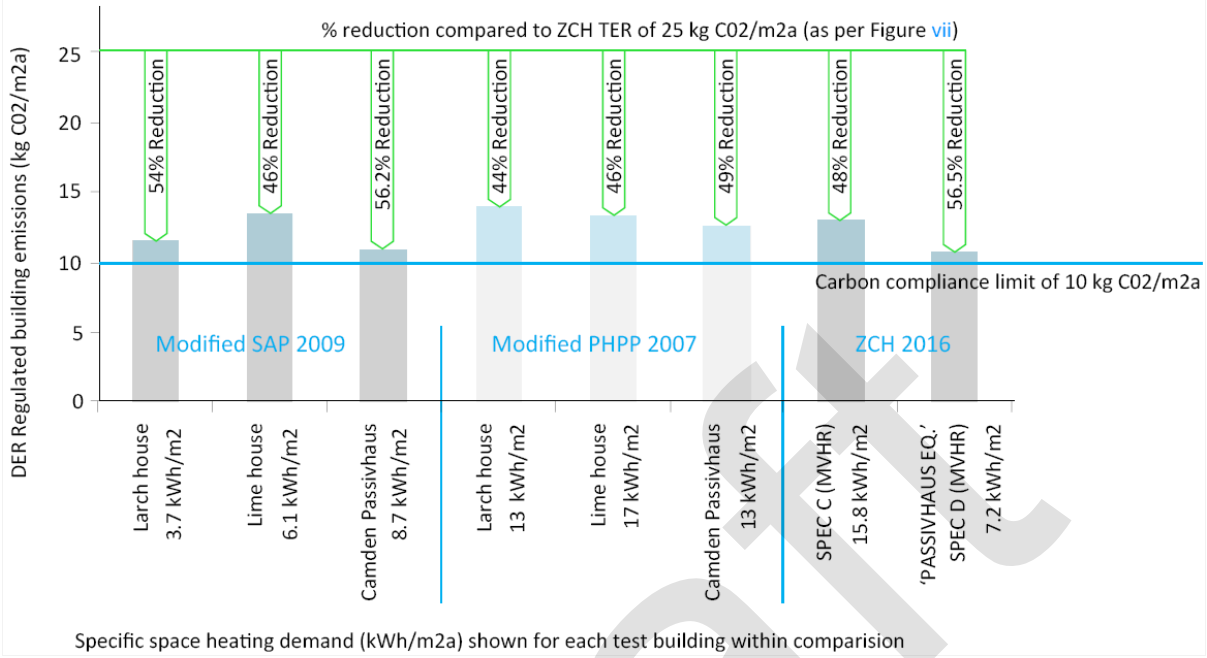
4.0 Results ...notes to be populated and expanded...

4.1 DER output

Chart comparing SAP 2009 and PHPP 2007 Dwelling Emission Rate outputs for each of the sample buildings with two FEES compliant building fabric specifcations from the ZCH 2016 report.

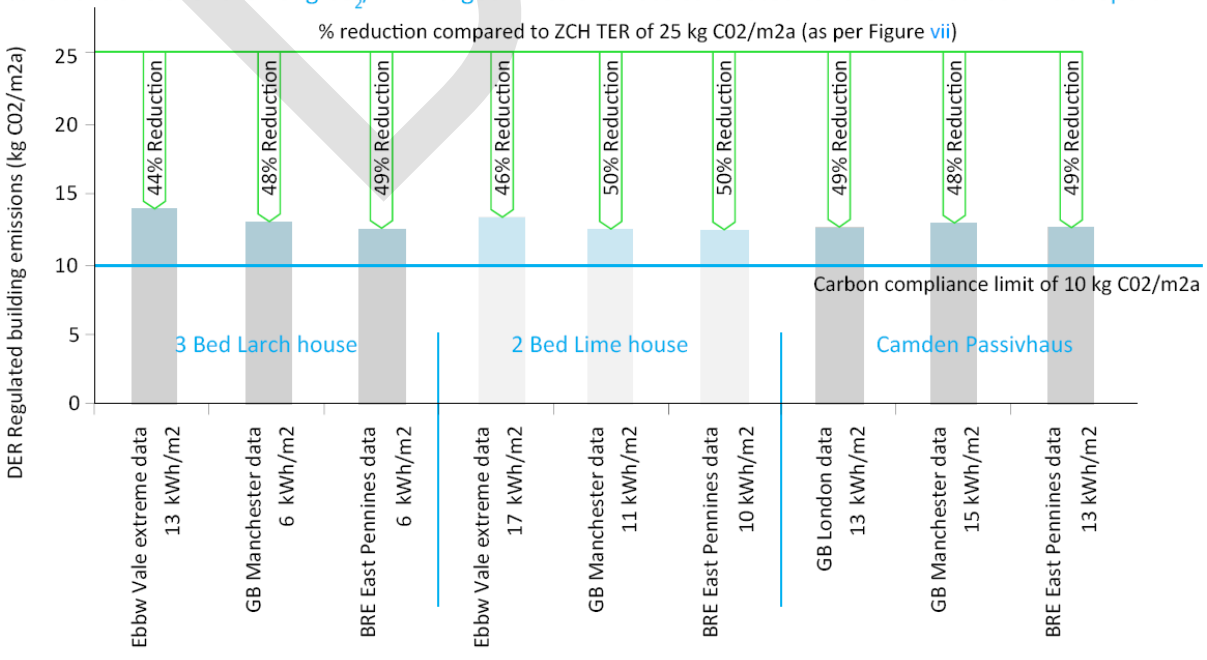


4.2 Regional Variation

To test implication of regional weather data.

Reference to BRE data download page "Global radiation and temperature values can be very site specific, as a result the PHPP outputs can differ for sites which have extreme exposures such as very dense urban, highly exposed or height above sea level compared to the default data sets for the region. This could affect the heating and cooling load results significantly." [6]

Chart showing impact of regional weather data on DER outputs from PHPP 2007 - with associated % reductions over the 25kg $C0_2/m^2a$ Target Emissions Rate calculated for the Zero Carbon Hub report



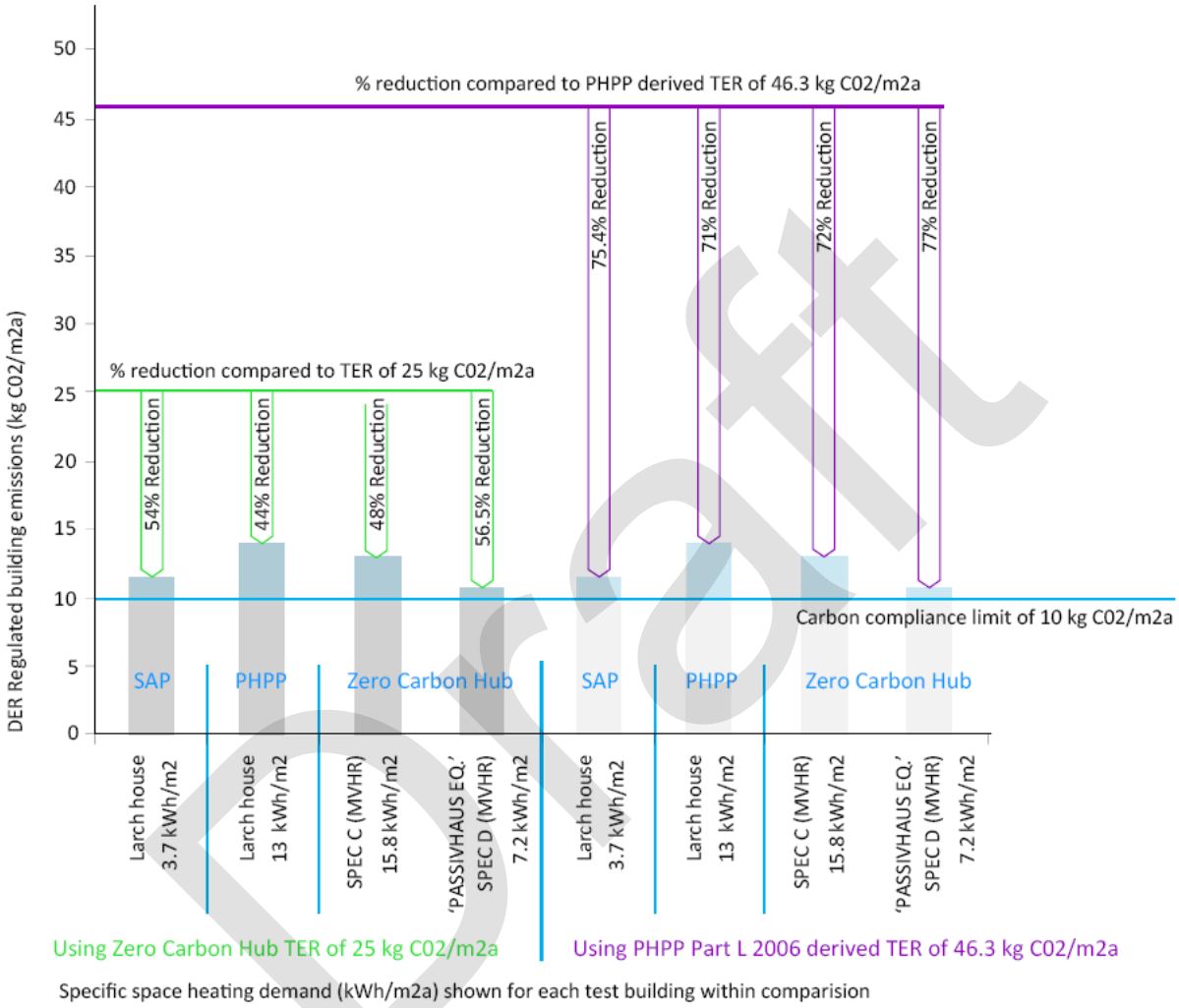
5 Zero Carbon Hub (2011) *National or Regional Weather: Implications for Carbon Compliance. Accessed June 2011 at* http://www.zerocarbonhub.org/resources.aspx

6 *Building Research* Establishment (2011) *Regional Climate Data Map. Accessed June 2011 at* http://www.passivhaus.org.uk/regional-climate-data

4.3. Creation of a 2006 Part L equivalent building in PHPP

The outputs in steps 4.1 and 4.2 show a clear range of percentage improvements of PHPP outputs of 44-50% even taking into account regional differences. However whilst the figures for CO_2/m^2a remain absolute, the 2006 Part L base figure (from which the percentage improvements are calculated) was established using SAP. The following exercise aims to calculate an equivalent TER building in PHPP, and compare all PHPP results to this figure. See Appendix B for full workings

Chart illustrating % reduction over Target Emission Rates for a 2006 Part L building modelled in PHPP, as compared with a TER of 25kg CO_2/m^2a calculated for the Zero Carbon Hub report



5.0 Analysis, 6.0 Conclusion ...to be populated.....

...Initial findings and recommendations (to be expanded)

- DER results between SAP, PHPP and ZCH report are surprisingly similar, suggesting that from this limited data set the ZCH modelling of the detached 'SPEC D' PH equivalent dwelling was indeed a good representation of a Passivhaus.
- Regional variation – ie the same building placed in different weather data produces significant enough an effect on the overall C02/space heat demand for the report to recommend regional variation being accounted for within the Carbon Compliance calculation.
- The amount of confusion generated from the research and discussion of percentage improvements over TER figures was such that any future work by bere:architects is unlikely to refer to them. The report will show examples to support the ZCH recommendation for the adoption of absolute figures in place of relative improvements. Calls will be made for this to be incorporated as early as possible – the earliest date realistically being the 2013 Part L review.
- Comparing space heating demand kWh/m^2a figures and DER kg CO_2/m^2 on the same graph has allowed for simpler correlations to be drawn between results than if two separate graphs were used.

- Regardless of scenario/ modelling protocol, the Certified Passivhaus dwellings typically range have between 11 and 14kg CO_2/m^2. Although the report does not intend to express a stance on the use of LZC technology, it will be acknowledged
- It is of key importance that the Government adopts the ZCH recommendation for built performance targets as opposed to as designed targets.
- Although the creation of a 2006 Part L equivalent building in PHPP may be considered by some as 'comparing Apples with Pears' it is felt that the exercise highlights the potential underestimation of regulated emissions for past and current building regulations standard construction.

Appendix A – SAP Calculations

Calculations for Figure iv
Input data from Page 50 of ZCH "*Defining a Fabric Energy Efficiency Standard for zero carbon homes",* Appendix A Work Group 1 Form and Fabric (2009).
Carbon intensity factors from ZCH as per Figure ii

	Baseline Page 50 Detached house form fabric final						
	As adjusted to ZCH carbon emissions factors						
	kWh/m2						
Space heating	61.5	x	0.227		13.9605		
Hot Water	19.1	x	0.227		4.3357		
Pumps & fans	1.5	x	0.527		0.7905		
Lighting	6.5	x	0.527		3.4255		percentage improvement
				DER	**22.5122**	If TER = 25....	10.0%
Total	88.6						

	SPEC A (NV) Page 50 Detached house form fabric final						
	As adjusted to ZCH carbon emissions factors						
	kWh/m2						
Space heating	49.7	x	0.227		11.2819		
Hot Water	19.1	x	0.227		4.3357		
Pumps & fans	1.5	x	0.527		0.7905		
Lighting	3.8	x	0.527		2.0026		percentage improvement
				DER	**18.4107**	If TER = 25....	26.4%
Total	74.1						

	SPEC B (NV) Page 50 Detached house form fabric final						
	As adjusted to ZCH carbon emissions factors						
	kWh/m2						
Space heating	40.7	x	0.227		9.2389		
Hot Water	19.1	x	0.227		4.3357		
Pumps & fans	1.5	x	0.527		0.7905		
Lighting	3.8	x	0.527		2.0026		percentage improvement
				DER	**16.3677**	If TER = 25....	34.5%
Total	65.1						

	SPEC B (MVHR) Page 50 Detached house form fabric final						
	As adjusted to ZCH carbon emissions factors						
	kWh/m2						
Space heating	30.5	x	0.227		6.9235		
Hot Water	19.1	x	0.227		4.3357		

Pumps & fans	5.8	x	0.527		3.0566		
Lighting	3.8	x	0.527		2.0026		percentage improvement
				DER	**16.3184**	If TER = 25....	34.7%
Total	59.2						

SPEC C (NV) Page 50 Detached house form fabric final

As adjusted to ZCH carbon emissions factors

	kWh/m2						
Space heating	30.2	x	0.227		6.8554		
Hot Water	19.1	x	0.227		4.3357		
Pumps & fans	1.5	x	0.527		0.7905		
Lighting	3.8	x	0.527		2.0026		percentage improvement
				DER	**13.9842**	If TER = 25....	44.1%
Total	54.6						

Spec C (MVHR) Page 50 Detached house form fabric final

As adjusted to ZCH carbon emissions factors

	kWh/m2						
Space heating	15.8	x	0.227		3.5866		
Hot Water	19.1	x	0.227		4.3357		
Pumps & fans	5.8	x	0.527		3.0566		
Lighting	3.9	x	0.527		2.0553		percentage improvement
				DER	**13.0342**	If TER = 25....	47.9%
Total	44.6						

Spec D (MVHR) Page 50 Detached house form fabric final

As adjusted to ZCH carbon emissions factors

	kWh/m2						
Space heating	7.2	x	0.227		1.6344		
Hot Water	19.1	x	0.227		4.3357		
Pumps & fans	5.4	x	0.527		2.8458		
Lighting	3.9	x	0.527		2.0553		percentage improvement
				DER	**10.8712**	If TER = 25....	56.5%
Total	35.6						

Calculations for SAP DER outputs – adjusted to take into account Carbon emissions factors
Input data from Brooks Devlin, SAP worksheets to follow
Carbon emission factors from ZCH as per Figure ii

	SAP As prepared by Brooks Devlin		**3 Bed Larch house**	Area 99	**SAP**		**3 Bed Larch house** As adjusted to ZCH carbon emissions factors	
Space heat	372.58	x	0.198	73.77084	372.58	x	0.227	84.57566
water heat	2749.82	x	0.198	544.46436	2749.82	x	0.227	624.20914
pump fan etc	393.97	x	0.517	203.68249	393.97	x	0.527	207.62219

lighting	401.01	x	0.517		207.32217		401.01	x	0.527		211.33227		
					1029.23986						1127.73926		percentage improvement is ....
				DER	10.39636222					**DER**	**11.39130566**	If TER 25.....	54.4%
				TER	19.32					TER	19.32	If TER is (Y11)	41.0%

	SAP	**2 Bed Lime house**		Area	77.58		**SAP**	**2 Bed Lime house**					
	As prepared by Brooks Devlin						**As adjusted to ZCH carbon emissions factors**						
Space heat	475.02	x	0.198		94.05396		475.02	x	0.227		107.82954		
water heat pump	2583.85	x	0.198		511.6023		2583.85	x	0.227		586.53395		
fan etc	335	x	0.517		173.195		335	x	0.527		176.545		
lighting	350.26	x	0.517		181.08442		350.26	x	0.527		184.58702		
					959.93568						1055.49551		percentage improvement
				DER =	12.37342					**DER =**	**13.60525277**	If TER 25.....	45.6%
				TER =	20.57					TER =	20.57	If TER is (Y11)	33.9%

	SAP	**Camden Passivhaus**		Area	117.1		**SAP**	**Camden Passivhaus**					
	As prepared by Brooks Devlin						**As adjusted to ZCH carbon emissions factors**						
Space heat	1024.6	x	0.198		202.8708		1024.6	x	0.227		232.5842		
water heat pump	2573.91	x	0.198		509.63418		2573.91	x	0.227		584.27757		
fan etc	437.97	x	0.517		226.43049		437.97	x	0.527		230.81019		
lighting	443.03	x	0.517		229.04651		443.03	x	0.527		233.47681		
					1167.98198						1281.14877		percentage improvement is ....
				DER =	9.974226985					**DER =**	**10.94063851**	If TER 25.....	56.2%

	TER =	18.86		TER =	18.86	If TER is (Y1	42.0%

Appendix B – PHPP Calculations

Calculations to removing unregulated emissions from all PHPP worksheets and to insert ZCH carbon emissions factors

Worksheet	Cell Range	Description	Adjustment	Units	Notes
Solar DHW	F11:F18	Selection of collector for solar DHW	Values cleared	N/A	Removal of solar thermal collectors - to demonstrate performance of fabric without addition of LZC technology
	F27,F33	Secondary Calculation of Storage Losses	Values cleared	N/A	No solar collectors - storage losses related to solar storage tank no longer relevant
Electricity	D11:F21, D24:F25	Usage for cooking, electronics, appliances etc (Binary Selection)	Values changed to "0"	N/A	Note: All lighting left unchanged (Row 23) as the lighting detailed on these projects is fixed and therefore part of regulated emissions
Aux Electricity	F30	Electricity for solar DHW pump (Binary Selection)	Value changed to "0"	N/A	Electricity use for solar DHW pump no longer relevant
PE Value	F107	Planned Annual Electricity Generation (Solar PV)	Value cleared	kWh	PV array removed for clarity (calculation is actually separate, meaning this step is not strictly necessary)
Data	E6	Natural gas, CO_2-equivalent emission factor	Value changed to "0.227"	kg/kWh Final	Emission factor adjusted to align with ZCH calculation, as per ZCH 'Modelling_2016_using_SAP_2009_Technical_Guide'
	E10	Electricity-mix, CO_2-equivalent emission factor	Value changed to "0.527"	kg/kWh Final	Emission factor adjusted to align with ZCH calculation, as per ZCH 'Modelling_2016_using_SAP_2009_Technical_Guide'

PHPP and SAP outputs for main calculations

Larch House	Lime House	Camden Passivhaus
		

Carbon compliance result using results from PHPP (Target for 'Zero Carbon Compliance' 10kg CO_2/m^2)		
14.0 kg CO_2/m^2a	**13.5 kg CO_2/m^2a**	**12.7 kg CO_2/m^2a**
Equivalent % improvement over TER of 25 kg $CO_{2(eq)}/m^2a$ (Target 60%)		
44% improvement	**46% improvement**	**49% improvement**

Carbon compliance using results from SAP (Target for 'Zero Carbon Compliance' 10kg CO_2/m^2)		
11.4 kg CO_2/m^2a	**13.6 kg CO_2/m^2a**	**10.9 kg CO_2/m^2a**
Equivalent % improvement using TER of 25 kg $CO_{2(eq)}/m^2a$ (Target 60%)		
54% improvement	**46% improvement**	**56% improvement**
Equivalent % improvement over TER individually calculated for each project (as per SAP convention)		
TER of 19.32 C02(eq)/m2a	TER of 20.57 C02(eq)/m2a	TER of 18.86 C02(eq)/m2a

41% improvement	**34% improvement**	**42% improvement**

Regional Variation

Larch House	Lime House	Camden Passivhaus
		
Decrease of 1.0 kg CO_2/m^2a in Manchester weather data	Decrease of 0.9 kg CO_2/m^2a in Manchester weather data	Increase of 0.1 kg CO_2/m^2a in Manchester weather data
Carbon compliance result using 'average climate' (East Pennines) - Target for detached house 10kg CO_2/m^2		
13.0kg CO_2/m^2a	**12.6kg CO_2/m^2a**	**13.0kg CO_2/m^2a**
Equivalent percentage improvement over 2006 Part L - Target for detached house 60% improvement		
48% improvement	**50% improvement**	**48% improvement**

Larch House	Lime House	Camden Passivhaus
		
Decrease of 1.2 kg CO_2/m^2a in East Pennines weather data	Decrease of 1.0 kg CO_2/m^2a in East Pennines weather data	Increase of 0.1 kg CO_2/m^2a in East Pennines weather data
Carbon compliance result using 'average climate' (East Pennines) - Target for detached house 10kg CO_2/m^2		
12.8kg CO_2/m^2a	**12.5kg CO_2/m^2a**	**12.8kg CO_2/m^2a**
Equivalent percentage improvement over 2006 Part L - Target for detached house 60% improvement		
49% improvement	**50% improvement**	**49% improvement**

Calculations to create a PHPP 2006 TER equivalent for the 3 bed Larch house
Achieved by modelling to 2006 Part L fabric regulations, - planned extension exercise to model an equivalent 2006 TER as per Notional building specifications.

Certified Larch house

Element	Build up of thermal envelope from interior to exterior.	Thickness (mm)	U value W/(m2k)
Floor slab	Flooring	20	
	Screed	75	
	Concrete	225	**0.076**
	Floormate 500-A	480	
	Total	**800**	
Exterior Walls	Plasterboard	15	
	Timber studs wood fibre ins.	100	**0.095**
	OSB	18	
	Timber studs w/ frame ins.	225	

Reductions to create Part L 2006 equivalent

Build up of thermal envelope from interior to exterior.	Reduced build up (mm)	Resulting U value W/(m^2K)
Flooring	20	
Screed	75	
Concrete	225	**0.250**
Floormate 500-A	**80**	
Total	**400**	
Plasterboard	15	
Air gap	25	**0.350**
Timber studs w/ frame ins.	104	

	Panelvent	9	
	Wood fibre insulation	100	
	Total	**467**	
Roof	OSB	18	
	Timber truss w/ frame ins.	560	**0.074**
	Total	**578**	
Exterior wall behind kitchen unit	Plasterboard	15	
	Softwood panel	20	
	Timber studs w/ fibre ins.	75	
	OSB	18	**0.098**
	Timber studs w/ frame ins.	225	
	OSB	15	
	Wood fibre insulation	100	
	Total	**468**	
Thermal envelope	343.29m^2		
Window U-values	0.8 W/(m^{2}K)		
Window shading	Window reveal depth ranging from 0.30-0.32m		
LZC technology	4.7 kWp PV array, flat panel solar thermal collector		
Airtightness	$q_{50\ Air\ permeability}$ 0.24m^3/(hm^2)	$n_{50\ Air\ changes}$ 0.23 h^{-1}	
Space heating demand	13 kWh/m^{2}a		
CO_2 emissions factors	Natural gas 0.25	Electricity Mix 0.68	
Ventilation	MVHR, Passivhaus certified, 85% efficiency		

	OSB	18	
	Total	**162**	
	OSB	18	
	Timber truss w/ frame ins.	185	**0.250**
	Total	**203**	
	Plasterboard	15	
	Air gap	25	
	Timber studs w/ frame ins.	104	**0.350**
	OSB	18	
	Total	**162**	
Thermal envelope after fabric reductions (as above)	294.39 m^2		
Window U-values	2.2 W/(m^{2}K)		
Window shading	Reveal depths reduced by 0.2m		
LZC technology	Removed from calculation		
Airtightness	$q_{50\ Permeability}$ 10m^3/(hm^2)	$n_{50\ Air\ changes}$ 10.55 h^{-1}	
Resulting space heating demand	155 kWh/m^{2}a		
CO_2 emissions factors	Natural gas 0.227	Electricity Mix 0.527	
Ventilation	Extract only no heat recovery		