Report

Chimney Sheep™

Draught Excluders for Chimneys

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Carried out for:

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SUMMARY

The building stock in the UK is one the oldest in Europe and the rate of renewing this ageing stock is very slow (less than 1% per year). In order to achieve large scale better building energy efficiency in the short term refurbishment is now a key activity for the construction sector, particularly in housing. The UK government is committed to an 80% reduction of carbon dioxide (CO_2) emissions by 2050. As approximately a quarter of the UK's carbon emissions come from domestic energy use then a range of governmental schemes have been introduced to cut domestic carbon emissions significantly. These schemes include large expenditure on loft and cavity wall insulation, double glazing and exterior cladding. However, particularly for older and harder to heat homes, the issue of heat loss up existing but unused open chimneys is not a high profile issue, even though having an unblocked open chimney flue is like leaving a window open all the time during winter months.

Small but inexpensive improvements to energy efficiency and thermal comfort could be achieved in rooms with open chimneys if the open flue were blocked by an insulating and relatively air tight draught excluder that could be removed when not required – for example, in summer months when the chimney could provide a cooling air flow.

This report examines the potential of one such device - the Chimney Sheep (which is a simple and effective wool-based device for blocking chimneys) when the chimney is not in use. Advanced computer simulation has been used to provide estimates of energy, CO_2 and cost savings resulting from the application of the Chimney Sheep when used in three types of dwellings for three locations across the UK.

Results indicate that using a Chimney Sheep can:

- prevent over 4% of heated air from going up the chimney
- provide payback times of less than six months for poorly insulated dwellings
- be nearly as effective thermally as completely blocking/removing a fire place, but at a much lower cost and while still providing some air movement up the flue to prevent damp
- for, a well-insulated house a warm city like London, provide up to 63% less discomfort hours during hot summer weather conditions

1. INTRODUCTION

1.1 Energy Conservation in Dwellings and Chimneys

The Government and devolved administrations had targets to eradicate fuel poverty among vulnerable households by 2010 and 'as far as reasonably practicable' no household should be in fuel poverty by 2016 (2018 in Wales) [1]. The energy efficiency of dwelling is one of the primarily determinant of household fuel poverty. In addition, as a quarter of the UK's carbon emissions come from energy used in the homes then it is critical that energy conservation in dwellings is a major performance objective in the design or rehabilitation of buildings.

Major progress is currently being made by various governmental schemes aimed to cut carbon emissions significantly in existing housing by providing a subsidized loft and wall insulation services. According to the Energy Saving Trust these are the most cost-effective ways of reducing heating bills. [2]

However, this money is wasted if the home is draughty as too much heat can be lost and outflow from gaps. Draught proofing is one of the cheapest ways to save energy at home, but is often overlooked [3]. Chimneys are the most significant air leakage elements in the house to be considered as they can lose as much heat as all the draughty windows and doors put together. Chimneys work well when a solid fuel or wood fire is burning in the house, and do an excellent job in removing not just fire smoke but also stale air, moisture and indoor pollutants. However, an open chimney will also provide a mechanism (through buoyancy forces) to remove warm air from a room that is being heated by other means, such as central heating or electric heaters. Discomfort draughts can then be a problem and result in higher heating costs by letting warm air out and cold air in during the heating Thus, blocking or removing a chimney is one of the first decisions when refurbishing an old existing housing.

Chimney stacks are key features of the UK's urban skyline. Up to the 1960s, chimneys were provided on virtually every new house. Until 1965 (before Building Regulations appeared) the construction of fireplaces and chimneys was controlled by local law and good practice. Chimneys built at that time are either still in use as a primary or secondary heat source or they are just aesthetic elements inside the house [4]. The English Housing Survey report [5] has provided clues about the number of houses built before 1965 with chimneys. In 2008, there were around 22.2 million dwellings in England, while just over one million dwellings were vacant at the time of survey; 57.4% (12,168,800) of these existing occupied dwellings were built before 1965. Deducting around 1,100,000 flats from this number gives 11,068,800 houses and bungalows. Therefore, there are approximately eleven million houses and bungalows in the UK with chimney built before Building Regulation appeared (1965) [5]. This number indicates that, potentially, millions of pounds are spent on domestic heating that disappears up these outdated chimneys.

Similarly, chimney stacks are one the most common problem elements in the exterior fabric of a building, with over three million houses experiencing chimney stack problems (Figure 1). As a result, finding a way to both keep a chimney whilst preventing heat loss from chimneys is essential.

	percentage	number (000s)		percentage	number (000s)
exterior fabric			**interior fabric**		
wall finish	22.6	5,026	ceilings	16.9	3,758
windows/frames	18.5	4,114	walls	12.4	2,758
roof covering	15.6	3,469	doors	10.8	2,402
chimney stacks	15.1	3,358	floors	5.8	1,290
gutters/downpipes	13.6	3,025	**any interior faults**	**30.2**	**6,716**
doors/frames	12.2	2,713			
fascias	11.3	2,513	**building structure**		
wall structure	4.8	1,067	any structural faults	8.4	1,868
stacks/wastes	5.2	1,156			
valley gutter	4.6	1,023	**services and amenities**		
roof structure	3.2	712	fences	15.0	3,336
bays	2.7	600	kitchen	12.9	2,869
DPC (damp proof course)	3.3	734	boundary walls	9.5	2,113
porches	2.0	445	bathroom	8.7	1,935
conservatories	1.6	356	primary services (gas and electricity)	11.1	2,469
party parapets	0.8	178			
dormers	0.7	156	CH boiler/distribution	5.3	1,179
balconies	0.4	89	other heating	3.1	689
any exterior faults	**54.4**	**12,098**	hot water	2.3	512

Figure 1. *Dwellings with faults to different building components, 2008[6]*

1.2 Chimney Sheep

This report gives the results of the potential energy, CO_2 and cost savings in dwellings with chimneys resulting from the use of the Chimney Sheep, a draught excluder for chimneys. The Chimney Sheep is designed and manufactured by '*Chimney Sheep Ltd'* to prevent the heat loss from chimneys. This is achieved by fitting the wool head of the Chimney Sheep into the narrow part of the flue. The Sheep comes in five sizes which fit the vast majority of chimney flues. Figure 2 shows different shapes of Chimney Sheep:

Figure 2. *Chimney Sheep[7]*

For chimneys which are not in use, a Chimney Sheep offers a cost-effective way to prevent warm air escaping up the chimney and prevents cold air coming down into the home. They can also be re-used too.

The manufacturer claims some benefits for the Chimney Sheep [8] are:

Environmental Credentials

- It is a sustainable product as wool is a naturally occurring, sustainable product.
- It can be washed several times, but at the end of its life is compostable.
- The handle is made out of recycled plastic, and at the end of its life can be recycled again.

Heat and Carbon Saving

- Chimneys are cleverly designed to draw air up and out of a building. The use of a Chimney Sheep prevents heat loss due to stack effect by blocking the flue. Therefore, it results in the reduced use of fossil fuels from primary heat sources and, thereby, also reduces carbon emissions.

Other benefits

- Stops debris, soot and bird mess.
- Reduces outside noise entering the room.
- Allows a little ventilation.
- Sizes available to fit all chimneys.

1.3 Objectives

The main objectives of this report are:

- To demonstrate the potential annual energy, carbon and cost savings when the Chimney Sheep is employed. This effect has been measured for three types of houses in three cities across the UK with three different weather conditions: Aberdeen in the north of Scotland, Liverpool in the northwest of England and London in the south of England
- To evaluate the effect of the Chimney Sheep on operative temperature of the house and cooling energy consumption for a typical terrace house under weather data for London during summer
- To estimate the extent of this effect on the UK's carbon reduction by evaluating the number of houses with chimneys

2 TEST METHODOLOGY

Dynamic thermal computer modelling using the advanced thermal simulation package DesignBuilder was undertaken to calculate changes in annual heating energy consumption resulting from the installation of the Chimney Sheep.

2.1 Computer Modelling and Simulation

A typical 19th century type end-terraced house and also a typical 19th type detached house were modeled using the advanced thermal simulation package DesignBuilder. In addition, to examine the impact of using Chimney Sheep to seal the chimney in a well-insulated house compared to a pre-refurbished house, an airtight refurbished end terraced house has been modeled and simulated in DesignBuilder. The retrofitted model of the house included: very high levels of insulation, timber framed triple glazed windows and high

levels of air tightness (1.0 ACH@50Pa). Table 1 and 2 compare the pre and post refurbishment thermal features of the models.

For all models, the occupancy densities and occupied period profiles were modeled for a family of four (two adults and two children). Additionally, internal heat gain allowances were selected according to the activity of each zone in the building. Then, simulations were carried out with all treated zones assumed to be kept to a nominal set point temperature of 22 °C and heated to set points of between 18 °C and 22 °C (depending on the nature of usage). Table 3 shows the height and diameter of the modeled chimney for all the modeled houses.

Table 1. *Pre and post refurbishment thermal features of a 19th century terraced house [9],[10]*

Element	Roof	Walls	Floor	Windows	Doors
Typical existing construction (Fabric U-value, W/m^{2}K)	0.40	2.10	0.50	4.80	3.00
Upgraded (refurbished) fabric construction (Fabric U-value, W/m^{2}K)	0.15	0.11	0.12	0.78	1.00

Table 2. *Thermal features of a 19th century detached house [9]*

Element	Roof	Walls	Floor	Windows	Doors
Typical existing construction (Fabric U-value, W/m^{2}K)	0.44	1.7	0.70	4.80	3.00

Table 3. *Diameter and height of modelled chimney*

Diameter of chimney mm	**Height of chimney mm**
408	7500

Weather Data for Simulation

Current weather data for Aberdeen, Liverpool and London were used to evaluate and compare the effect of using Chimney Sheep with blocking or removing chimney on heating energy demand and comfort levels inside the house.

Table 4. *2009 monthly mean external air temperature (°C) for Aberdeen, Liverpool and London*

Weather data scenarios	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aberdeen-2009	3.1	3.2	4.5	6.6	8.9	11.7	13.5	13.4	11.5	8.9	5.1	3.9
Liverpool-2009	4.1	4.2	5.7	8.2	11.6	14.2	15.9	15.9	13.6	10.6	6.5	5.0
London-2009	4.1	4.3	5.8	8.3	11.6	14.2	15.9	15.9	13.6	10.7	6.5	5.1

2.2 Calculation of the Costs Savings

The total cost savings per annum due to applying Chimney Sheep is calculated by the following relation.

Total costs saving = [gas usage for heating before applying Chimney Sheep (kWh) - gas usage for heating after applying Chimney Sheep (kWh)] × energy price

The same relationship has been used to evaluate the savings per annum resulted from removing or blocking a chimney. Table 5 presents the energy cost per kWh which is used for calculation.

Table 5. *Energy prices*

Fuel	units	£ per unit
Natural Gas	kWh	0.05
Grid Electricity	kWh	0.14

2.3 Calculation of the Carbon Saving

The carbon savings per annum due to applying a Chimney Sheep or blocking the chimney was calculated using below relation:

CO_2 emission (kg) per annum= total energy savings per annum (kWh) × Fuel emission factor ($kgCO_2$/kWh)

Table 6 shows the conversion factors used to work out the greenhouse gas emissions associated with energy use.

Table 6. *Energy conversion factors*

Fuel	units	$KgCO_2e$ per unit
Natural Gas	kWh	0.1836
Grid Electricity	kWh	0.52462

3 RESULTS

3.1 DesignBuilder Predictions – properties with one chimney

Results from Applying Chimney Sheep

Pre and post-refurbished houses in different cities under current weather condition were simulated to see the effect of using Chimney Sheep on annual heating consumption, energy cost savings and carbon emission reduction. Simulation results given in Table 7 show savings for the pre refurbished end terrace house in different cities. More than 4% reduction in heating demand and CO_2 emission can be seen after applying Chimney Sheep in all three cities for the existing 19th century 3 bedroom terraced house. Saving of more than £50 in annual energy bills for the house in all cities can be seen.

Table 7. *Savings results from using Chimney Sheep in an existing 19th century 3 bedroom end terraced house*

Savings from using Chimney Sheep	Savings in gas usage for heating kWh/yr	Savings in energy bill £/yr	Savings in CO_2 $KgCO_2e/yr$	Savings per annum %
Aberdeen-2009	1481.59	74.08	272.02	4.35
Liverpool-2009	1282.80	64.14	235.52	4.26
London-2009	1143.42	57.17	209.93	4.14

Savings for an existing 3 bedroom detached house are presented in Table 8. Although results indicate that saving in a detached house is around 50% less than the savings in end terrace house but then again more than £30 savings in annual heating bills can be seen after applying Chimney Sheep.

Outcomes for the refurbished house presented in Table 9 confirm over 1.5% reduction in savings for all three cities.

Table 8. *Savings results from using Chimney Sheep in an existing 19th century 3 bedroom detached house*

Savings from using Chimney Sheep	Savings in gas usage for heating kWh/yr	Savings in energy bill £/yr	Savings in CO_2 $KgCO_2e/yr$	Savings per annum %
Aberdeen-2009	900.65	45.03	165.36	2.76
Liverpool-2009	768.70	38.43	141.13	2.68
London-2009	679.42	33.97	124.74	2.57

Table 9. *Savings in an eco-refurbished 3 bedroom end terraced house results from using Chimney Sheep*

Savings from using Chimney Sheep	Savings in gas usage for heating kWh/yr	Savings in energy bill £/yr	Savings in CO_2 $KgCO_2e/yr$	Savings per annum %
Aberdeen-2009	173.17	8.66	31.79	1.93
Liverpool-2009	122.93	6.15	22.57	1.59
London-2009	111.91	5.59	20.55	1.58

Results from Blocking/Removing Chimney

Changes in heating consumption, CO_2 emissions and energy cost for pre-refurbished end terraced house, detached house and refurbished terrace house in London, Liverpool and Aberdeen resulting from blocking/removing the chimney are given in Tables 10, 11 and 12. It can be concluded from the results that for both pre and post refurbished terrace house in all three cities, savings in heating consumption, CO_2 emissions and energy costs after blocking the chimney is only 0.5% more than using a Chimney Sheep. Comparing Table 11 and Table 8 shows that savings from blocking the chimney in a detached house is almost the same as applying a Chimney Sheep.

Table 10. *Savings results from blocking/removing chimney in an existing 19th century 3 bedroom terraced house*

Savings from blocking chimney	Savings in gas usage for heating kWh/yr	Savings in energy bill £/yr	Savings in CO_2 $KgCO_2e/yr$	Savings per annum %
Aberdeen-2009	1632.19	81.61	299.67	4.79
Liverpool-2009	1410.17	70.51	258.91	4.70
London-2009	1258.29	62.91	231.02	4.55

Table 11. *Savings results from blocking/removing chimney in an existing 19th century 3 bedroom detached house*

Savings from blocking chimney	Savings in gas usage for heating kWh/yr	Savings in energy bill £/yr	Savings in CO_2 $KgCO_2e/yr$	Savings per annum %
Aberdeen-2009	897.88	44.89	164.85	2.76
Liverpool-2009	762.92	38.15	140.07	2.66
London-2009	673.66	33.68	123.68	2.55

Table 12. *Savings results from blocking/removing chimney in an eco-refurbished 3 bedroom terraced house*

Savings from blocking chimney	Savings in gas usage for heating kWh/yr	Savings in energy bill £/yr	Savings in CO_2 $KgCO_2e/yr$	Savings per annum %
Aberdeen-2009	215.3	10.76	39.53	2.45
Liverpool-2009	159.03	7.95	29.19	2.05
London-2009	144.72	7.23	26.57	2.04

3.2 DesignBuilder Predictions – properties with two chimneys and basic energy efficiency

A series of simulations were undertaken to investigate the impact of changing the computer models to represent the terraced house with (i) one chimney and just loft insulation; (ii) two chimneys and no loft insulation; (iii) two chimneys and just loft insulation. As this exercise was only seeking to examine the relative sensitivity of adding the new parameters then the simulation were undertaken only for the Liverpool terraced house and using the 2009 weather data.

Table 13 shows the results from using a Chimney Sheep for the Liverpool terraced house with one chimney and just loft insulation as the only energy saving measure.

Table 13. *Savings from using Chimney Sheep for the terraced house with one chimney and loft insulation*

Savings from using Chimney Sheep	Savings in gas usage for heating kWh/yr	Savings in energy bill £/yr	Savings in CO_2 $KgCO_2e/yr$	Savings per annum %
Liverpool-2009	1279.46	63.97	234.91	4.28

The saving of 4.28 % compare to a saving of 4.26% for the same terrace with no energy saving measures and 1.59% for an eco-refurbished terrace. These findings indicate that the Chimney Sheep works effectively and in tandem with a basic energy saving measure such as loft insulation.

Table 14 shows the results from using a Chimney Sheep for the Liverpool terraced house with two chimneys and no energy saving measures (i.e. not even loft insulation).

Table 14. *Savings from using 'Chimney Sheep' for the house with two chimneys*

Savings from using 'Chimney Sheep'	Savings in gas usage for heating kWh/yr	Savings in energy bill £/yr	Savings in CO_2 $KgCO_2e/yr$	Savings per annum %
Liverpool-2009	1417.2	70.86	260.19	5.23

The saving of 5.23% shows that there is a proportionately bigger saving by employing a Chimney Sheep in each chimney even for a property with no other energy saving measures.

Table 15 shows the results from using a Chimney Sheep for the Liverpool terraced house with two chimneys and loft insulation as the only energy saving measure.

Table 15. *Savings from using 'Chimney Sheep' for the terraced house with two chimneys and loft insulation*

Savings from using 'Chimney Sheep'	Savings in gas usage for heating kWh/yr	Savings in energy bill £/yr	Savings in CO_2 $KgCO_2e/yr$	Savings per annum %
Liverpool-2009	1427.29	71.36	262.05	5.29

The saving of 5.29% indicate that there is an increased benefit if both chimneys in a property are filled with Chimney Sheep and that, as with the one chimney scenario, the Chimney Sheep works effectively and in tandem with a basic energy saving measure such as loft insulation.

3.3 Cooling Demand and Discomfort Hours

Cooling and ventilation are important, especially for a refurbished, airtight house in warmer cities like London. For this reason, discomfort hours have been simulated for the refurbished terrace house in London. For comfort calculations DesignBuilder uses ASHRAE Standard 55-2004, which states that when the air is very humid an operative temperature above 26.8°C is considered too hot, even when wearing summer clothes [11].

Discomfort hours are a measure of how many hours during a period of time internal temperatures exceeded 26.8°C i.e. the duration of discomfort. Figure 3 compares discomfort hours during summer (June, July and August) for post and pre refurbished terraced house under London current weather data with an open chimney flue, applying Chimney Sheep and blocking the chimney.

Results indicate that not only can an open fireplace let heat escape through the chimney in winter, but that it can also, in the summer, allow warm air to enter the occupied space. Simulation results indicate that an open chimney can result in a 63% increase in discomfort hours during summer in a refurbished house compared to the same house with either a Chimney Sheep or a blocked chimney. Therefore, sealing the chimney during summer is just as important as blocking it during the winter.

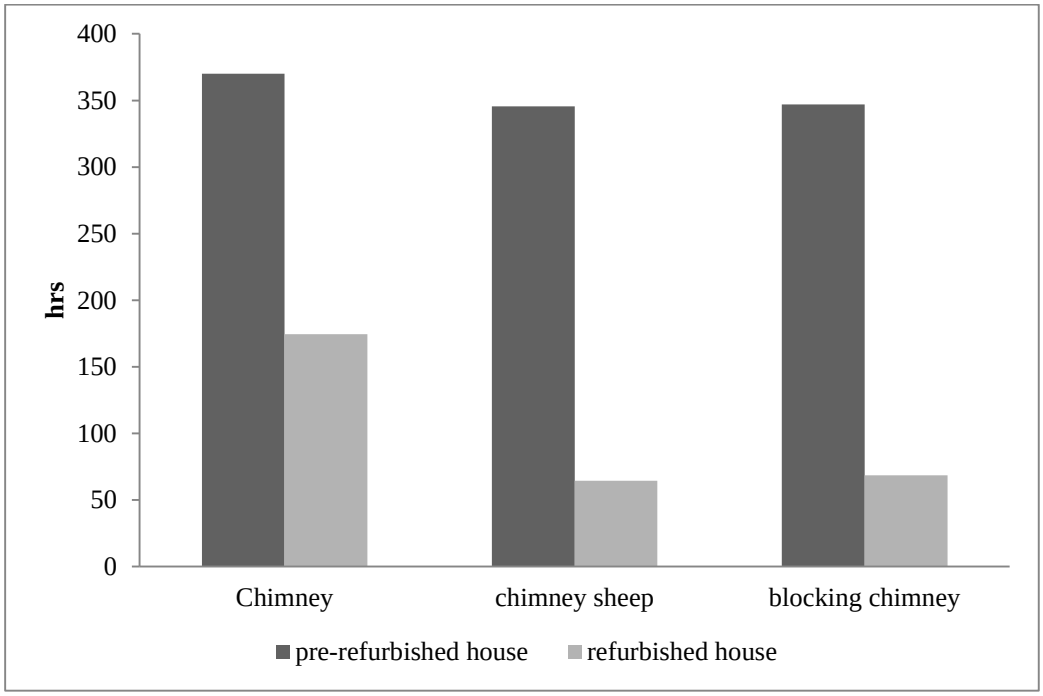

Figure 3. *Discomfort hours of pre and post refurbished terraced house in London during summer*

4. CONCLUSIONS

Computer simulations were carried out to determine the potential energy, cost and CO_2 savings that would results from applying a Chimney Sheep.

Computer Simulations were performed for three types of house in three cities across the UK with various weather conditions. Furthermore, results from applying Chimney Sheep were compared to blocking or removing chimney. The main findings are given below.

1. The use of the Chimney Sheep in an existing three bedroom terraced house results in a total cost saving of £74.08 for the house in Aberdeen, £64.14 for the house in Liverpool and £57.17 for the house in London per annum when gas is charged at 5.00 p/kWh.

2. The use of the Chimney Sheep in an existing three bedroom detached house results in a total cost saving of £45.03 for the house in Aberdeen, £38.43 for the house in Liverpool and £33.97 for the house in London per annum when gas is charged at 5.00 p/kWh.

3. The use of the Chimney Sheep in well-sealed and well-insulated three bedroom terraced house results in a total cost saving of £8.66 for the house in Aberdeen, £6.15 for the house in Liverpool and £5.59 for the house in London per annum when gas is charged at 5.00 p/kWh. It is also results in a total cost saving of £8.16 in cooling energy for the house in London.

4. A comparison of savings from using a Chimney Sheep and from blocking a chimney for all houses and under all three weather conditions shows very small differences between the results. Considering the required time and costs for removing and blocking chimney to reach these savings compared to applying Chimney Sheep, it can be said it is more beneficial to seal the chimney with a Chimney Sheep.

5. Using a Chimney Sheep in a property with just a basic level of loft insulation produced savings of over 4% per annum, and a proportionately larger saving for properties with two chimneys (over 5%).

6. Comparison of discomfort hours during summer before and after using Chimney Sheep suggest that sealing the chimney during summer is as important as closing it during winter.

7. From this study the average reduction in CO_2 emissions resulting from applying a Chimney Sheep in a house with a chimney built before 1965 is around 0.19 tonnes CO_2/yr. Multiplying this number by the estimated 11,068,800 houses with chimneys in England gives an approximate reduction in CO_2 emissions of over 2 million tonnes per year if Chimney Sheep were to be used in every dwelling with a chimney in England.

5. REFERENCES

1. Bolton, P.; Richards, P. Electricity, Energy, Energy conservation, Fuel poverty, Oil, Petrol and Natural Gas, July 2012, Available online: http://www.parliament.uk/briefing-papers/SN05115 (accessed on 20 July 2013).
2. Energy Saving Trust. Available online: http://www.energysavingtrust.org.uk/Insulation/Roof-and-loft-insulation (accessed on 20 July 2013).
3. Energy Saving Trust. Available online: http://www.energysavingtrust.org.uk/Insulation/Draught-proofing (accessed on 20 July 2013).
4. UWE Bristol, Faculty of Built Environment. Available online: https://environment7.uwe.ac.uk/resources/constructionsample/conweb/heating/chimneys/section3.htm (accessed on 20 July 2013).
5. English Housing Survey, Housing Stock Report 2008, published October 2010, Department for Communities and Local Government. ISBN 978-1-4098-2601-9. Page 1-Available online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6703/1750754.pdf (accessed on 20 July 2013).
6. English Housing Survey, Housing Stock Report 2008, published October 2010, Department for Communities and Local Government. ISBN 978-1-4098-2601-9. Page 69.Available online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6703/1750754.pdf (accessed on 20 July 2013).
7. Chimney Sheep. Available online: http://www.chimneysheep.co.uk/shop/category/1-draught-excluders (accessed on 20 July 2013).
8. Chimney Sheep. Available online: http://www.chimneysheep.co.uk/ (accessed on 20 July 2013).
9. Appendix S: Reduced Data SAP for existing dwellings. Available online: 9. Appendix S: Reduced Data SAP for existing dwellings. Available online: http://www.bre.co.uk/filelibrary/accreditation/scheme_standards/SAP_2009_9-91_Appendix_S_January_2012.pdf (accessed on 20 July 2013).
10. Plus Dane Group. Available online: http://www.plusgroupltd.org.uk/article.asp?id=389 (accessed on 20 July 2013).
11. DesignBuilder. Available online: http://www.designbuilder.co.uk/helpv2/Content/Comfort_Analysis.htm (accessed on 20 July 2013).