Advanced upgrades but HRV improved to 88%

- Baseline but opposite orientation.
- Overheating summary.

6 Conclusion

The research reported here examines three example buildings (detached house, mid floor flat and city centre office) built to the 2007 standards and also to improved standards of insulation and air permeability. It uses the EU Passive House Planning Package (PHPP) to calculate space heating energy performance and compares the results to the criteria for Passive House and, for dwellings, the CarbonLite standards. The results for space heating energy use from the PHPP calculations are also compared to those generated using SAP and SBEM. The research does not attempt to validate the methodologies used.

There are significant differences between SAP and PHPP, so that SAP should not be used to make comparisons with Passive House or CarbonLite standards. The PHPP assumes lower internal gains than SAP (2.1 W/m^2 vs. 6.7 W/m^2 and 7.7 W/m2 for the 2007 detached house and mid-floor flat respectively) and therefore gives a higher space heating energy demand. Other differences between PHPP and SAP include the use of local climates and the treatment of air permeability and thermal bridges.

For the dwellings (detached house and mid-floor flat), none of the upgrade packages achieved the Passive House or CarbonLite Gold standard, only the advanced improvement package achieved the criterion for CarbonLite Silver.

The differences in the calculated useful space heating energy demand between the PHPP and SBEM when applied to the city centre office are less marked than between PHPP and SAP for the dwellings. For the city centre office, none of the improvement packages achieved the Passive House standard.

The findings should contribute to an understanding of the levels of proposed energy standards in building regulations relative to Passive House and CarbonLite standards.

Appendix A
Energy demand calculated using SAP and SBEM

This part of the report comprises a study prepared by Davis Langdon, with SBEM modeling input by Faber Maunsell Aecom. It addresses the full range of buildings from two recent reports by Davis Langdon.[1,2]

A.1 Methodology

The work undertaken comprises an assessment of the useful energy requirement for space heating of the following buildings:

- a range of baseline houses and flats, that are designed to just comply with energy standard 6.1 'Carbon dioxide emissions' in the 2007 Technical Handbooks.
- the baseline houses and flats adjusted by improvement scenarios designed to achieve reductions in CO_2 emissions, beyond the 2007 levels.
- four non-domestic baseline buildings ,that are designed to just comply with energy standard 6.1 'Carbon dioxide emissions' in the 2007 Technical Handbooks: a primary school, a secondary school, a city centre office building, and a retail warehouse.
- the baseline primary school and office building adjusted by improvement scenarios designed to achieve reductions in CO_2 emissions, beyond the 2007 levels.

The baseline buildings are outlined at Annex A. The improvement scenarios are described in Annex B.

The earlier reports addressed the demand for delivered energy and associated CO_2 emissions. The energy performance of the baseline buildings was established and then re-assessed following the application of a package of energy efficiency measures, with low carbon equipment added as necessary in order to achieve specified levels of reductions of CO_2 emissions and demand for delivered energy. For this study, the energy performance calculations were re-examined and interpreted in terms of the useful space heating requirement. The energy performance modelling of the earlier reports used the national calculation methods, SAP and SBEM.

Domestic

The domestic buildings were assessed using BRE approved software based on SAP 2005 version 9.80. SAP 2005 does not allow the percentage of energy efficient lighting to be altered and where energy efficiency improvement packages are applied, this figure is adjusted manually to take account of the decreased internal heat gains due to a change from 50% to 100% energy efficient lighting.

The following table describes the energy efficiency measures used in the baseline buildings and the three levels of improvements applied in the earlier cost impacts study:

Table A.1: Energy efficiency measures in baseline dwellings and improvement packages				
	Baseline	**Improvement levels**		
U-values	(W/m^2K)	Basic (W/m^2K)	Intermediate (W/m^2K)	Advanced (W/m^2K)
Walls: houses	0.23 & 0.25	0.19 & 0.21	0.15 & 0.17	0.10 & 0.12
Walls: flats	0.25	0.19	0.15	0.10
Ground Floors	0.21	0.15	0.15	0.10
Roofs	0.16	0.13	0.13	0.10
Openings	1.80	1.50	1.30	1.10
Airtightness and ventilation	$m^3/h.m^2$@50Pa	$m^3/h.m^2$@50Pa	$m^3/h.m^2$@50Pa	$m^3/h.m^2$@50Pa
Max air permeability	10	7	7	3
MVHR efficiency	-	-	-	90%
Specific fan power	–	–	-	1W / litre / sec
Gas boiler efficiency	86%	90.2%	90.2%	90.2%
Energy efficient lighting	50%	100%	100%	100%

The useful energy requirement for space heating was obtained from box 81 in the SAP worksheets for the baseline dwellings and for the dwellings with enhancement packages for energy efficiency measures.

In the previous Davis Langdon studies, low carbon equipment was used to further reduce CO_2 emissions beyond the levels that could be achieved by energy efficiency measures alone. Although the useful energy requirement for space heating is unaffected by the means with which energy is supplied, the results for all the scenarios are shown in order to allow a direct comparison with the earlier work.

Non-Domestic

The SBEM data from the previous non-domestic study were used to calculate the space heating requirement of the four different building types examined: a primary school, a secondary school, a city centre office building, and a retail warehouse. Unlike both SAP and the dynamic modelling software IES, SBEM does not disaggregate the space heating requirement but gives the delivered energy consumption by the heating equipment. Therefore space heating loads were calculated by multiplying the delivered energy consumption of the space heating equipment by the equipment efficiency.

The space heating requirement was calculated for the baseline dwellings and for the dwellings as adjusted with enhancement packages for energy efficiency measures. The results for all the improvement scenarios that include low carbon equipment are also shown, in order to allow a direct comparison with the earlier work.

A.2 Findings: Domestic

Table A.2 displays the useful energy requirement for space heating for different dwelling types with various levels of energy efficiency.
Houses and bungalows require more energy for space heating per unit area than the flats.
Table 4 displays the useful energy requirement for space heating per unit floor area as well as the DER (Dwelling Emissions Rate) achieved by each of the CO_2 reduction scenarios used in the earlier study.

These findings cover the full range of buildings examined in the original studies by Davis Langdon, of which a selection were examined by ESRU.

Table A.2: SAP calculations: Useful space heating requirements ratings for baseline dwellings and fabric upgrades

Key to table	Useful energy requirement for space heating only																			
Total annual useful space heating requirement (kWh/yr) / **Annual useful space heating requirement (kWh/m^{2}yr)**	Social housing														Private sector housing					
	A 4p2b Semi-d House 73 m^2		B 5p3b Semi-d House 88 m^2		C 2p1b Bungalow 56 m^2		D 3p2b Bungalow 82 m^2		E 2p1b Flat 56 m^2		F 3p2b Flat 61 m^2		G 5p3b Flat 85 m^2		H 4 Bedroom Detached 118 m^2		I 3 Bedroom Detached 100 m^2		J 2 Bedroom Flat 82 m^2	
Baseline dwelling: Target Emissions Rate (TER)	3350	**46**	4230	**48**	3140	**56**	4540	**55**	2030	**36**	2140	**35**	2830	**33**	6190	**52**	5510	**55**	2950	**36**
Baseline dwelling: Dwelling Emissions Rate (DER)	3020	**41**	3700	**42**	2940	**53**	4110	**50**	1840	**33**	2050	**34**	2340	**28**	5960	**51**	5620	**56**	2740	**33**
Basic energy efficiency improvement package only	2524	**35**	3137	**36**	2425	**43**	3454	**42**	1610	**29**	1761	**29**	2062	**24**	4953	**42**	4518	**45**	2260	**28**
Intermediate energy efficiency improvement package only	2294	**31**	2857	**32**	2255	**40**	3174	**39**	1470	**26**	1591	**26**	1862	**22**	4473	**38**	4158	**42**	2020	**25**
Advanced energy efficiency with MVHR	1164	**16**	1507	**17**	1185	**21**	1694	**21**	780	**14**	841	**14**	912	**11**	2393	**20**	2178	**22**	850	**10**

Table A.3: SAP calculations: Useful energy requirement for space heating and CO_2 emissions for each scenario

Scenario	Key to table	Social housing														Private sector housing					
	DER Kg $CO_2/m^2/yr$ / **Annual useful space heating requirement ($kWh/yr/m^2$)**	A 4p2b Semi-d House 73 m^2		B 5p3b Semi-d House 88 m^2		C 2p1b Bungalow 56 m^2		D 3p2b Bungalow 82 m^2		E 2p1b Flat 56 m^2		F 3p2b Flat 61 m^2		G 5p3b Flat 85 m^2		H 4 bedroom Detached 118 m^2		I 3 Bedroom Detached 100 m^2		J 2 bedroom Flat 82 m^2	
	Baseline dwelling	22.56	**41**	21.74	**42**	26.34	**53**	24.61	**50**	22.48	**33**	21.95	**34**	19.19	**28**	22.22	**51**	23.57	**56**	20.34	**33**
1	Basic energy efficiency upgrade only	18.32	**35**	17.41	**36**	21.68	**43**	19.96	**42**	18.86	**29**	18.46	**29**	15.52	**24**	18.42	**42**	19.94	**45**	16.74	**28**
2	Intermediate energy efficiency upgrade only	17.60	**31**	16.72	**32**	20.99	**40**	19.17	**39**	18.28	**26**	17.80	**26**	14.99	**22**	18.06	**38**	19.23	**42**	16.05	**25**
3	Basic energy efficiency upgrade and solar water heating	15.79	**35**	15.20	**36**	18.81	**43**	17.60	**42**	15.89	**29**	15.63	**29**	13.20	**24**	16.51	**42**	17.87	**45**	14.32	**28**
4	Advanced energy efficiency upgrade and MVHR	15.77	**16**	14.85	**17**	18.25	**21**	16.91	**21**	16.90	**14**	16.42	**14**	13.89	**11**	15.15	**20**	16.29	**22**	14.44	**10**
5	Intermediate energy efficiency upgrade and solar water heating	15.09	**31**	14.48	**32**	18.10	**40**	16.81	**39**	15.33	**26**	14.97	**26**	12.67	**22**	16.15	**38**	17.14	**42**	13.65	**25**
6	Intermediate energy efficiency upgrade and photovoltaics	14.15	**31**	13.91	**32**	16.57	**40**	16.02	**39**	13.67	**26**	13.50	**26**	11.94	**22**	15.89	**38**	16.64	**42**	12.83	**25**
7	Intermediate energy efficiency & communal on-site wind turbine (low capacity)	14.51	**31**	14.20	**32**	17.04	**40**	16.32	**39**	14.14	**26**	13.96	**26**	12.26	**22**	16.11	**38**	16.92	**42**	13.16	**25**
8	Basic energy efficiency upgrade and air source heat pump	15.61	**35**	14.85	**36**	18.46	**43**	17.01	**42**	16.12	**29**	15.76	**29**	13.30	**24**	15.71	**42**	16.92	**45**	14.03	**28**
9	Basic energy efficiency upgrade and GSHP	12.45	**35**	12.80	**36**	15.46	**43**	13.73	**42**	13.60	**29**	13.19	**29**	11.57	**24**	13.22	**42**	14.24	**45**	12.10	**28**
10	Advanced energy efficiency upgrade, MVHR, and solar water heating	11.73	**16**	11.11	**17**	13.88	**21**	12.62	**21**	12.48	**14**	12.09	**14**	10.06	**11**	11.47	**20**	12.56	**22**	10.25	**10**
11	Intermediate energy efficiency upgrade, solar water heating, PV	11.64	**31**	11.67	**32**	13.70	**40**	13.66	**39**	10.72	**26**	10.67	**26**	9.61	**22**	13.95	**38**	14.57	**42**	10.41	**25**
12	Advanced energy efficiency, MVHR, solar water heating, high capacity wind turbine	3.27	**16**	4.50	**17**	2.61	**21**	5.02	**21**	0.63	**14**	1.14	**14**	2.72	**11**	6.91	**20**	6.74	**22**	2.73	**10**
13	Basic energy efficiency upgrade, biomass boiler	6.36	**35**	6.11	**36**	7.48	**43**	6.96	**42**	6.54	**29**	6.37	**29**	5.57	**24**	6.51	**42**	6.93	**45**	5.96	**28**
14	Advanced energy efficiency upgrade, MVHR biomass boiler	6.70	**16**	6.44	17	7.53	**21**	7.01	**21**	7.01	**14**	6.85	**14**	6.14	**11**	6.80	**20**	6.95	**22**	6.53	**10**

A.3 Findings: Non-domestic

Table A.4 displays the useful energy requirement for space heating for of each of the four non-domestic buildings, at three different energy efficiency levels as defined in the previous study. Each of these energy efficiency improvements includes increased insulation levels and the advanced level requires MVHR systems which decrease heat losses (refer annex A). However the energy efficiency improvements also decrease lighting loads, which in turn decreases internal heat gains, therefore increases heating demand. Low carbon equipment does not change heat gains and losses, so it does not have an effect on the space heating demand.

Table A.4: Useful energy for space heating at various energy efficiency levels, non-domestic buildings

Key to table							
Total annual useful space heating energy (kWh/yr)	**Useful space heating energy per floor area (kWh/yr/m²)**	Energy efficiency improvement					
	Floor area (m²)	Baseline		Intermediate		Advanced	
Secondary school	11,193	755,813	**68**	629,740	**57**	571,760	**51**
Primary school	4,466	359,809	**80**	321,281	**72**	295,152	**66**
City centre office	12,236	686,008	**65**	464,607	**44**	280,491	**26**
Retail warehouse	4,981	29,942	**6**	31,414	**7**	32,300	**6**

The secondary school has a lower heat requirement per square metre than the primary school, which is due to the compact geometry of the secondary school. The compact geometry decreases external heat losses, which in turn decreases the space heating demand. For the city centre office, the baseline heat requirement per square meter is similar to that of the secondary school, but the energy efficiency improvement measures are more effective. This is again a result of the differences in building geometry, use and occupant densities.

The retail warehouse has the lowest heat requirement, due to the massive internal heat gains caused by the extensive lighting requirement. With the intermediate energy efficiency improvement, efficient lighting fixtures cut down the heat gains, therefore more heat needs to be provided by the heating equipment (this explains the increase from 6 to 7 kWh/yr/m^2 despite an improvement in energy efficiency in a warehouse in Table A.4). With the advanced level, even though there are further cuts in the lighting energy, the space heating demand decreases below the baseline levels. This is because the decrease in the internal heat gains due to efficient lighting is offset by the decreased external heat loss as a result of higher insulation levels. Therefore the space heating demand stays almost the same even when the advanced energy efficiency measures, designed to reduce CO_2 emissions, are introduced.

Tables 6a, 6b, 6c, 7a, 7b and 7c present the useful heating energy requirements when the baseline buildings are adapted with various scenarios designed to reduce CO_2 emissions by 25%, 37%, and 50%. They illustrate that low carbon equipment designed to reduce CO_2 emissions has no impact on useful heating energy requirements, which are only reduced by energy efficiency improvements. Energy efficiency improvements alone do not achieve even a 25% reduction in CO_2 emissions.

These findings cover the full range of buildings examined in the original studies by Davis Langdon, of which a selection were examined by ESRU.

Table A.5a: SBEM calculations: Primary school (SBEM-baseline): scenarios for achieving 25% CO_2 savings										
Ref	Upgrade	Units	% CO_2 reduction/ unit	Units required	Total % CO_2 reduction achieved	Cost per unit	Total cost	% increase in capital cost	Useful energy requirement for space heating (kWh/yr/m²)	Notes
	None - baseline								115	
25A	Advanced energy efficiency upgrade	nr	14.96%	1	14.96%	£455,009	£455,009	4.58%	86	Does not achieve 25% reduction in emissions.
25B	Baseline energy efficiency + biomass	*kW*	0.20%	125	25.00%	£900	£112,633	1.13%	115	
25C	Baseline energy efficiency + large wind	*kW*	0.42%	59	25.00%	£1,750	£103,535	1.04%	115	
25D	Baseline energy efficiency + small wind + GSHP				25.00%		£183,107	1.84%	115	Based on the maximum size of small wind
	Small wind	*kW*	*0.45%*	*20*	*8.96%*	*£1,750*	*£35,000*			
	GSHP	*kW*	*0.12%*	*135*	*16.04%*	*£1,100*	*£148,107*			
25E	Baseline energy efficiency + small wind + biomass	*kW*			25.00%		£106,470	1.07%	115	Based on the maximum size of small wind
	Small wind	*kW*	*0.45%*	*20*	*8.96%*	*£1,750*	*£35,000*			
	Biomass	*kW*	*0.20%*	*79*	*16.04%*	*£900*	*£71,470*			

Table A.5b: SBEM calculations: Primary school (SBEM-baseline): scenarios for achieving 37% CO_2 savings										
Ref	**Upgrade**	**Units**	**% CO_2 reduction/ unit**	**Units required**	**Total % CO_2 reduction achieved**	**Cost per unit**	**Total cost**	**% increase in capital cost**	**Useful energy requirement for space heating (kWh/yr/m^2)**	**Notes**
37B	Baseline energy efficiency + biomass	*kW*	0.20%	186	37.00%	£900	£167,735	1.69%	115	
37C	Baseline energy efficiency + large wind	*kW*	0.43%	86	37.00%	£1,750	£151,046	1.52%	115	
37D	Baseline energy efficiency + small wind + biomass				37.00%		£161,572	1.63%	115	Based on the maximum size of small wind
	Small wind	*kW*	*0.45%*	*20*	*8.96%*	*£1,750*	*£35,000*			
	Biomass	*kW*	*0.20%*	*141*	*28.04%*	*£900*	*£126,572*			
37E	Baseline energy efficiency + small wind + GSHP				37.00%		£369,023	3.72%	115	Based on the maximum size of small wind
	Small wind	*kW*	*0.45%*	*20*	*8.96%*	*£1,750*	*£35,000*			
	GSHP	*kW*	*0.09%*	*304*	*28.04%*	*£1,100*	*£334,023*			

Table A.5c: SBEM calculations: Primary school (SBEM-baseline): scenarios for achieving 50% CO_2 savings										
Ref	**Upgrade**	**Units**	**% CO_2 reduction/ unit**	**Units required**	**Total % CO_2 reduction achieved**	**Cost per unit**	**Total cost**	**% increase in capital cost**	**Useful energy requirement for space heating ($kWh/yr/m^2$)**	**Notes**
50A	Baseline energy efficiency + biomass	*kW*	0.20%	253	50.00%	£900	£227,429	2.29%	115	
50B	Baseline energy efficiency + large wind	*kW*	0.43%	116	50.00%	£1,750	£202,517	2.04%	115	
50C	Baseline energy efficiency + small wind + biomass				50.00%		£221,266	2.23%	115	Based on the maximum size of small wind
	Small wind	*kW*	*0.45%*	*20*	*8.96%*	*£1,750*	*£35,000*			
	Biomass	*kW*	*0.20%*	*207*	*41.04%*	*£900*	*£186,266*			
50D	Baseline energy efficiency + small wind + GSHP + Solar thermal + PV	*kW*			50.00%		£625,543	6.30%	115	Based on the maximum size of small wind + GSHP + solar thermal
	Small wind	*kW*	*0.45%*	*20*	*8.96%*	*£1,750*	*£35,000*			
	GSHP		*0.09%*	*340*	*30.70%*	*£1,100*	*£373,450*			
	Solar thermal	*kW*	*0.05%*	*70*	*3.55%*	*£1,000*	*£70,000*			
	Photovoltaics	*kW*	*0.05%*	*147*	*6.78%*	*£1,000*	*£147,093*			

Table A.6a: SBEM calculations: City centre office (SBEM-baseline): scenarios for achieving 25% CO_2 savings										
Ref	**Upgrade**	**Units**	**% CO_2 reduction/ unit**	**Units required**	**Total % CO_2 reduction achieved**	**Cost per unit**	**Total cost**	**% increase in capital cost**	**Useful energy requirement for space heating ($kWh/yr/m^2$)**	**Notes**
	None - baseline								92	
25A	Advanced energy efficiency upgrade	nr	36.1%	1	36.1%	£978,730	£978,730	3.3%	35	
25B	Basic energy efficiency + CHP	*kW*	0.2%	115	25.0%	£2,900	£334,942	1.1%	92	
25C	Basic energy efficiency + biomass + small wind + solar thermal + PV				25.0%		£432,932	1.4%	92	Based on maximum size of biomass & small wind & solar thermal
	Biomass	*kW*	*0.06%*	*394*	*24.0%*	*£900*	*£354,600*			
	Small wind	*kW*	*0.04%*	*12*	*0.5%*	*£1,750*	*£21,000*			
	Solar thermal	*kW*	*0.01%*	*30*	*0.2%*	*£1,000*	*£30,000*			
	Photovoltaics	*kW*	*0.01%*	*27*	*0.3%*	*£1,000*	*£27,332*			
25D	Basic energy efficiency + biomass + photovoltaics				25.0%		£439,421	1.5%	92	Based on maximum size of biomass
	Biomass	*kW*	*0.06%*	*394*	*24.0%*	*£900*	*£354,600*			
	Photovoltaics	*kW*	*0.01%*	*85*	*1.0%*	*£1,000*	*£84,821*			
25E	Intermediate energy efficiency + CHP				30.5%		£757,380	2.5%	60	Based on the minimum size of CHP. Reduction in useful energy due to energy efficiency improvement only.
	Intermediate energy efficiency upgrade	*nr*	*23.6%*	*1*	*23.6%*	*£708,080*	*£708,080*			
	CHP	*kW*	*0.4%*	*17*	*6.9%*	*£2,900*	*£49,300*			

Table A6b: SBEM calculations: City centre office (SBEM-baseline): scenarios for achieving 37% CO_2 savings

Ref	Upgrade	Units	% CO_2 reduction/ unit	Units required	Total % CO_2 reduction achieved	Cost per unit	Total cost	% increase in capital cost	Useful energy requirement for space heating ($kWh/yr/m^2$)	Notes
37A	Basic energy efficiency + CHP	*kW*	0.2%	182	37.0%	£2,900	£527,207	1.8%	92	
37B	Intermediate energy efficiency + CHP				37.0%		£895,843	3.0%	60	Reduction in useful energy due to energy efficiency improvement only.
	Intermediate energy efficiency	*nr*	*23.6%*	*1*	*23.6%*	*£708,080*	*£708,080*			
	CHP	*kW*	*0.2%*	*65*	*13.4%*	*£2,900*	*£187,763*			
37C	Intermediate energy efficiency + biomass	*kW*			37.0%		£960,617	3.2%	60	Reduction in useful energy due to energy efficiency improvement only.
	Intermediate energy efficiency	*nr*	*23.6%*	*1*	*23.6%*	*£708,080*	*£708,080*			
	Biomass	*kW*	*0.05%*	*281*	*13.4%*	*£900*	*£252,537*			
37D	Advanced energy efficiency + biomass				37.3%		£993,220	3.3%	35	Based on the minimum size of biomass. Reduction in useful energy due to energy efficiency improvement only.
	Advanced energy efficiency	*nr*	*36.08%*	*1*	*36.1%*	*£978,730*	*£978,730*			
	Biomass	*kW*	*0.1%*	*16*	*1.2%*	*£900*	*£14,490*			

Ref	Upgrade	Units	% CO_2 reduction/ unit	Units required	Total % CO_2 reduction achieved	Cost per unit	Total cost	% increase in capital cost	Useful energy requirement for space heating (kWh/yr/m^2)	Notes
50A	Advanced energy efficiency + CHP				50.0%		£1,131,404	3.8%	35	Reduction in useful energy due to energy efficiency improvement only.
	Advanced energy efficiency	*nr*	*36.1%*	*1*	*36.1%*	*£978,730*	*£978,730*			
	CHP	*kW*	*0.26%*	*53*	*13.9%*	*£2,900*	*£152,674*			
50B	Advanced energy efficiency + biomass + PV				50.0%		£1,560,207	5.2%	35	Based on the minimum size of biomass. Reduction in useful energy due to energy efficiency improvement only.
	Advanced energy efficiency	*nr*	*36.08%*	*1*	*36.1%*	*£978,730*	*£978,730*			
	Biomass	*kW*	*0.04%*	*209*	*9.2%*	*£900*	*£188,010*			
	PV	*kW*	*0.01%*	*393*	*4.7%*	*£1,000*	*£393,467*			

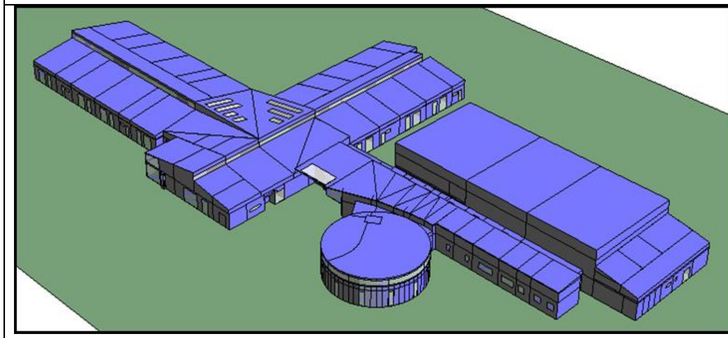
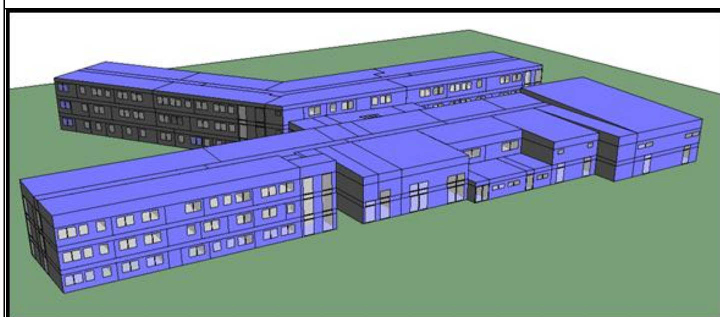
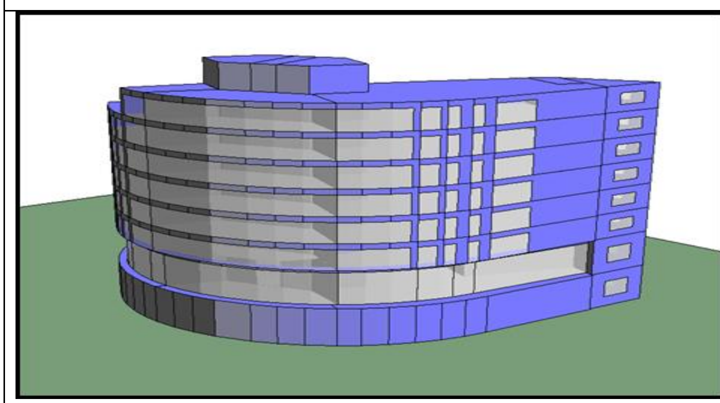
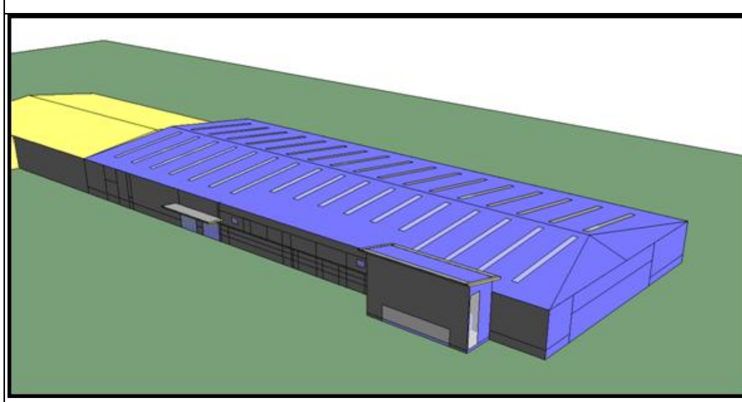
Table A6c: SBEM calculations: City centre office (SBEM-baseline): scenarios for achieving 50% CO_2 savings

Appendix A: Annex A: Baseline buildings

Full details of the baseline buildings are given in the original reports. The following is a simple overview.

Table A.A1: Overview of baseline dwelling types	
a) Social housing	
Dwelling type A: 2 bedroom house	2-storey semi-detached house $73m^2$ floor area
Dwelling type B: 3 bedroom house	2-storey semi-detached house $88m^2$ floor area
Dwelling type C: 1 bedroom bungalow	Semi-detached bungalow $56m^2$ floor area
Dwelling type D: 2 bedroom bungalow	Semi-detached bungalow $82m^2$ floor area
Dwelling type E: 1 bedroom flat	Mid-floor flat as part of a 4-storey, 8 flat block $56m^2$ floor area
Dwelling type F: 2 bedroom flat	Mid-floor flat as part of a 4-storey, 8 flat block $61m^2$ floor area
Dwelling type G: 3 bedroom flat	Mid-floor flat as part of a 4-storey, 8 flat block $85m^2$ floor area
b) Private sector housing	
Dwelling type H: 4 bedroom detached house	2-storey detached house $118m^2$ floor area
Dwelling type I: 3 bedroom detached house - from T&T study	2-storey detached house $100m^2$ floor area
Dwelling type J: 2 bedroom flat - from T&T study	Mid-floor flat (gable end location) $82m^2$ floor area

Table A.A2: Overview of baseline non-domestic buildings

	The baseline primary school is based on a recent public sector project with a gross floor area of 4,466m^2 and a largely single storey layout.
	The baseline secondary school is based on a recent Public Private Partnership (PPP) project with a gross floor area of 11,193m^2 and a largely 2 and 3 storey layout.
	The baseline city centre office building is based on a recent Glasgow project with a gross floor area of 12,236m^2 over 8 storeys.
	The baseline retail warehouse building is based on a recent Aberdeen project with a gross floor area of 4,981m^2.

Appendix A: Annex B Improvement scenarios

A.B.1 Domestic

As part of earlier research, Davis Langdon analysed a long-list of potential design and specification improvements to the baseline dwellings using the SAP-based software under the following four key headings:

a) Insulation improvements
b) Ventilation and airtightness improvements
c) Lighting improvements
d) Low carbon equipment

This analysis enabled a series of grouped potential improvement scenarios to be identified and modelled, based on combinations of two or more of the above options. It is worth noting that the list of proposed scenarios is not intended to be exhaustive and that there are further design strategies available for achieving improvements, such as passive solar design, thermal mass, reduction in thermal bridging, enhanced heating and lighting controls.

14 improvement scenarios were modelled as part of the current study, that were known to achieve certain levels of reductions in CO_2 emissions and delivered energy demand.

A.B.1.1 Domestic: thermal insulation upgrades

The list of improvement scenarios was established on the basis of three levels of thermal insulation upgrades, as follows:

Table B1: U-value improvements modelled

	Baseline dwellings (W/m^2K)	Basic improvements (W/m^2K)	Intermediate improvements (W/m^2K)	Advanced improvements (W/m^2K)
Walls, Houses	0.23 & 0.25	0.19 & 0.21*	0.15 & 0.17*	0.10 & 0.12*
Walls, Flats	0.25	0.19	0.15	0.10
Ground Floors	0.21	0.15	0.15	0.10
Roofs	0.16	0.13	0.13	0.10
Openings	1.80	1.50	1.30	1.10

* 2 types of walls are used in the houses, wall types a and b

All U-values are area weighted average U-values (including frame for glazing).

Further insulation improvements were considered but were discounted due to their prohibitive costs, their impact on the design and construction of the building, or their current limited availability within the UK market (e.g. ultra high performance windows).

A.B.1.2 Domestic: Airtightness

Airtightness improvements were modelled from the baseline position of 10 $m^3/m^2.h$@50Pa, to 7 $m^3/m^2.h$ and 3 $m^3/m^2.h$. The level of 7 was selected as an intermediate improvement as this is readily achievable without significant changes in construction detailing, and is unlikely to lead to concerns over deterioration in indoor air quality and condensation risks. Improvements to 5 $m^3/m^2.h$ were to have been modelled; however, following discussions with Building Standards Division these were discounted. There are widespread concerns that unless combined with MVHR or similar system, air permeability levels of less than 5 $m^3/m^2.h$@50Pa would be likely to result in a deterioration in indoor air quality that could lead to condensation and mound growth, and, consequently, to an impact on the health of occupants. Although passive ventilation is likely to be feasible at 5 $m^3/m^2.h$@50Pa, recent experience has shown that when constructed, some dwellings can unintentionally achieve greater airtightness that would then require mechanical ventilation. However, achieving this low level of air permeability is not guaranteed for every development and it is probable that modelling at 7 $m^3/m^2.h$@50Pa makes appropriate allowance for such a margin of error.

The use of whole house mechanical ventilation and heat recovery (MVHR) systems was modelled in combination with airtightness improvements to 3.0 $m^3/m^2.h$. A heat recovery efficiency of 90% was assumed for the MVHR system, with a specific fan power of 1.2 W/l/s.

For the advanced fabric insulation options an airtightness of 3.0 $m^3/m^2.h$@50Pa was assumed, along with a MVHR system. This is because it is considered likely with such high insulation standards that airtightness values of less than 5.0 $m^3/m^2.h$@50Pa will actually be achieved in practice. It was therefore considered prudent to assume a high level of airtightness will be achieved and to therefore include MVHR as part of any advanced insulation scenarios.

Although it is possible to achieve the designed level of air-tightness, it is also possible to achieve a much higher standard of air-tightness than intended, particularly where multi-layered insulation is used.

Consideration should be given in every case to the possible incorporation of a whole house ventilation system to limit the risk of condensation, with heat recovery to avoid an increase in energy demand and CO_2 emissions. This includes those scenarios that include basic and intermediate levels of insulation

A.B.1.3 Domestic: Internal lighting improvements

Improvements in the proportion of internal lighting provided by low energy light fittings were modelled, from the Technical Handbooks guidance of 50%, to 100%. The assumption is that light fittings have a luminous efficacy of at least 40 lumens per circuit watt.

A.B.1.4 Domestic: Boiler efficiency

Where gas boilers were included in improvement scenarios, the boiler efficiency was improved to SEDBUK 90.2% (from 86%). This applies to each scenario except those with a heat pump or biomass boiler. An efficiency of 90.2% SEDBUK is an average for A-band natural gas system boilers readily available in the market.

A.B.1.5 Domestic: Low carbon equipment

Various low and zero carbon technologies were modelled as part of this study, selected as those most likely to be used in new dwellings in Scotland: biomass boilers, solar water heating, photovoltaic cells, ground source heat pump, an air source heat pump, and communal on-site wind turbines. Details of each technology modelled are given in the earlier report.

The scenarios for reducing CO_2 emissions were selected as being options that can be readily applied to improve traditionally built houses, without leading to significant changes in design or construction methods. Although it is possible to design houses such that they require little or no heating (such as the Passive House concept), this requires design for passive solar gain that limits the possible orientations and may affect site layouts.

A.B.2.1 Non-Domestic: Energy efficiency scenarios

Thermal models for four baseline buildings were developed and adjusted to meet the guidance to standards 6.1 to 6.7 in the Non-Domestic Technical Handbook 2007, for the insulation envelope, HVAC and lighting. These buildings formed the 2007 compliant 'baseline' cases.

Two further energy efficiency scenarios incorporating improvements to the insulation envelope, lighting and HVAC to 'intermediate' and 'advanced' levels were used in order to identify the impact of the implementation of energy efficiency measures, and to determine whether the target CO_2 and energy reductions could be achieved through fabric, lighting and HVAC upgrades alone.

The specifications of the baseline scenario and of the intermediate and advanced energy efficiency scenarios are detailed in the table below.

Table B2: Baseline buildings & energy efficiency scenarios			
Element	**Baseline**	**Intermediate**	**Advanced**
Roof (U-value W/m²K)	0.25	0.15	0.1
Wall (U-value W/m²K)	0.3	0.25	0.15
Floor (U-value W/m²K)	0.25	0.2	0.1
Windows, doors and rooflights (U-value W/m²K)	2.2	1.6	1.2
Air permeability (m³/(h.m²) @ 50Pa)	10	7	3
Solar shading (effective g-value)	0.7	0.5	0.5
Heating - gas fired (Sη & delivery η) (%)	88 & 95	90 & 95	92 & 95
Cooling - electric (EER & delivery η (%))	3 & 90	3.5 & 90	4 & 90
Lighting (W/m²/100 lux): Primary school Secondary school City centre office Retail warehouse	3.2 3.1 2.8 3.9	2.5 2.25 2.25 2.5	2 2 2 2
Ventilation Specific Fan Power (W/l/s): Schools Office & retail warehouse	2 2.5	2.5 2.5	2.5 2.5
Hot Water – gas indirect (Sη & delivery η) (%)	85	90 & 85	92 & 85
Power Factor Correction	0.95+	0.95+	0.95+
Lighting Controls	-	MS	DD & MS
BMS Controls	-	AM&T+A	AM&T+A

Key to abbreviations:

g-value = Total solar energy transmittance of glazing
Sη = Seasonal boiler efficiency
Delivery η = delivery efficiency (allowance for losses primarily in pipework)
EER = Energy efficiency ratio
MS = Motion sensing controls
DD = Daylight dimming controls
AM&T+A = Automatic Monitoring and Targeting with Alarms

With the primary and secondary schools, the ventilation specific fan power increased from 2W/l/s in the baseline model, to 2.5W/l/s in the intermediate and advanced energy efficiency upgrade models which may appear to be a reduction in performance. However, the reason for this change is that in the baseline model the air handling unit did not always have heat recovery and in the improved and advanced energy efficiency models heat recovery has been added which raises the pressure drop through the air handling unit, making the required specific fan power harder to achieve. Recent experience in buildings in England and Wales has shown the specific fan power standards to be difficult to meet and so the backstop value of 2.5 W/l/s has been used. However, with careful consideration of the need for lower specific fan powers at the early stage of the design (allowing for larger air handling units and ductwork), higher performance could be achieved.

A.B.1.5 Non-domestic: Low carbon equipment

The following types of low carbon equipment were assessed for the intermediate and advanced scenarios: solar thermal hot water, PV (solar electric), biomass heating, ground source heat pump, small wind, and large wind. However, for the city centre office, gas fired combined heat and power was assessed instead of large wind.

These were considered as some of the most likely solutions that could be implemented on many sites in Scotland. However, various architectural solutions could also be used to reduce emissions of CO_2 and delivered energy, such as design for passive solar gain and enhanced daylighting, or the use of thermal mass to modulate temperature change.

Details of the equipment and associated assumptions used in the modelling are given in the earlier Davis Langdon reports.

Appendix B PHPP summary sheets

B.1 Detached house: PHPP output summary sheets

The following sheets are attached below:

- Baseline
- Baseline with HRV
- Basic upgrade
- Intermediate upgrade
- Advanced upgrades (NV)
- Advanced upgrades including HRV
- Intermediate upgrades plus CL Silver Details for thermal bridges
- Advanced upgrades (NV) plus CL Silver Details for thermal bridges
- Advanced upgrades including HRV plus CL Silver Details for thermal bridges
- Advanced upgrades, HRV, CL Silver Details, 0.6ac/h at 50Pa, South glazing.

The following sections give extracts from the SAP calculation. (Note: these are intended as a record of the calculations and an illustration of how the individual bridge details can be added in a current SAP tool).

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - 09 regs	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.234	*	1.00	*	72.9	=	3016	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.160	*	1.00	*	72.9	=	804	
4.	Floor Slab	B	69.0	*	0.209	*	0.70	*	72.9	=	739	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	2.213	*	1.00	*	72.9	=	1919	
9.	Exterior Door	A	3.8	*	1.800	*	1.00	*	72.9	=	498	
10.	Exterior TB (length/m)	A	120.4	*	0.022	*	1.00	*	72.9	=	194	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
		Total of All Building Envelope Areas	330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	7171	60.8

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		118.0	*	2.60	=	306.8
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.000	(1 -	0.00	) +	0.647	=	0.647

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.647	*	0.33	*	72.9	=	4770	40.4

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	7171	+	4770	)	1.0	=	11941	101.2

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.30	*	0.76	*	5.95	*	170	=	235	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.30	*	0.76	*	5.95	*	181	=	250	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	485	4.1

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1701	14.4
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.14	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F / Q_L)^5) / (1 - (Q_F / Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1701	14.4
Annual Heat Demand Q_H	$Q_L - Q_G$	=	10240	87

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - 09regs HRV(88)	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.234	*	1.00	*	72.9	=	3016	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.160	*	1.00	*	72.9	=	804	
4.	Floor Slab	B	69.0	*	0.209	*	0.70	*	72.9	=	739	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	2.213	*	1.00	*	72.9	=	1919	
9.	Exterior Door	A	3.8	*	1.800	*	1.00	*	72.9	=	498	
10.	Exterior TB (length/m)	A	120.4	*	0.022	*	1.00	*	72.9	=	194	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	7171	60.8

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		118.0	*	2.60	=	306.8
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	88%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.300	(1 -	0.88	) +	0.647	=	0.683

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.683	*	0.33	*	72.9	=	5035	42.7

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	7171	+	5035	)	1.0	=	12206	103.4

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.30	*	0.76	*	5.95	*	170	=	235	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.30	*	0.76	*	5.95	*	181	=	250	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	485	4.1

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	1701	14.4
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.14	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	η_G * Q_F	=	1701	14.4
Annual Heat Demand Q_H	Q_L - Q_G	=	10505	89

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - Basic Upgrades	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area (m²)		U-Value (W/(m²K))		Temp. Factor f_t		G_t (kKh/a)		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.194	*	1.00	*	72.9	=	2496	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.130	*	1.00	*	72.9	=	653	
4.	Floor Slab	B	69.0	*	0.150	*	0.70	*	72.9	=	529	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	1.913	*	1.00	*	72.9	=	1659	
9.	Exterior Door	A	3.8	*	1.500	*	1.00	*	72.9	=	415	
10.	Exterior TB (length/m)	A	120.4	*	0.022	*	1.00	*	72.9	=	194	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	5946	50.4

			A_{TFA} (m²)		Clear Room Height (m)		m³
Ventilation System:	Effective Air Volume, V_V		118.0	*	2.60	=	306.8
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ (1/h)		Φ_{HR}		$n_{V,Res}$ (1/h)		1/h
Energetically Effective Air Exchange n_v	0.000	(1	0.00	) +	0.608	=	0.608

	V_V (m³)		n_V (1/h)		c_{Air} (Wh/(m³K))		G_t (kKh/a)		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.608	*	0.33	*	72.9	=	4488	38.0

		Q_T (kWh/a)		Q_V (kWh/a)		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	5946	+	4488	)	1.0	=	10434	88.4

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area (m²)		Radiation HP (kWh/(m²a))		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.30	*	0.70	*	5.95	*	170	=	216	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.30	*	0.70	*	5.95	*	181	=	230	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	446	3.8

	kh/d		Length Heat. Period (d/a)		Spec. Power q_I (W/m²)		A_{TFA} (m²)		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1663	14.1
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.16	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1663	14.1
Annual Heat Demand Q_H	$Q_L - Q_G$	=	8772	74

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - Intermediate Upgrades	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area (m²)		U-Value (W/(m²K))		Temp. Factor f_t		G_t (kKh/a)		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.154	*	1.00	*	72.9	=	1979	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.130	*	1.00	*	72.9	=	653	
4.	Floor Slab	B	69.0	*	0.150	*	0.70	*	72.9	=	529	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	1.713	*	1.00	*	72.9	=	1486	
9.	Exterior Door	A	3.8	*	1.300	*	1.00	*	72.9	=	360	
10.	Exterior TB (length/m)	A	120.4	*	0.022	*	1.00	*	72.9	=	194	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	5200	44.1

			A_{TFA} (m²)		Clear Room Height (m)		m³
Ventilation System:	Effective Air Volume, V_V		118.0	*	2.60	=	306.8
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ (1/h)		Φ_{HR}		$n_{V,Res}$ (1/h)		1/h
Energetically Effective Air Exchange n_v	0.000	(1 -	0.00	) +	0.608	=	0.608

	V_V (m³)		n_V (1/h)		c_{Air} (Wh/(m³K))		G_t (kKh/a)		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.608	*	0.33	*	72.9	=	4488	38.0

		Q_T (kWh/a)		Q_V (kWh/a)		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	5200	+	4488	)	1.0	=	9688	82.1

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area (m²)		Radiation HP (kWh/(m²a))		kWh/a
1.	North	0.40	*	0.00	*	0.00	*	90	=	0
2.	East	0.30	*	0.64	*	5.95	*	170	=	198
3.	South	0.40	*	0.00	*	0.00	*	344	=	0
4.	West	0.30	*	0.64	*	5.95	*	181	=	210
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0

Available Solar Heat Gains Q_S — Total: 408 kWh/a; 3.5 kWh/(m²a)

	kh/d		Length Heat. Period (d/a)		Spec. Power q_I (W/m²)		A_{TFA} (m²)		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1624	13.8
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.17	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1624	13.8
Annual Heat Demand Q_H	$Q_L - Q_G$	=	8064	68

Limiting Value (kWh/(m²a))	15	**Requirement met?** (Yes/No)	No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - Advanced Upgrades NV	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.104	*	1.00	*	72.9	=	1344	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.100	*	1.00	*	72.9	=	505	
4.	Floor Slab	B	69.0	*	0.100	*	0.70	*	72.9	=	352	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	1.513	*	1.00	*	72.9	=	1312	
9.	Exterior Door	A	3.8	*	1.100	*	1.00	*	72.9	=	305	
10.	Exterior TB (length/m)	A	120.4	*	0.022	*	1.00	*	72.9	=	194	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
		Total of All Building Envelope Areas	330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	4011	34.0

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		118.0	*	2.60	=	306.8
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.000	(1	0.00	) +	0.540	=	0.540

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.540	*	0.33	*	72.9	=	3982	33.7

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	4011	+	3982	)	1.0	=	7993	67.7

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.30	*	0.56	*	5.95	*	170	=	173	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.30	*	0.56	*	5.95	*	181	=	184	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	kWh/(m²a)
	Available Solar Heat Gains Q_S								Total	357	3.0

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1573	13.3
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.20	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1573	13.3
Annual Heat Demand Q_H	$Q_L - Q_G$	=	6420	54

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - Advanced Upgrades HRV	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.104	*	1.00	*	72.9	=	1344	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.100	*	1.00	*	72.9	=	505	
4.	Floor Slab	B	69.0	*	0.100	*	0.70	*	72.9	=	352	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	1.513	*	1.00	*	72.9	=	1312	
9.	Exterior Door	A	3.8	*	1.100	*	1.00	*	72.9	=	305	
10.	Exterior TB (length/m)	A	120.4	*	0.022	*	1.00	*	72.9	=	194	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
		Total of All Building Envelope Areas	330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	4011	34.0

Ventilation System:

		A_{TFA} m²		Clear Room Height m		m³
Effective Air Volume, V_V		118.0	*	2.60	=	306.8

Effective Heat Recovery Efficiency of Heat Recovery η_{eff} 88%

Efficiency of Subsoil Heat Exchanger η_{SHX} 0%

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.300	(1 -	0.88	) +	0.194	=	0.230

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.230	*	0.33	*	72.9	=	1696	14.4

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	4011	+	1696	)	1.0	=	5707	48.4

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.30	*	0.56	*	5.95	*	170	=	173	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.30	*	0.56	*	5.95	*	181	=	184	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	357	3.0

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1573	13.3
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.28	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F / Q_L)^5) / (1 - (Q_F / Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1572	13.3
Annual Heat Demand Q_H	$Q_L - Q_G$	=	4136	35

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0	°C
Building:	SBS Detached House - Int Upg SilverDetails	Building Type/Use:	Detached house	
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0	m²

	Building Element	Temperature Zone	Area (m²)		U-Value (W/(m²K))		Temp. Factor f_t		G_t (kKh/a)		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.154	*	1.00	*	72.9	=	1979	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.130	*	1.00	*	72.9	=	653	
4.	Floor Slab	B	69.0	*	0.150	*	0.70	*	72.9	=	529	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	1.386	*	1.00	*	72.9	=	1202	
9.	Exterior Door	A	3.8	*	1.300	*	1.00	*	72.9	=	360	
10.	Exterior TB (length/m)	A	120.4	*	-0.071	*	1.00	*	72.9	=	-619	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	4104	34.8

			A_{TFA} (m²)		Clear Room Height (m)		m³
Ventilation System:	Effective Air Volume, V_V		118.0	*	2.60	=	306.8
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ (1/h)		Φ_{HR}		$n_{V,Res}$ (1/h)		1/h
Energetically Effective Air Exchange n_v	0.000	(1 -	0.00	) +	0.608	=	0.608

	V_V (m³)		n_V (1/h)		c_{Air} (Wh/(m³K))		G_t (kKh/a)		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.608	*	0.33	*	72.9	=	4488	38.0

		Q_T (kWh/a)		Q_V (kWh/a)		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	4104	+	4488	)	1.0	=	8592	72.8

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area (m²)		Radiation HP (kWh/(m²a))		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.30	*	0.64	*	5.95	*	170	=	198	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.30	*	0.64	*	5.95	*	181	=	210	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	408	3.5

	kh/d		Length Heat. Period (d/a)		Spec. Power q_I (W/m²)		A_{TFA} (m²)		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1624	13.8
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.19	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F / Q_L)^5) / (1 - (Q_F / Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1624	13.8
Annual Heat Demand Q_H	$Q_L - Q_G$	=	6968	59

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - Adv Upg NV SilverDetails	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.104	*	1.00	*	72.9	=	1344	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.100	*	1.00	*	72.9	=	505	
4.	Floor Slab	B	69.0	*	0.100	*	0.70	*	72.9	=	352	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	1.186	*	1.00	*	72.9	=	1029	
9.	Exterior Door	A	3.8	*	1.100	*	1.00	*	72.9	=	305	
10.	Exterior TB (length/m)	A	120.4	*	-0.071	*	1.00	*	72.9	=	-619	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		330.6									kWh/(m²a)
	Transmission Heat Losses Q_T										Total 2915	24.7

Ventilation System:

			A_{TFA} m²		Clear Room Height m		m³		
Effective Air Volume, V_V			118.0	*	2.60	=	306.8		
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%							
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%							
		$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h	
Energetically Effective Air Exchange n_v		0.000	(1 -	0.00	) +	0.540	=	0.540	

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.540	*	0.33	*	72.9	=	3982	33.7

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	2915	+	3982	)	1.0	=	6897	58.4

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.30	*	0.56	*	5.95	*	170	=	173	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.30	*	0.56	*	5.95	*	181	=	184	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	357	3.0

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1573	13.3
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.23	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1573	13.3
Annual Heat Demand Q_H	$Q_L - Q_G$	=	5324	45

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - Adv Upg HRV SilverDetails	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.104	*	1.00	*	72.9	=	1344	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.100	*	1.00	*	72.9	=	505	
4.	Floor Slab	B	69.0	*	0.100	*	0.70	*	72.9	=	352	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	1.186	*	1.00	*	72.9	=	1029	
9.	Exterior Door	A	3.8	*	1.100	*	1.00	*	72.9	=	305	
10.	Exterior TB (length/m)	A	120.4	*	-0.071	*	1.00	*	72.9	=	-619	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
		Total of All Building Envelope Areas	330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	2915	24.7

Ventilation System:

		A_{TFA} m²		Clear Room Height m		m³
Effective Air Volume, V_V		118.0	*	2.60	=	306.8

Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	88%
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.300	(1 -	0.88	) +	0.194	=	0.230

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.230	*	0.33	*	72.9	=	1696	14.4

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	2915	+	1696	)	1.0	=	4611	39.1

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a
1.	North	0.40	*	0.00	*	0.00	*	90	=	0
2.	East	0.30	*	0.56	*	5.95	*	170	=	173
3.	South	0.40	*	0.00	*	0.00	*	344	=	0
4.	West	0.30	*	0.56	*	5.95	*	181	=	184
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0

		kWh/(m²a)
Available Solar Heat Gains Q_S	Total 357	3.0

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1573	13.3
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.34	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1569	13.3
Annual Heat Demand Q_H	$Q_L - Q_G$	=	3043	**26**

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**No**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - Adv Upg HRV SiDet PH Sglz	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.104	*	1.00	*	72.9	=	1344	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.100	*	1.00	*	72.9	=	505	
4.	Floor Slab	B	69.0	*	0.100	*	0.70	*	72.9	=	352	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	1.177	*	1.00	*	72.9	=	1020	
9.	Exterior Door	A	3.8	*	1.100	*	1.00	*	72.9	=	305	
10.	Exterior TB (length/m)	A	120.4	*	-0.071	*	1.00	*	72.9	=	-619	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	2907	24.6

Ventilation System:

		Effective Air Volume, V_V	A_{TFA} m²	*	Clear Room Height m	=	306.8 m³		
Effective Heat Recovery Efficiency	η_{eff}	88%							
of Heat Recovery									
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%							
			118.0		2.60				

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.300	(1 -	0.88	) +	0.036	=	0.072

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.072	*	0.33	*	72.9	=	531	4.5

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	2907	+	531	)	1.0	=	3438	29.1

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.30	*	0.56	*	5.95	*	170	=	173	
3.	South	0.39	*	0.56	*	5.95	*	344	=	444	
4.	West	0.40	*	0.00	*	0.00	*	181	=	0	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	617	5.2

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	1833	15.5
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.53	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	98%	
Heat Gains Q_G	η_G * Q_F	=	1795	15.2
Annual Heat Demand Q_H	Q_L - Q_G	=	1643	**14**

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**Yes**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Detached House - Adv Upg HRV SilvDet PH EW glaze	Building Type/Use:	Detached house
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	118.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	176.9	*	0.104	*	1.00	*	72.9	=	1344	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	69.0	*	0.100	*	1.00	*	72.9	=	505	
4.	Floor Slab	B	69.0	*	0.100	*	0.70	*	72.9	=	352	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	11.9	*	0.934	*	1.00	*	72.9	=	810	
9.	Exterior Door	A	3.8	*	1.100	*	1.00	*	72.9	=	305	
10.	Exterior TB (length/m)	A	120.4	*	-0.071	*	1.00	*	72.9	=	-619	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		330.6									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	2697	22.9

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		118.0	*	2.60	=	306.8
Effective Heat Recovery Efficiency	η_{eff}	88%					
of Heat Recovery							
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.300	(1 -	0.88	) +	0.036	=	0.072

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	307	*	0.072	*	0.33	*	72.9	=	531	4.5

	Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(2697	+	531	)	1.0	=	3228	27.4

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a
1.	North	0.40	*	0.00	*	0.00	*	90	=	0
2.	East	0.30	*	0.51	*	5.95	*	170	=	157
3.	South	0.40	*	0.00	*	0.00	*	344	=	0
4.	West	0.30	*	0.51	*	5.95	*	181	=	168
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0

		kWh/a	kWh/(m²a)
Available Solar Heat Gains Q_S	Total	325	2.8

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	118.0	=	1216	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1542	13.1
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.48	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	99%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1521	12.9
Annual Heat Demand Q_H	$Q_L - Q_G$	=	1707	14

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	Yes

B.2 Mid floor flat: PHPP output summary sheets

The following sheets are attached below:

- Baseline
- Baseline with HRV
- Basic upgrade
- Intermediate upgrade
- Advanced upgrades (NV)
- Advanced upgrades including HRV
- Advanced upgrades, PH details

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow		Interior Temperature:	20.0 °C
Building:	SBS TT Flat 09 Regs NV		Building Type/Use:	Mid floor flat
Location:	Scotland, Glasgow PH climate		Treated Floor Area A_{TFA}:	80.2 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	91.6	*	0.234	*	1.00	*	72.9	=	1563	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A		*		*	1.00	*		=		
4.	Floor Slab	B		*		*	0.70	*		=		
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	10.6	*	2.223	*	1.00	*	72.9	=	1711	
9.	Exterior Door	A	2.0	*	1.800	*	1.00	*	72.9	=	262	
10.	Exterior TB (length/m)	A	73.1	*	0.018	*	1.00	*	72.9	=	98	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
		Total of All Building Envelope Areas	104.2									kWh/(m²a)

Transmission Heat Losses Q_T — Total: 3634 kWh/a — 45.3 kWh/(m²a)

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		80.2	*	2.86	=	229.4
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.000	(1 -	0.00	) +	0.643	=	0.643

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	229	*	0.643	*	0.33	*	72.9	=	3546	44.2

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	3634	+	3546	)	1.0	=	7180	89.5

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a
1.	North	0.40	*	0.00	*	0.00	*	90	=	0
2.	East	0.39	*	0.76	*	10.56	*	170	=	533
3.	South	0.40	*	0.00	*	0.00	*	344	=	0
4.	West	0.40	*	0.00	*	0.00	*	181	=	0
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0

Available Solar Heat Gains Q_S — Total: 533 kWh/a — 6.7 kWh/(m²a)

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	80.2	=	827	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	1360	17.0
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.19	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	η_G * Q_F	=	1360	17.0
Annual Heat Demand Q_H	Q_L - Q_G	=	5820	73

Limiting Value: 15 kWh/(m²a) — **Requirement met?** (Yes/No): **No**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS TT Flat 09 Regs HRV(PH 88)	Building Type/Use:	Mid floor flat
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	80.2 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	91.6	*	0.234	*	1.00	*	72.9	=	1563	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A		*		*	1.00	*		=		
4.	Floor Slab	B		*		*	0.70	*		=		
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	10.6	*	2.223	*	1.00	*	72.9	=	1711	
9.	Exterior Door	A	2.0	*	1.800	*	1.00	*	72.9	=	262	
10.	Exterior TB (length/m)	A	73.1	*	0.018	*	1.00	*	72.9	=	98	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		104.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	3634	45.3

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		80.2	*	2.86	=	229.4
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	88%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.300	(1 -	0.88	) +	0.321	=	0.357

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	229	*	0.357	*	0.33	*	72.9	=	1971	24.6

	Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(3634	+	1971	)	1.0	=	5605	69.9

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a
1.	North	0.40	*	0.00	*	0.00	*	90	=	0
2.	East	0.39	*	0.76	*	10.56	*	170	=	533
3.	South	0.40	*	0.00	*	0.00	*	344	=	0
4.	West	0.40	*	0.00	*	0.00	*	181	=	0
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0

		kWh/a	kWh/(m²a)
Available Solar Heat Gains Q_S	Total	533	6.7

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	80.2	=	827	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	1360	17.0
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.24	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F / Q_L)^5) / (1 - (Q_F / Q_L)^6)$	=	100%	
Heat Gains Q_G	η_G * Q_F	=	1359	16.9
Annual Heat Demand Q_H	Q_L - Q_G	=	4246	53

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**No**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow		Interior Temperature:	20.0 °C
Building:	SBS TT Flat BasicUpg NV		Building Type/Use:	Mid floor flat
Location:	Scotland, Glasgow PH climate		Treated Floor Area A_{TFA}:	80.2 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	91.6	*	0.194	*	1.00	*	72.9	=	1293	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A		*		*	1.00	*		=		
4.	Floor Slab	B		*		*	0.70	*		=		
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	10.6	*	1.923	*	1.00	*	72.9	=	1480	
9.	Exterior Door	A	2.0	*	1.500	*	1.00	*	72.9	=	219	
10.	Exterior TB (length/m)	A	73.1	*	0.018	*	1.00	*	72.9	=	98	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
		Total of All Building Envelope Areas	104.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	3090	38.5

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		80.2	*	2.86	=	229.4
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.000	(1 -	0.00	) +	0.607	=	0.607

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	229	*	0.607	*	0.33	*	72.9	=	3348	41.7

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	3090	+	3348	)	1.0	=	6437	80.3

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a
1.	North	0.40	*	0.00	*	0.00	*	90	=	0
2.	East	0.39	*	0.70	*	10.56	*	170	=	491
3.	South	0.40	*	0.00	*	0.00	*	344	=	0
4.	West	0.40	*	0.00	*	0.00	*	181	=	0
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0

		kWh/a	kWh/(m²a)
Available Solar Heat Gains Q_S	Total	491	6.1

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	80.2	=	827	10.3

				kWh/a	kWh/(m²a)
	Free Heat Q_F	Q_S + Q_I	=	1318	16.4
	Ratio of Free Heat to Losses	Q_F / Q_L	=	0.20	
Utilisation Factor Heat Gains η_G		$(1 - (Q_F / Q_L)^5) / (1 - (Q_F / Q_L)^6)$	=	100%	
Heat Gains Q_G		η_G * Q_F	=	1318	16.4
Annual Heat Demand Q_H		Q_L - Q_G	=	5120	64

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**No**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS TT Flat IntUpg NV	Building Type/Use:	Mid floor flat
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	80.2 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	91.6	*	0.154	*	1.00	*	72.9	=	1025	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A		*		*	1.00	*		=		
4.	Floor Slab	B		*		*	0.70	*		=		
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	10.6	*	1.723	*	1.00	*	72.9	=	1326	
9.	Exterior Door	A	2.0	*	1.300	*	1.00	*	72.9	=	189	
10.	Exterior TB (length/m)	A	73.1	*	0.018	*	1.00	*	72.9	=	98	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		104.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	2639	32.9

Ventilation System:	Effective Air Volume, V_V		A_{TFA} m²		Clear Room Height m		m³	
			80.2	*	2.86	=	229.4	
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%						
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%						
		$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v		0.000	(1 -	0.00	) +	0.607	=	0.607

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	229	*	0.607	*	0.33	*	72.9	=	3348	41.7

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	2639	+	3348	)	1.0	=	5986	74.6

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.39	*	0.64	*	10.56	*	170	=	449	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.40	*	0.00	*	0.00	*	181	=	0	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	449	5.6

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	80.2	=	827	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	1276	15.9
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.21	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	η_G * Q_F	=	1275	15.9
Annual Heat Demand Q_H	Q_L - Q_G	=	4711	59

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS TT Flat AdvUpg NV	Building Type/Use:	Mid floor flat
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	80.2 m²

	Building Element	Temperature Zone	Area (m²)		U-Value (W/(m²K))		Temp. Factor f_t		G_t (kKh/a)		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	91.6	*	0.104	*	1.00	*	72.9	=	696	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A		*		*	1.00	*		=		
4.	Floor Slab	B		*		*	0.70	*		=		
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	10.6	*	1.523	*	1.00	*	72.9	=	1172	
9.	Exterior Door	A	2.0	*	1.100	*	1.00	*	72.9	=	160	
10.	Exterior TB (length/m)	A	73.1	*	0.018	*	1.00	*	72.9	=	98	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		104.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	2127	26.5

Ventilation System:	Effective Air Volume, V_V		A_{TFA} (m²)		Clear Room Height (m)		m³	
			80.2	*	2.86	=	229.4	
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%						
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%	$n_{V,system}$ (1/h)	Φ_{HR}		$n_{V,Res}$ (1/h)		1/h
Energetically Effective Air Exchange n_v			0.000	(1 - 0.00) +		0.539	=	0.539

	V_V (m³)		n_V (1/h)		c_{Air} (Wh/(m³K))		G_t (kKh/a)		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	229	*	0.539	*	0.33	*	72.9	=	2973	37.1

		Q_T (kWh/a)		Q_V (kWh/a)		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	2127	+	2973	)	1.0	=	5100	63.6

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area (m²)		Radiation HP (kWh/(m²a))		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.39	*	0.56	*	10.56	*	170	=	393	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.40	*	0.00	*	0.00	*	181	=	0	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	393	4.9

	kh/d		Length Heat. Period (d/a)		Spec. Power q_I (W/m²)		A_{TFA} (m²)		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	80.2	=	827	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	1220	15.2
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.24	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	1219	15.2
Annual Heat Demand Q_H	$Q_L - Q_G$	=	3881	48

Limiting Value	15 kWh/(m²a)	**Requirement met?**	No (Yes/No)

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS TT Flat AdvUpg HRV (PH 88)	Building Type/Use:	Mid floor flat
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	80.2 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	91.6	*	0.104	*	1.00	*	72.9	=	696	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A		*		*	1.00	*		=		
4.	Floor Slab	B		*		*	0.70	*		=		
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	10.6	*	1.523	*	1.00	*	72.9	=	1172	
9.	Exterior Door	A	2.0	*	1.100	*	1.00	*	72.9	=	160	
10.	Exterior TB (length/m)	A	73.1	*	0.018	*	1.00	*	72.9	=	98	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		104.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	2127	26.5

		A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V	80.2	*	2.86	=	229.4

Effective Heat Recovery Efficiency of Heat Recovery η_{eff}: 88%

Efficiency of Subsoil Heat Exchanger η_{SHX}: 0%

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.300	(1 -	0.88	) +	0.094	=	0.130

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	229	*	0.130	*	0.33	*	72.9	=	719	9.0

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	2127	+	719	)	1.0	=	2846	35.5

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.39	*	0.56	*	10.56	*	170	=	393	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.40	*	0.00	*	0.00	*	181	=	0	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	393	4.9

	kh/d		Length Heat. Period d/a		Spec. Power q_i W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	80.2	=	827	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	1220	15.2
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.43	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	99%	
Heat Gains Q_G	η_G * Q_F	=	1210	15.1
Annual Heat Demand Q_H	Q_L - Q_G	=	1636	20

Limiting Value (kWh/(m²a))	15	**Requirement met?** (Yes/No)	No

B.2 Mid floor flat: PHPP output summary sheets

The following sheets are attached below:

- Baseline
- Baseline with HRV
- Basic upgrade
- Intermediate upgrade
- Advanced upgrades (NV)
- Advanced upgrades including HRV
- Advanced upgrades, PH details

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow		Interior Temperature:	20.0 °C
Building:	SBS TT Flat AdvUpg HRV PH details		Building Type/Use:	Mid floor flat
Location:	Scotland, Glasgow PH climate		Treated Floor Area A_{TFA}:	80.2 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	91.6	*	0.104	*	1.00	*	72.9	=	696	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A		*		*	1.00	*		=		
4.	Floor Slab	B		*		*	0.70	*		=		
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	10.6	*	1.184	*	1.00	*	72.9	=	911	
9.	Exterior Door	A	2.0	*	1.100	*	1.00	*	72.9	=	160	
10.	Exterior TB (length/m)	A	73.1	*	-0.009	*	1.00	*	72.9	=	-48	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		104.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	1719	21.4

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		80.2	*	2.86	=	229.4
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	88%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.300	(1 -	0.88	) +	0.042	=	0.078

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	229	*	0.078	*	0.33	*	72.9	=	430	5.4

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	1719	+	430	)	1.0	=	2149	26.8

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.40	*	0.00	*	0.00	*	90	=	0	
2.	East	0.39	*	0.56	*	10.56	*	170	=	393	
3.	South	0.40	*	0.00	*	0.00	*	344	=	0	
4.	West	0.40	*	0.00	*	0.00	*	181	=	0	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	393	4.9

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	2.10	*	80.2	=	827	10.3

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	1220	15.2
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.57	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	97%	
Heat Gains Q_G	η_G * Q_F	=	1188	14.8
Annual Heat Demand Q_H	Q_L - Q_G	=	962	12

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**Yes**

B.3 City centre office: PHPP output summary sheets

The following sheets are attached below:

- Baseline
- Intermediate upgrade
- Intermediate upgrade but NV
- Advanced upgrades
- Advanced upgrades but NV
- Advanced upgrades but HRV improved to 70%
- Advanced upgrades but HRV improved to 88%
- Baseline but opposite orientation
- Overheating summary

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Glasgow Office 2009 Regs	Building Type/Use:	Large Office
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	10500.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	1847.6	*	0.301	*	1.00	*	72.9	=	40522	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	1500.0	*	0.249	*	1.00	*	72.9	=	27175	
4.	Floor Slab	B	1500.0	*	0.249	*	0.70	*	72.9	=	19064	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	1777.6	*	2.314	*	1.00	*	72.9	=	299635	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	1378.0	*	0.041	*	1.00	*	72.9	=	4073	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		6625.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	390470	37.2

				A_{TFA} m²		Clear Room Height m		m³	
Ventilation System:	Effective Air Volume, V_V			10500.0	*	3.10	=	32550.0	
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	0%							
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%	$n_{V,system}$ 1/h	Φ_{HR}		$n_{V,Res}$ 1/h		1/h	
Energetically Effective Air Exchange n_v			0.556	(1 - 0.00)	+	0.122	=	0.678	

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	32550	*	0.678	*	0.33	*	72.9	=	530317	50.5

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	390470	+	530317	)	1.0	=	920787	87.7

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	
1.	North	0.47	*	0.70	*	420.00	*	90	=	12536	
2.	East	0.48	*	0.70	*	153.60	*	170	=	8699	
3.	South	0.50	*	0.40	*	574.00	*	344	=	39397	
4.	West	0.50	*	0.40	*	630.00	*	181	=	22745	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	kWh/(m²a)
	Available Solar Heat Gains Q_S								Total	83378	7.9

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	3.50	*	10500.0	=	180384	17.2

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	263762	25.1
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.29	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	263399	25.1
Annual Heat Demand Q_H	$Q_L - Q_G$	=	657388	63

Limiting Value	kWh/(m²a)	Requirement met?	(Yes/No)
	15		No

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Glasgow Office Int Upg HR40%	Building Type/Use:	Large Office
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	10500.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	1847.6	*	0.251	*	1.00	*	72.9	=	33763	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	1500.0	*	0.149	*	1.00	*	72.9	=	16254	
4.	Floor Slab	B	1500.0	*	0.201	*	0.70	*	72.9	=	15423	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	1777.6	*	1.771	*	1.00	*	72.9	=	229339	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	1378.0	*	0.041	*	1.00	*	72.9	=	4073	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		6625.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	298852	28.5

Ventilation System:

			A_{TFA} m²		Clear Room Height m		m³
	Effective Air Volume, V_V		10500.0	*	3.10	=	32550.0

Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	40%
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.556	(1 -	0.40	) +	0.085	=	0.419

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	32550	*	0.419	*	0.33	*	72.9	=	327675	31.2

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	298852	+	327675	)	1.0	=	626527	59.7

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.47	*	0.70	*	420.00	*	90	=	12536	
2.	East	0.48	*	0.70	*	153.60	*	170	=	8699	
3.	South	0.50	*	0.40	*	574.00	*	344	=	39397	
4.	West	0.50	*	0.40	*	630.00	*	181	=	22745	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	83378	7.9

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	3.50	*	10500.0	=	180384	17.2

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	263762	25.1
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.42	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	99%	
Heat Gains Q_G	η_G * Q_F	=	261731	24.9
Annual Heat Demand Q_H	Q_L - Q_G	=	364796	35

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**No**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Glasgow Office Int Upg NoHR	Building Type/Use:	Large Office
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	10500.0 m²

	Building Element	Temperature Zone	Area (m²)		U-Value (W/(m²K))		Temp. Factor f_t		G_t (kKh/a)		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	1847.6	*	0.251	*	1.00	*	72.9	=	33763	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	1500.0	*	0.149	*	1.00	*	72.9	=	16254	
4.	Floor Slab	B	1500.0	*	0.201	*	0.70	*	72.9	=	15423	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	1777.6	*	1.771	*	1.00	*	72.9	=	229339	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	1378.0	*	0.041	*	1.00	*	72.9	=	4073	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		6625.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	298852	28.5

		A_{TFA} (m²)		Clear Room Height (m)		m³
Ventilation System:	Effective Air Volume, V_V	10500.0	*	3.10	=	32550.0

Effective Heat Recovery Efficiency of Heat Recovery η_{eff}: 0%

Efficiency of Subsoil Heat Exchanger η_{SHX}: 0%

	$n_{V,system}$ (1/h)		Φ_{HR}		$n_{V,Res}$ (1/h)		1/h
Energetically Effective Air Exchange n_v	0.556	(1 -	0.00	) +	0.085	=	0.641

	V_V (m³)		n_V (1/h)		c_{Air} (Wh/(m³K))		G_t (kKh/a)		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	32550	*	0.641	*	0.33	*	72.9	=	501674	47.8

		Q_T (kWh/a)		Q_V (kWh/a)		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	298852	+	501674	)	1.0	=	800526	76.2

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area (m²)		Radiation HP (kWh/(m²a))		kWh/a	kWh/(m²a)
1.	North	0.47	*	0.70	*	420.00	*	90	=	12536	
2.	East	0.48	*	0.70	*	153.60	*	170	=	8699	
3.	South	0.50	*	0.40	*	574.00	*	344	=	39397	
4.	West	0.50	*	0.40	*	630.00	*	181	=	22745	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	83378	7.9

	kh/d		Length Heat. Period (d/a)		Spec. Power q_I (W/m²)		A_{TFA} (m²)		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	3.50	*	10500.0	=	180384	17.2

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	263762	25.1
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.33	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F / Q_L)^5) / (1 - (Q_F / Q_L)^6)$	=	100%	
Heat Gains Q_G	η_G * Q_F	=	263074	25.1
Annual Heat Demand Q_H	Q_L - Q_G	=	537452	51

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**No**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Glasgow Office Adv Upg HR60%	Building Type/Use:	Large Office
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	10500.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	1847.6	*	0.154	*	1.00	*	72.9	=	20672	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	1500.0	*	0.099	*	1.00	*	72.9	=	10839	
4.	Floor Slab	B	1500.0	*	0.100	*	0.70	*	72.9	=	7678	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	1777.6	*	1.409	*	1.00	*	72.9	=	182475	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	1378.0	*	0.041	*	1.00	*	72.9	=	4073	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		6625.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	225736	21.5

			A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V		10500.0	*	3.10	=	32550.0
Effective Heat Recovery Efficiency of Heat Recovery	η_{eff}	60%					
Efficiency of Subsoil Heat Exchanger	η_{SHX}	0%					

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.556	(1 -	0.60	) +	0.037	=	0.259

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	32550	*	0.259	*	0.33	*	72.9	=	202642	19.3

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	225736	+	202642	)	1.0	=	428378	40.8

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.47	*	0.50	*	420.00	*	90	=	8955	
2.	East	0.48	*	0.50	*	153.60	*	170	=	6214	
3.	South	0.50	*	0.40	*	574.00	*	344	=	39397	
4.	West	0.50	*	0.40	*	630.00	*	181	=	22745	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	77311	7.4

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	3.50	*	10500.0	=	180384	17.2

			kWh/a	kWh/(m²a)
Free Heat Q_F	Q_S + Q_I	=	257694	24.5
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.60	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	97%	
Heat Gains Q_G	η_G * Q_F	=	249204	23.7
Annual Heat Demand Q_H	Q_L - Q_G	=	179174	17

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**No**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Glasgow Office Adv Upg NoHR	Building Type/Use:	Large Office
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	10500.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	1847.6	*	0.154	*	1.00	*	72.9	=	20672	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	1500.0	*	0.099	*	1.00	*	72.9	=	10839	
4.	Floor Slab	B	1500.0	*	0.100	*	0.70	*	72.9	=	7678	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	1777.6	*	1.409	*	1.00	*	72.9	=	182475	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	1378.0	*	0.041	*	1.00	*	72.9	=	4073	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		6625.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	225736	21.5

Ventilation System:

			A_{TFA} m²		Clear Room Height m		m³
Effective Air Volume, V_V			10500.0	*	3.10	=	32550.0

Effective Heat Recovery Efficiency of Heat Recovery η_{eff}: 0%

Efficiency of Subsoil Heat Exchanger η_{SHX}: 0%

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.556	(1	0.00	) +	0.037	=	0.592

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	32550	*	0.592	*	0.33	*	72.9	=	463639	44.2

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	225736	+	463639	)	1.0	=	689376	65.7

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.47	*	0.50	*	420.00	*	90	=	8955	
2.	East	0.48	*	0.50	*	153.60	*	170	=	6214	
3.	South	0.50	*	0.40	*	574.00	*	344	=	39397	
4.	West	0.50	*	0.40	*	630.00	*	181	=	22745	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	77311	7.4

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	3.50	*	10500.0	=	180384	17.2

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	257694	24.5
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.37	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F / Q_L)^5) / (1 - (Q_F / Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	256513	24.4
Annual Heat Demand Q_H	$Q_L - Q_G$	=	432862	**41**

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**No**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Glasgow Office Adv Upg HR70%	Building Type/Use:	Large Office
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	10500.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	1847.6	*	0.154	*	1.00	*	72.9	=	20672	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	1500.0	*	0.099	*	1.00	*	72.9	=	10839	
4.	Floor Slab	B	1500.0	*	0.100	*	0.70	*	72.9	=	7678	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	1777.6	*	1.409	*	1.00	*	72.9	=	182475	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	1378.0	*	0.041	*	1.00	*	72.9	=	4073	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		6625.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	225736	21.5

		A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V	10500.0	*	3.10	=	32550.0

Effective Heat Recovery Efficiency of Heat Recovery η_{eff}: 70%

Efficiency of Subsoil Heat Exchanger η_{SHX}: 0%

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.556	(1 -	0.70	) +	0.037	=	0.203

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	32550	*	0.203	*	0.33	*	72.9	=	159142	15.2

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	225736	+	159142	)	1.0	=	384878	36.7

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.47	*	0.50	*	420.00	*	90	=	8955	
2.	East	0.48	*	0.50	*	153.60	*	170	=	6214	
3.	South	0.50	*	0.40	*	574.00	*	344	=	39397	
4.	West	0.50	*	0.40	*	630.00	*	181	=	22745	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	77311	7.4

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	3.50	*	10500.0	=	180384	17.2

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	257694	24.5
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.67	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	95%	
Heat Gains Q_G	$\eta_G * Q_F$	=	245102	23.3
Annual Heat Demand Q_H	$Q_L - Q_G$	=	139777	13

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**Yes**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Glasgow Office Adv Upg PLUS HR88%	Building Type/Use:	Large Office
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	10500.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	1847.6	*	0.154	*	1.00	*	72.9	=	20672	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	1500.0	*	0.099	*	1.00	*	72.9	=	10839	
4.	Floor Slab	B	1500.0	*	0.100	*	0.70	*	72.9	=	7678	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	1777.6	*	1.409	*	1.00	*	72.9	=	182475	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	1378.0	*	0.041	*	1.00	*	72.9	=	4073	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
	Total of All Building Envelope Areas		6625.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	225736	21.5

		A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V	10500.0	*	3.10	=	32550.0

Effective Heat Recovery Efficiency of Heat Recovery η_{eff}: 88%

Efficiency of Subsoil Heat Exchanger η_{SHX}: 0%

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.556	(1 -	0.88	) +	0.037	=	0.103

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	32550	*	0.103	*	0.33	*	72.9	=	80843	7.7

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	225736	+	80843	)	1.0	=	306579	29.2

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a
1.	North	0.47	*	0.50	*	420.00	*	90	=	8955
2.	East	0.48	*	0.50	*	153.60	*	170	=	6214
3.	South	0.50	*	0.40	*	574.00	*	344	=	39397
4.	West	0.50	*	0.40	*	630.00	*	181	=	22745
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0

		kWh/a	kWh/(m²a)
Available Solar Heat Gains Q_S	Total	77311	7.4

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	3.50	*	10500.0	=	180384	17.2

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	257694	24.5
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.84	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F/Q_L)^5) / (1 - (Q_F/Q_L)^6)$	=	90%	
Heat Gains Q_G	$\eta_G * Q_F$	=	231061	22.0
Annual Heat Demand Q_H	$Q_L - Q_G$	=	75518	**7**

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**Yes**

Passive House Planning

SPECIFIC ANNUAL HEAT DEMAND

Climate:	GB-Glasgow	Interior Temperature:	20.0 °C
Building:	SBS Glasgow Office 2009 Regs	Building Type/Use:	Large Office
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	10500.0 m²

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Temp. Factor f_t		G_t kKh/a		kWh/a	per m² Treated Floor Area
1.	Exterior Wall - Ambient	A	1847.6	*	0.301	*	1.00	*	72.9	=	40522	
2.	Exterior Wall - Ground	B		*		*	0.70	*		=		
3.	Roof/Ceiling - Ambient	A	1500.0	*	0.249	*	1.00	*	72.9	=	27175	
4.	Floor Slab	B	1500.0	*	0.249	*	0.70	*	72.9	=	19064	
5.		A		*		*	1.00	*		=		
6.		A		*		*	1.00	*		=		
7.		X		*		*	0.75	*		=		
8.	Windows	A	1777.6	*	2.314	*	1.00	*	72.9	=	299635	
9.	Exterior Door	A		*		*	1.00	*		=		
10.	Exterior TB (length/m)	A	1378.0	*	0.041	*	1.00	*	72.9	=	4073	
11.	Perimeter TB (length/m)	P		*		*	0.70	*		=		
12.	Ground TB (length/m)	B		*		*	0.70	*		=		
		Total of All Building Envelope Areas	6625.2									kWh/(m²a)
	Transmission Heat Losses Q_T									Total	390470	37.2

		A_{TFA} m²		Clear Room Height m		m³
Ventilation System:	Effective Air Volume, V_V	10500.0	*	3.10	=	32550.0

Effective Heat Recovery Efficiency of Heat Recovery η_{eff}: 0%

Efficiency of Subsoil Heat Exchanger η_{SHX}: 0%

	$n_{V,system}$ 1/h		Φ_{HR}		$n_{V,Res}$ 1/h		1/h
Energetically Effective Air Exchange n_v	0.556	(1	0.00	) +	0.122	=	0.678

	V_V m³		n_V 1/h		c_{Air} Wh/(m³K)		G_t kKh/a		kWh/a	kWh/(m²a)
Ventilation Heat Losses Q_V	32550	*	0.678	*	0.33	*	72.9	=	530317	50.5

		Q_T kWh/a		Q_V kWh/a		Reduction Factor Night/Weekend Saving		kWh/a	kWh/(m²a)
Total Heat Losses Q_L	(	390470	+	530317	)	1.0	=	920787	87.7

	Orientation of the Area	Reduction Factor See Windows Sheet		g-Value (perp. radiation)		Area m²		Radiation HP kWh/(m²a)		kWh/a	kWh/(m²a)
1.	North	0.50	*	0.70	*	574.00	*	90	=	18092	
2.	East	0.50	*	0.40	*	630.00	*	170	=	21358	
3.	South	0.47	*	0.40	*	420.00	*	344	=	27299	
4.	West	0.48	*	0.40	*	153.60	*	181	=	5294	
5.	Horizontal	0.40	*	0.00	*	0.00	*	243	=	0	
	Available Solar Heat Gains Q_S								Total	72043	6.9

	kh/d		Length Heat. Period d/a		Spec. Power q_I W/m²		A_{TFA} m²		kWh/a	kWh/(m²a)
Internal Heat Gains Q_I	0.024	*	205	*	3.50	*	10500.0	=	180384	17.2

			kWh/a	kWh/(m²a)
Free Heat Q_F	$Q_S + Q_I$	=	252427	24.0
Ratio of Free Heat to Losses	Q_F / Q_L	=	0.27	
Utilisation Factor Heat Gains η_G	$(1 - (Q_F / Q_L)^5) / (1 - (Q_F / Q_L)^6)$	=	100%	
Heat Gains Q_G	$\eta_G * Q_F$	=	252143	24.0
Annual Heat Demand Q_H	$Q_L - Q_G$	=	668644	**64**

	kWh/(m²a)		(Yes/No)
Limiting Value	15	**Requirement met?**	**No**

Passive House Planning

SUMMER

Climate:	GB-Glasgow	Interior Temperature:	20 °C
Building:	SBS Glasgow Office Adv Upg PLUS HR88%	Building Type/Use:	Large Office
Location:	Scotland, Glasgow PH climate	Treated Floor Area A_{TFA}:	10500.0 m²
Spec. Capacity:	132 Wh/K pro m² TFA		
Overheating Limit:	25 °C		

	Building Element	Temperature Zone	Area m²		U-Value W/(m²K)		Red. Factor $f_{T,Summer}$		H_{Summer} Heat Conductance
1.	Exterior Wall - Ambien	A	1847.6	*	0.154	*	1.00	=	283.7
2.	Exterior Wall - Ground	B		*		*	1.00	=	
3.	Roof/Ceiling - Ambient	A	1500.0	*	0.099	*	1.00	=	148.8
4.	Floor Slab	B	1500.0	*	0.100	*	1.00	=	150.1
5.		A		*		*	1.00	=	
6.		A		*		*	1.00	=	
7.		X		*		*	0.75	=	
8.	Windows	A	1777.6	*	1.409	*	1.00	=	2504.5
9.	Exterior Door	A		*		*	1.00	=	
10.	Exterior TB (length/m)	A	1378.0	*	0.041	*	1.00	=	55.9
11.	Perimeter TB (length/m	P		*		*	1.00	=	
12.	Ground TB (length/m)	B		*		*	1.00	=	

Exterior Thermal Transmittance, $H_{T,e}$ 2992.9 W/K

Ground Thermal Transmittance, $H_{T,g}$ 150.1 W/K

				A_{TFA} m²		Clear Room Height m		m³
Heat Recovery Efficiency	η_{HR}	88%	Effective Air Volume V_V	10500.0	*	3.10	=	32550
SHX Efficiency	η^*_{SHX}	0%						

Summer Ventilation continuous ventilation to provide sufficient indoor air quality

Air Change Rate by Natural (Windows & Leakages) or Exhaust-Only Mechanical Ventilation, Summer: 1/h

Mechanical Ventilation Summer: 0.56 1/h with HR (check if applicable)

	$n_{L,nat}$ 1/h		$n_{V,system}$ 1/h		Φ_{HR}			$n_{V,Rest}$ 1/h		1/h
Energetically Effective Airchange Rate n_V	0.000	+	0.560	* (1 -	0.000	)	+	0.037	=	0.597

	V_V m³		$n_{V,equi,fraction}$ 1/h		c_{Air} Wh/(m³K)			
Ventilation Transm. Ambient $H_{V,e}$	32550	*	0.597	*	0.33	=	6408.4	W/K
Ventilation Transm. Ground $H_{V,g}$	32550	*	0.000	*	0.33	=	0.0	W/K

Additional Summer Ventilation for Cooling Temperature Amplitude Summer 0.0 K

Select: Window Night Ventilation, Manual — Corresponding Air Change Rate 1/h

Mechanical, Automatically Controlled Ventilation — (for window ventilation: at 1 K temperature difference indoor - outdoor)

Minimum Acceptable Indoor Temperature 22.0 °C

	Orientation of the Area	Angle Factor Summer		Shading Factor Summer		Dirt		g-Value (perp. radiation)		Area m²		Portion of Glazing		Aperture m²
1.	North	0.9	*	1.00	*	0.95	*	0.50	*	420.0	*	78%	=	140.0
2.	East	0.9	*	1.00	*	0.95	*	0.50	*	153.6	*	78%	=	51.5
3.	South	0.9	*	1.00	*	0.95	*	0.40	*	574.0	*	82%	=	161.6
4.	West	0.9	*	1.00	*	0.95	*	0.40	*	630.0	*	82%	=	177.1
5.	Horizontal	0.9	*	1.00	*	0.95	*	0.00	*	0.0	*	0%	=	0.0
6	Sum Opaque Areas													0.0

Solar Aperture Total 530.3 m²/m² 0.05

	Specif. Power q_I W/m²		A_{TFA} m²		W	W/m²
Internal Heat Gains Q_I	3.50	*	10500	=	36750	3.5

Frequency of Overheating $h_{\vartheta \geq \vartheta max}$ **5.1%** **at the overheating limit ϑ_{max} = 25 °C**

If the "frequency over 25°C" exceeds 10%, additional measures to protect against summer heat waves are necessary.

Appendix C: Passive House and Thermal Bridges in SAP

As a follow up to the main report the following analysis was carried out:

1. SAP calculations were done to determine the SAP Space Heating Demand values for the Detached House and the Mid-floor Flat with the further improvements that were required to achieve the Passive House criterion of < 15 kWh / m^2 p.a. as calculated using the PHPP. The SAP calculated Space Heating Demand values were 8.26 and 4.96 kWh/m^2 p.a. for the Detached House and Mid-floor Flat respectively compared to 14 and 12 kWh/m^2 p.a. as calculated by the PHPP. In SAP the gains utilisation factor decreases as heat losses are reduced.

2. To gain insight into the treatment in SAP of thermal bridging, the SAP calculations for the Baseline dwellings (2007 Technical Handbook) were carried out using the two different approaches to entering the thermal bridges. In both cases it was assumed that accredited details had been applied. The first approach taken was to use the ‘y’ value of 0.08 associated with the accredited details which is multiplied by the exposed surface area. The second approach was to use the ‘Psi’ values associated with each element of the accredited details together with the lengths of the different bridges for each of the two dwellings. This second approach gives more accurate results but requires the lengths of the thermal bridges to be input. For the Detached House the ‘y’ value method overestimated the thermal bridge heat losses by 12.5%, while for the Mid-floor Flat the ‘y’ value method underestimated the thermal bridge heat losses by 35%. The effect on the Space Heating Demand of these differences was 1.2 kWh/m^2 p.a. (2.5%) and 1.5 kWh/m^2 p.a. (4.4%) respectively. These differences may become relatively larger were other heat losses to be reduced in future. From this analysis it would appear that the additional time taken to enter the thermal bridge lengths would be justified by the improvement in the accuracy of the calculations and could also have the benefit of improved understanding of thermal bridging. The effective ‘y’ values for the Detached House and Mid-floor Flat with TH2007 Accredited details were 0.07 and 0.11 and with PH details were 0.018 and 0.025 respectively.

The following sections give extracts from the SAP calculations:
i) The Mid-floor Flat upgraded to meet Passive House criterion
ii) The Detached House upgraded to meet Passive House criterion
iii) The Mid-floor Flat to 2007 TH accredited details (y=0.08)
iv) The Mid-floor Flat to 2007 TH accredited details (Psi values)
v) The Detached House to 2007 TH accredited details (y=0.08)
vi) The Detached House to 2007 TH accredited details (Psi values)

i) The Mid-floor Flat upgraded to meet Passive House criterion.

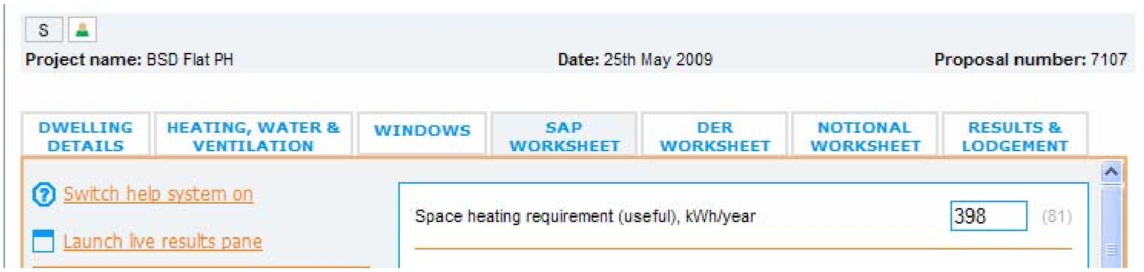


Fig 1.1. Space heating demand = 398 / 80.18 = 4.96 kWh/m2 p.a.

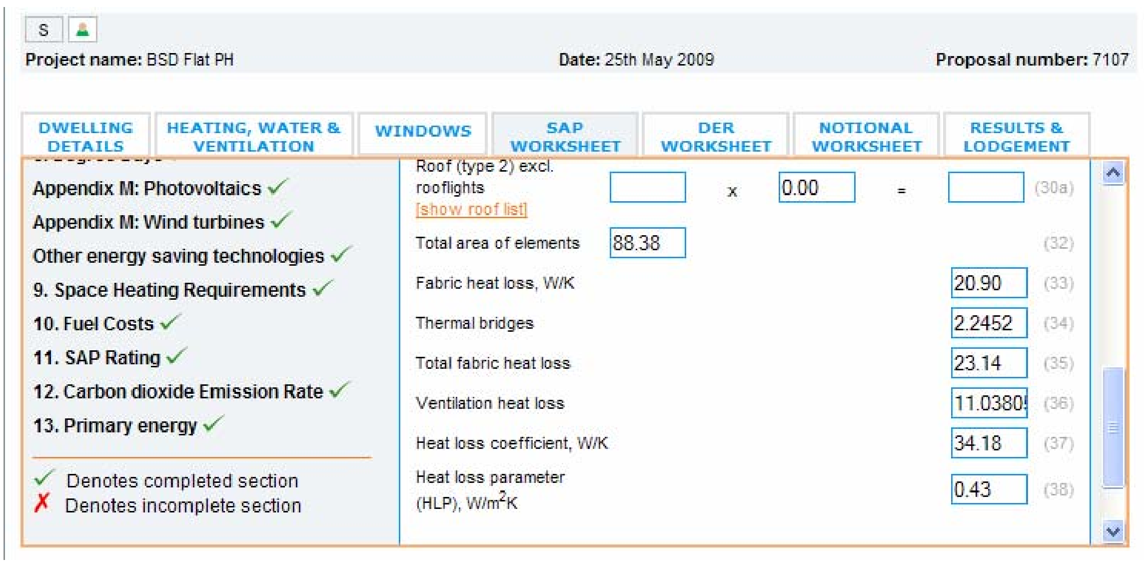


Fig 1.2. Thermal bridge effective ‘y’ value = 2.2452/88.38 = 0.025

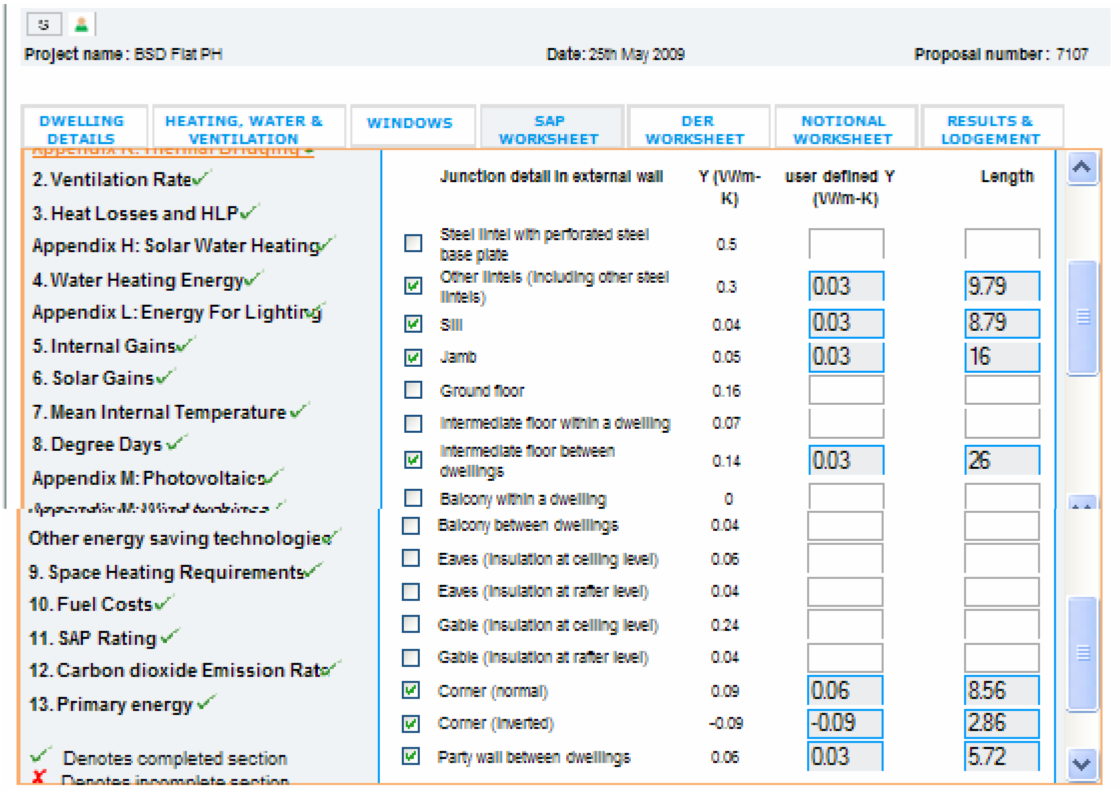


Fig 1.3. Passive House Thermal bridge details.

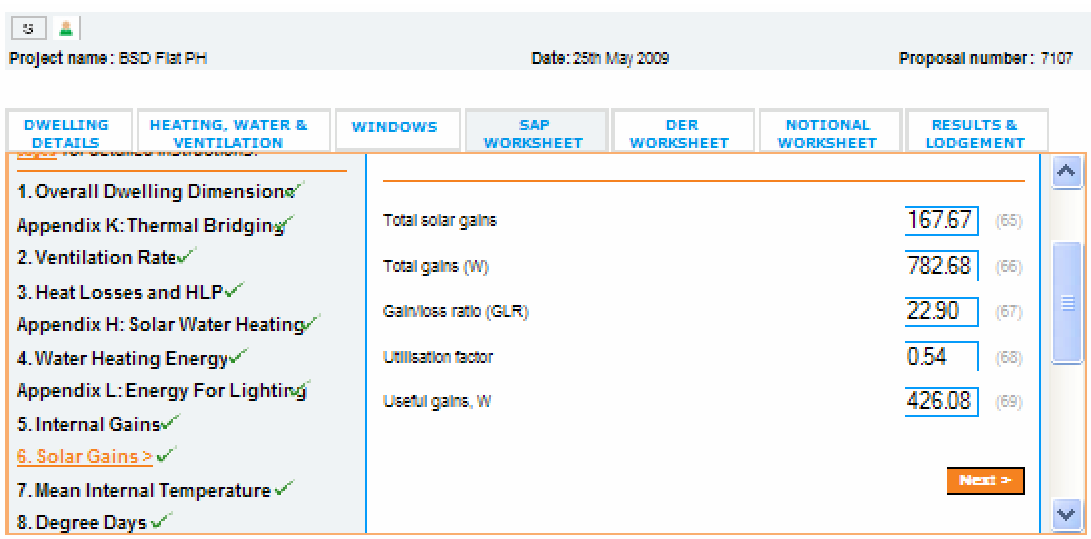


Fig 1.4. Gains utilisation decreases in SAP as Gains/Loss ratio increases – heating demand tends not to go to zero. For the Passive House version SAP assumes a gains utilisation of 0.54 compared to 0.89 for the 2007 TH case.

ii) The Detached House upgraded to meet Passive House criterion.

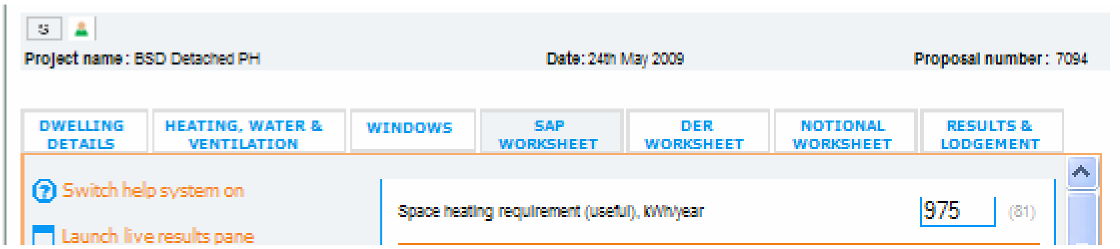


Fig 2.1. Space heating demand = 975 / 118 = 8.26 kWh/m^2 p.a.

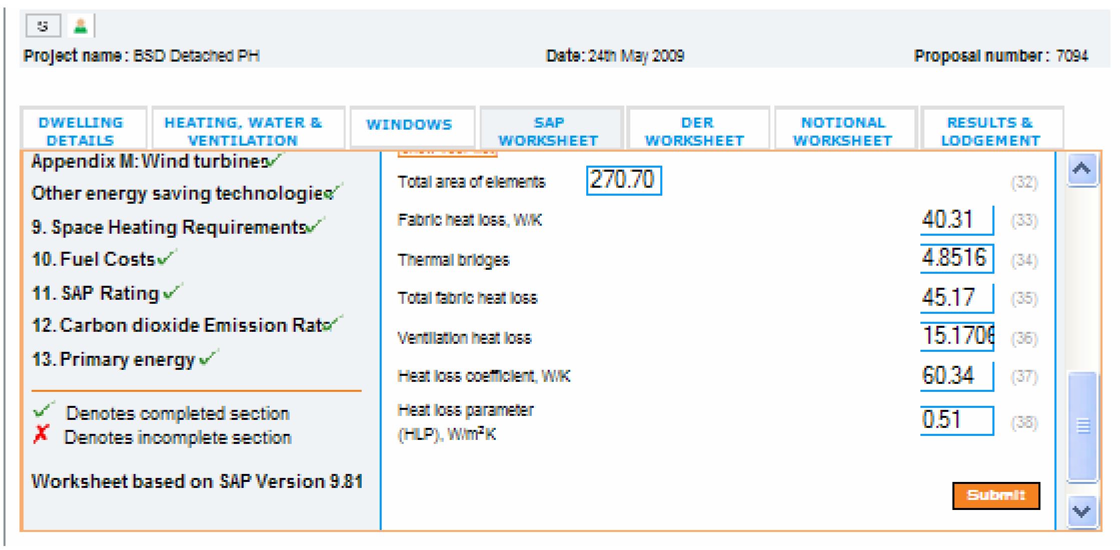


Fig 2.2. Thermal bridge effective ‘y’ value = 4.8516/270.7 = 0.018

iii) The Mid-floor Flat to 2007 TH accredited details (y=0.08)

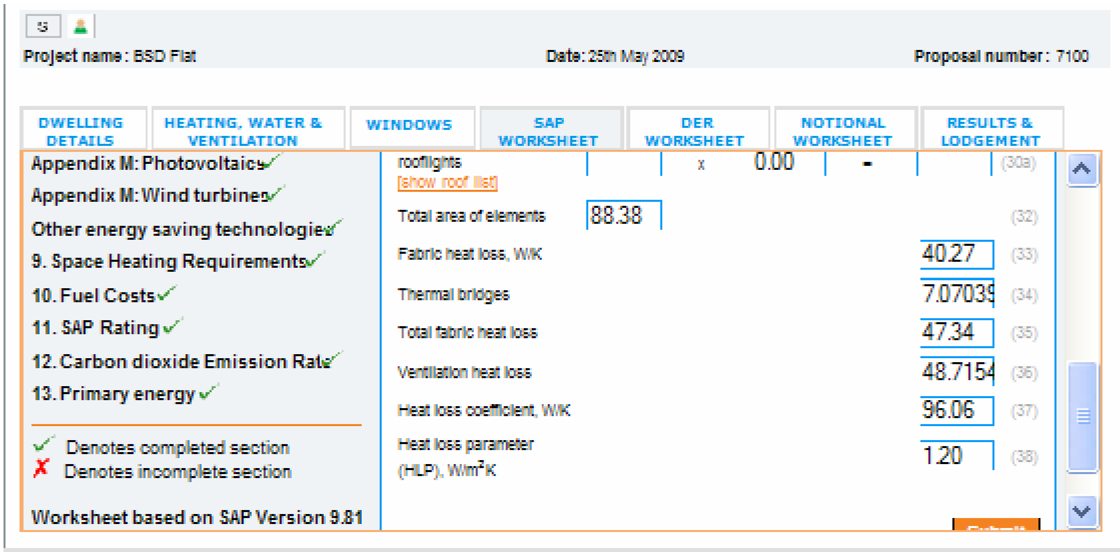


Fig 3.1. Thermal bridge assumed y = 0.08.

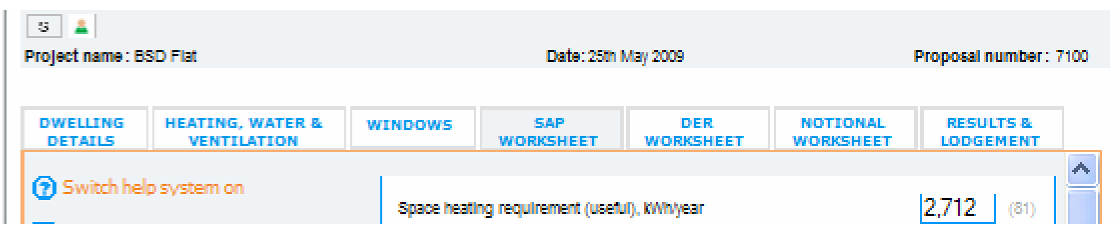


Fig 3.2. Space heating demand (with y=0.08) = 2712 / 80.2 = 33.8.

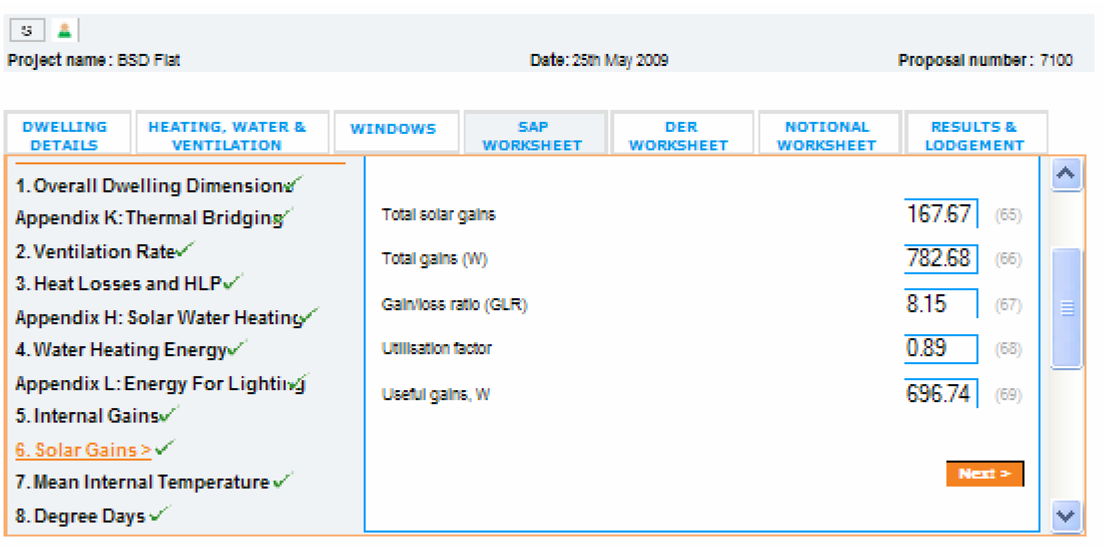


Fig 3.3. Gains utilisation in 2007 TH Mid-floor Flat = 0.89

iv) The Mid-floor Flat to 2007 TH accredited details (Psi values)

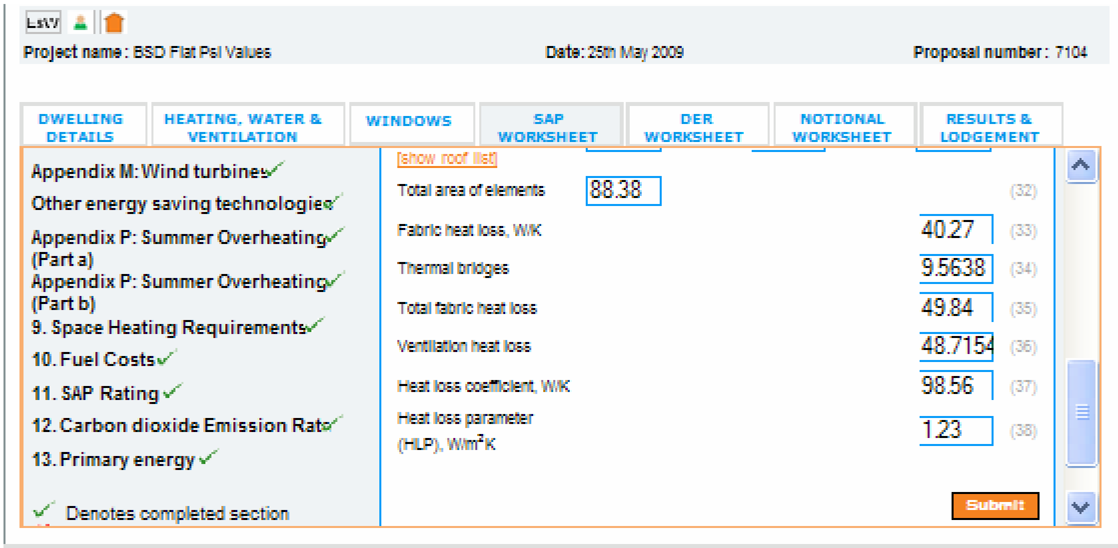


Fig 4.1. With accredited ‘Psi’ values and lengths, effective ‘y’ = 9.5638 / 88.38 = 0.108. This is 35% higher than using the allowed ‘y’ value of 0.08.

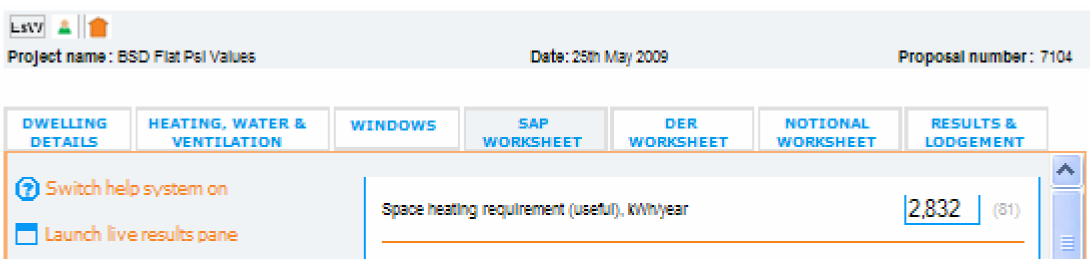
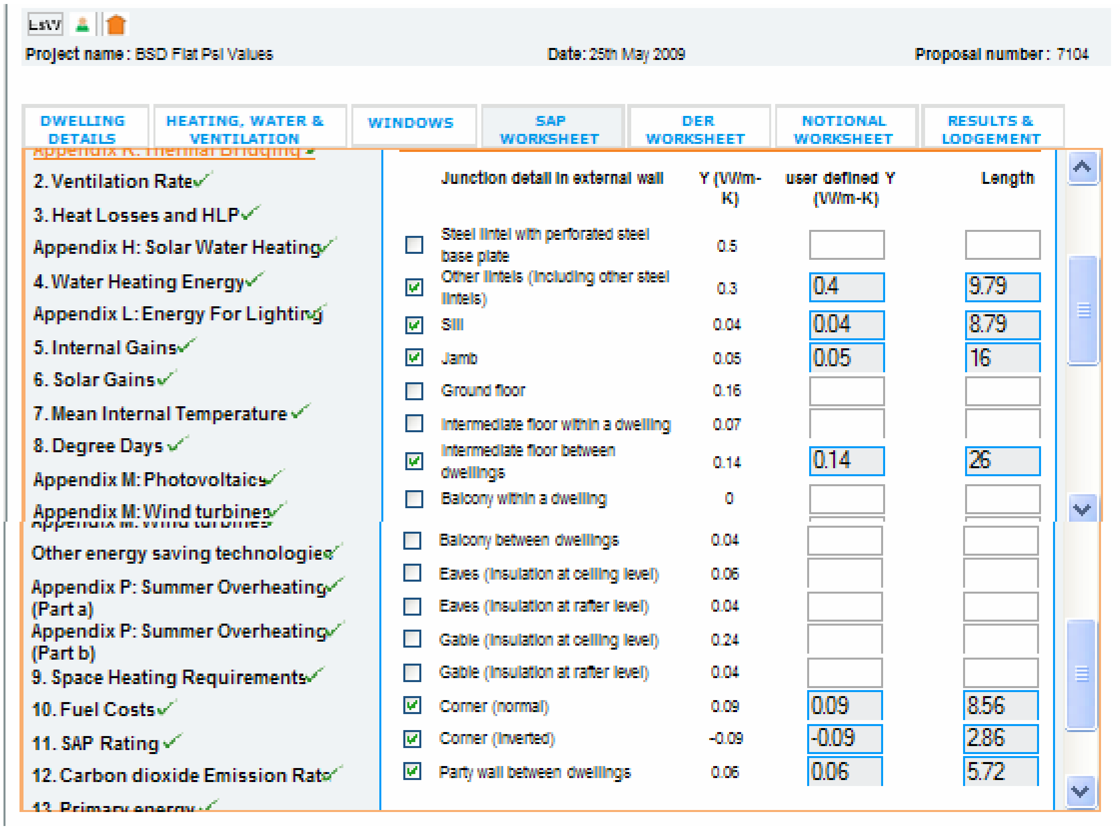


Fig 4.2. Space heating demand (with accredited Psi values) = 2832 / 80.2 = 35.31 kWh/m^2 p.a., this is 4.4% higher than if y = 0.08 is assumed. (35.31 compared to 33.8).



Junction detail in external wall	Y (W/m-K)	user defined Y (W/m-K)	Length
Steel lintel with perforated steel base plate	0.5		
Other lintels (including other steel lintels)	0.3	0.4	9.79
Sill	0.04	0.04	8.79
Jamb	0.05	0.05	16
Ground floor	0.16		
Intermediate floor within a dwelling	0.07		
Intermediate floor between dwellings	0.14	0.14	26
Balcony within a dwelling	0		
Balcony between dwellings	0.04		
Eaves (insulation at ceiling level)	0.06		
Eaves (insulation at rafter level)	0.04		
Gable (insulation at ceiling level)	0.24		
Gable (insulation at rafter level)	0.04		
Corner (normal)	0.09	0.09	8.56
Corner (inverted)	-0.09	-0.09	2.86
Party wall between dwellings	0.06	0.06	5.72

Fig 4.3. Thermal bridge details (Psi and lengths) assumed for the Mid-floor flat (2007 TH).

v) The Detached House to 2007 TH accredited details (y=0.08)

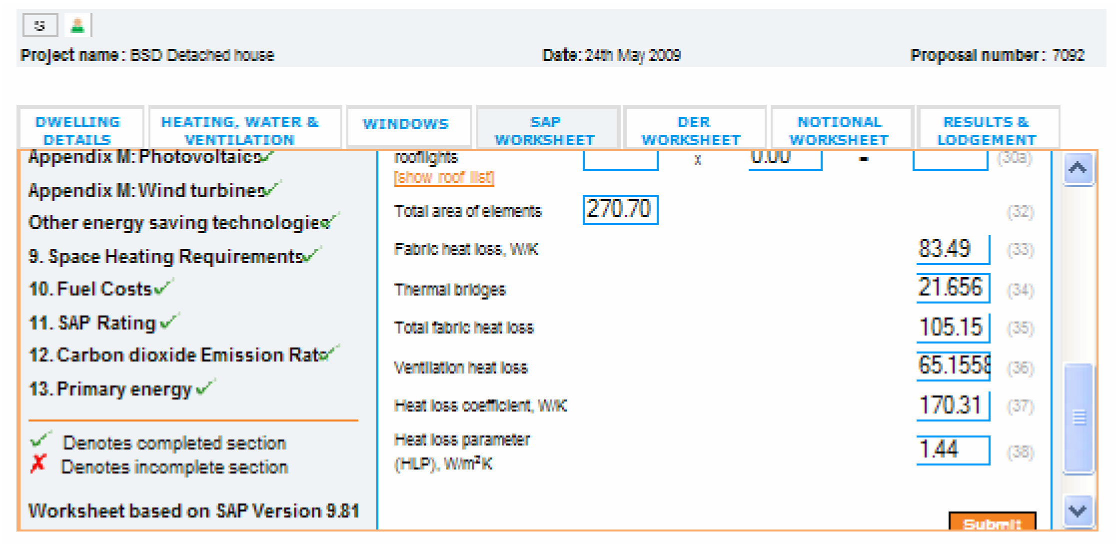


Fig 5.1. Thermal bridge heat losses assuming y = 0.08 (2007 TH).

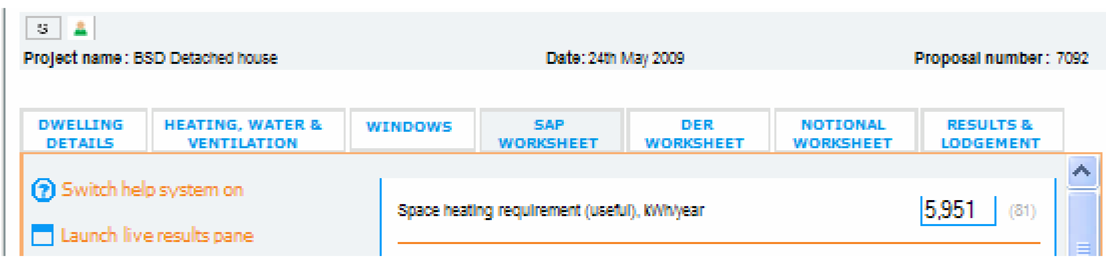


Fig 5.2. Space heating demand (y = 0.08) = 5951 / 118 = 50.4 kWh/m^2 p.a.

vi) The Detached House to 2007 TH accredited details (Psi values)

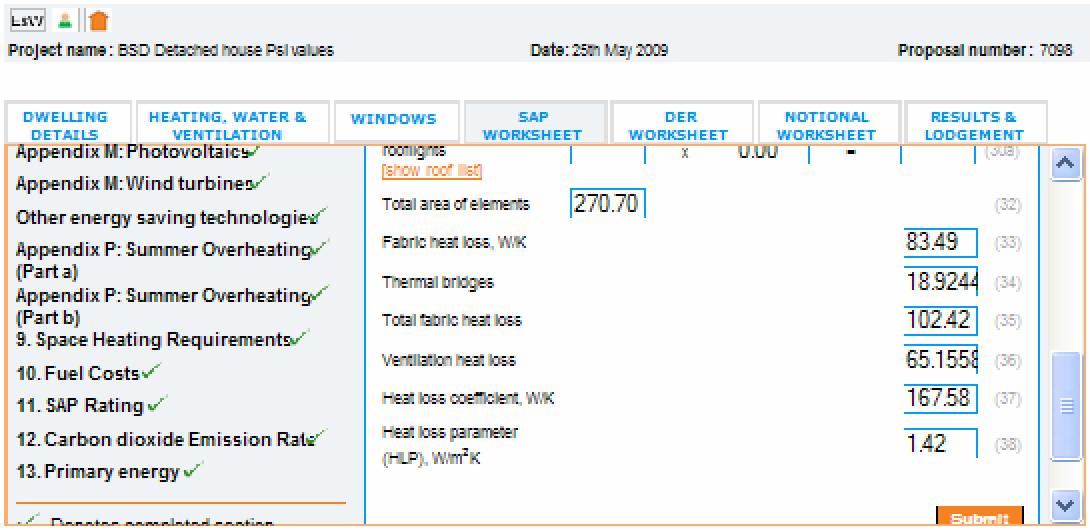


Fig 6.1. Thermal bridges assuming accredited details Psi values and actual lengths. Effective 'y' value = 18.9244 / 270.7 = 0.0699. This is 12.6% lower than using the y = 0.08 assumption.

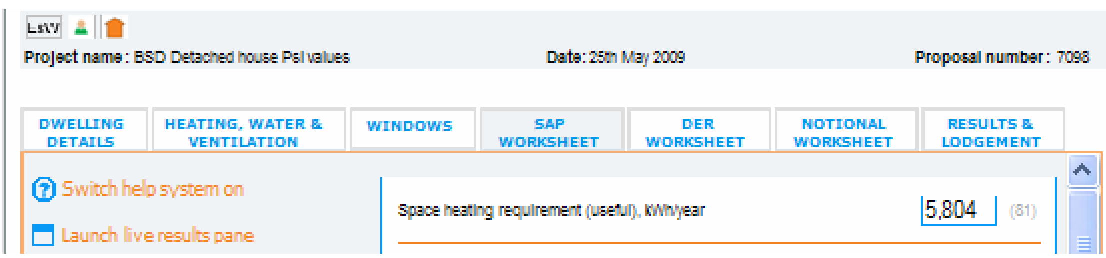
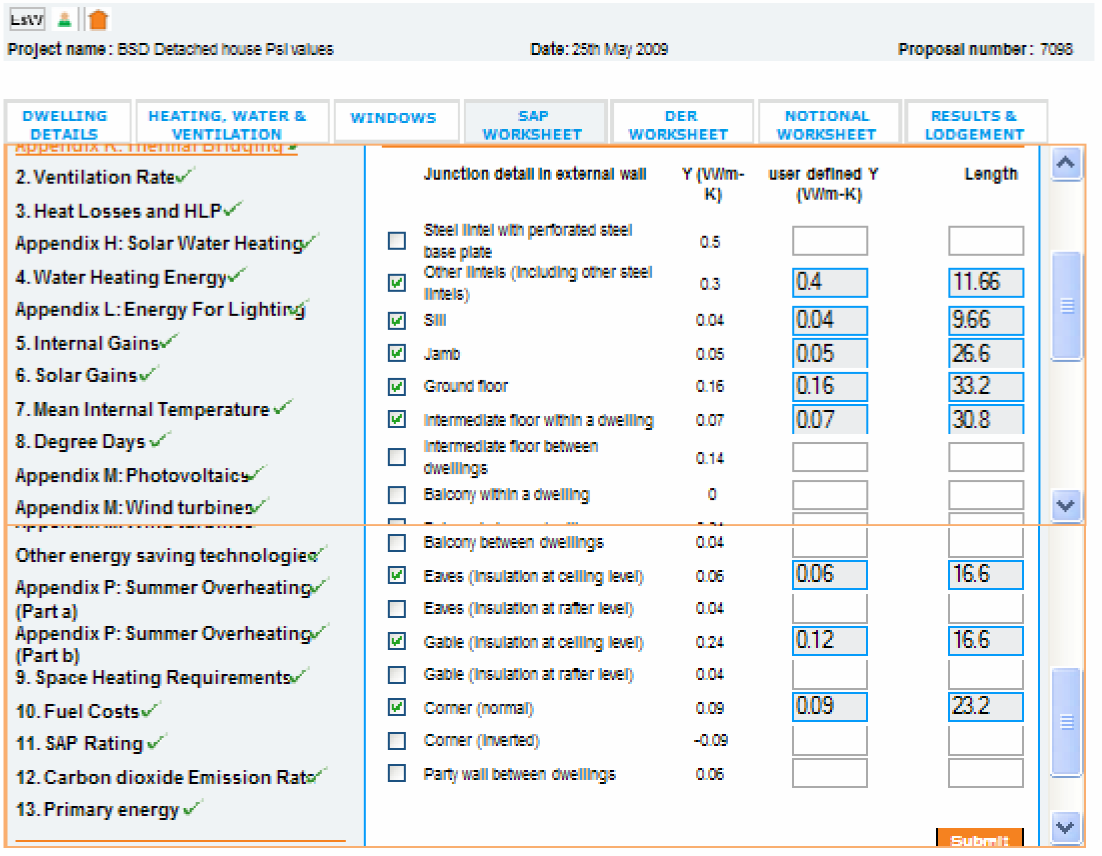


Fig 6.2. Space heating demand (Psi values and lengths) = 5804 / 118 = 49.19 kWh/m^2 p.a. This is 2.5% lower than assuming y = 0.08.



Junction detail in external wall	Y (W/m-K)	user defined Y (W/m-K)	Length
Steel lintel with perforated steel base plate	0.5		
Other lintels (including other steel lintels)	0.3	0.4	11.66
Sill	0.04	0.04	9.66
Jamb	0.05	0.05	26.6
Ground floor	0.16	0.16	33.2
Intermediate floor within a dwelling	0.07	0.07	30.8
Intermediate floor between dwellings	0.14		
Balcony within a dwelling	0		
Balcony between dwellings	0.04		
Eaves (insulation at ceiling level)	0.06	0.06	16.6
Eaves (insulation at rafter level)	0.04		
Gable (insulation at ceiling level)	0.24	0.12	16.6
Gable (insulation at rafter level)	0.04		
Corner (normal)	0.09	0.09	23.2
Corner (inverted)	-0.09		
Party wall between dwellings	0.06		

Fig 6.3. Thermal bridge accredited details Psi values and lengths for the detached house.