HISTORIC SCOTLAND

Conservation Group

Technical Paper 8

Energy modelling of the Garden Bothy, Dumfries House

Prepared for Historic Scotland by Changeworks & HEADS

CHANGEWORKS
RESOURCES FOR LIFE

Home Energy & Data Services Limited

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May 2010

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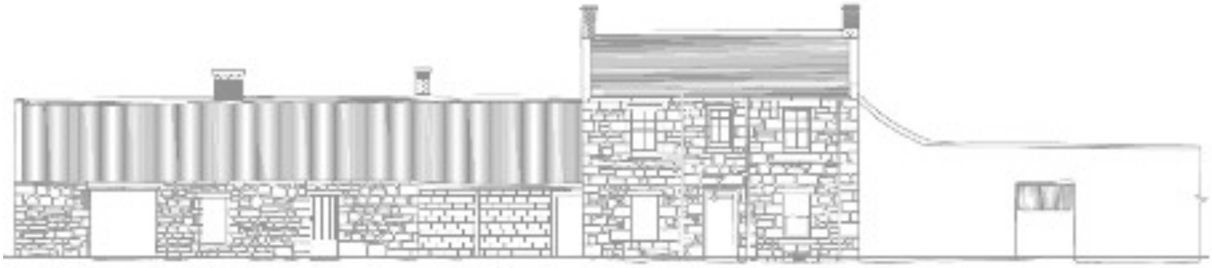

Energy modelling of the Garden Bothy, Dumfries House

Report for Historic Scotland by Changeworks & HEADS, May 2010

This report presents pre- and post-improvement energy performance data and analysis for the Dumfries House Garden Bothy, an unoccupied 19th-century stone building in Ayrshire. The baseline data was gathered from a site survey in January 2010, and calculated using a range of energy modelling software packages. Improvement measures and specifications were provided by Historic Scotland and measured subsequently.

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1 Executive summary

(This report presents pre- and post-improvement energy performance data and analysis for the Dumfries House Garden Bothy, an unoccupied 19th-century stone building in Ayrshire. The baseline data was gathered from a site survey in January 2010, and calculated using a range of energy modelling software packages. Improvement measures and specifications were provided by Historic Scotland and measured subsequently.)

All the software used in the modelling gave a predicted saving. However, all results varied widely among the different software programmes, and the CO_2 savings predicted by the proposed improvement measures ranged from 64% and 97% (with rdSAP and SAP giving the 'best' results). No lineal comparison between the tools is possible, as there is no consistent pattern between energy, CO_2 or cost before and after the specified improvements.

The wide range of results, and their lack of consistency, makes it hard to rely on any one of the software programmes in this report. It is not clear which programme provides the most accurate (i.e. close to reality) results. Furthermore, the sensitivity of any software model is limited considerably by the 'human element': on the one hand, the knowledge and experience of the software user, and on the other hand, the way in which the building's occupants behave and use energy. Behavioural change thus remains a significant issue.

Having a number of different software predictions, and knowing what assumptions lie behind these, allows for a more accurate and thorough understanding of a building's energy use, associated costs and emissions. The number of assumptions made by some of these software programmes can reduce their sensitivity significantly; as such it is important to understand the level of detail required by each software programme, and the level to which this can or cannot be tailored by the user.

The range of assumptions made by the different software models can build in inaccuracies. Assumptions relating to fuel cost, heating patterns, heating mix, occupancy patterns, U-values and so on vary between the models, and in some cases require regular updating to remain accurate.

The EPC is a very basic energy rating, and by comparison with other models does not provide a full picture particularly for older properties. However, it is currently the standard UK methodology for generating energy ratings when selling and letting properties, which makes it very important. The variation in ratings in this report could be significant were legislation put in place requiring improvements to properties falling into the lowest EPC bands before they can be sold or re-let. Similarly it could affect the property owner's eligibility, or otherwise, for grant assistance for energy efficiency improvements. Where the rating lies close to either end of an EPC band, any variation either way could cause the property to be rated F rather than E, for example. Such variations could also impact on the value of the property if energy-efficient properties become more desirable.

The initial improvement measures to be applied to the Bothy were not sufficient to bring the energy consumption down in line with new-build Building Standards, and as such the post-improvement predictions did not give particularly high ratings to the property. This situation will be exacerbated by the changes in the regulations due for implementation in October 2010, and the planned changes for 2013 and 2016, by which time new-build properties must be 'zero-carbon'.

Cost-effectiveness, value for money and replicability should be considered when planning improvement measures in demonstration projects. Given the number of traditional buildings in Scotland and the rest of the UK, it is important to find widely replicable improvement measures, which means they must be affordable. In addition, this report shows a major CO_2 saving following the improvement works, however this improvement comes from an extremely poor baseline: most inhabited properties are in better condition than the Bothy, and the better the baseline energy performance of a building, the harder it becomes to achieve an 80% CO_2 reduction. Again, this becomes important when assessing replicability.

It is clear that there is a pressing need to provide cost-effective and practical models for the physical improvement of traditional buildings. In order for traditionally constructed buildings such as the Garden Bothy to achieve high ratings for energy efficiency and environmental impact, it is likely that a significant investment will have to be made in terms of fabric upgrades and renewable energy installations. (It is important to note, however, that most energy efficiency rating tools do not take account of the broader environmental strengths – embodied energy, build quality, etc. – of many traditionally constructed buildings.) Improving and re-using buildings in this way will maximise the inherently sustainable qualities of traditional buildings and the existing investment in energy and materials that they embody.

Recommendations

- **It is recommended that the actual energy consumption, CO_2 emissions and running costs should be monitored once the Bothy is improved and occupied. This will allow the accuracy of the software predictions, and the gap between predicted and actual performance, to be fully assessed.**

- **More widely, considerable further *in-situ* monitoring would seem to be required to test the calibration of each of the programmes.**

2 Introduction

Changeworks Resources For Life and Home Energy And Data Services (HEADS) were commissioned by Historic Scotland to model the energy efficiency of the 19th-Century Garden Bothy at Dumfries House in Ayrshire, using a range of energy modelling software programmes. These models generated baseline (pre-improvement) predictions of the building's energy rating, energy consumption, CO_2 emissions and running costs.

A specification of physical improvement measures was subsequently provided by Historic Scotland's appointed design team. The energy efficiency of the building was then re-modelled using the same software programmes, to provide post-improvement energy efficiency predictions.

Running the building through a number of different energy modelling software programmes allowed these to be compared alongside one another, and assessed in terms of accuracy and data requirements. It also provided average predictions, and enabled the reasons for different predictions to be analysed. This would provide a robust base for making informed decisions on the improvement of the property and its actual energy performance.

This project builds on previous related research carried out by Changeworks on behalf of Historic Scotland. The findings of this research are contained in Historic Scotland's Technical Paper 3: Energy modelling analysis of a traditionally built Scottish tenement flat (Historic Scotland, 2008).

3 Property details

Fig. 1 West wall of the Garden Bothy, showing open aspect to north

The Garden Bothy is a two-storey stone-built cottage situated in the grounds of Dumfries House in Ayrshire, South-West Scotland. There are two rooms on the ground floor, and three rooms (including a small bathroom) on the upper floor. It is currently unoccupied, and in its present state (at April 2010) could be deemed derelict.

The cottage is in a very exposed rural location, and is therefore subject to considerable weather impacts (wind / rain / snow etc.). This is likely to affect the heating requirements for the property, which in turn will impact on its associated CO_2 emissions.

Its principal elevation faces North. With only two South-facing windows, and the East and West walls being shaded by the garden wall, the potential for passive solar heating is limited in its current form.

An unheated outbuilding is built onto the East wall, providing partial shelter to this elevation.

Fig. 2 Location of the Garden Bothy

The main building elements are as follows:

Windows

- Timber-framed, single-glazed, sash-and-case windows in the North- and South-facing walls (left)
- No windows in the East or West walls
- One small, iron-framed rooflight window (right)

Roof

- Slated

Walls

- Solid rubble (left)
- Internally they are lined with plasterboard in places
- Externally the rear (South-facing) elevation incorporates a brick garden wall (which dates from the 19th century) (right)

Floor

- Suspended timber floor in the main ground floor room
- Solid floor in the kitchen
- Suspended timber floors in the upper rooms

Heating

- Based on the existing hearth and chimney, it is assumed that the main heating fuel was house coal
- It is assumed that the post-improvement heating fuel will be biomass

4 Energy modelling background

Typical energy rating software datasets have varying degrees of detail on items such as property characteristics (built form, age of construction and location); dimensions (floor areas, floor room heights; window and door openings; exposed wall perimeters/areas; building fabric (wall, roof and floor construction, insulation, doors and windows); space and water heating (primary and secondary systems, and heating controls). Some programmes also include details of ventilation and fixed appliances.

For this research, data was collected and processed using a range of energy modelling software packages:

- Standard Assessment Procedure
- Reduced data SAP (which also generated an Energy Performance Certificate rating)
- National Home Energy Rating: Stock Assessor & Plan Assessor
- Simplified Building Energy Model
- Building Simulation Model

The following summarise the essential characteristics of each system. It is important to be aware of how the different systems work, in order to understand the results fully.

4.1 Standard Assessment Procedure (SAP)

SAP is the National Calculation Methodology for new dwellings in all parts of the UK. It is used to demonstrate the compliance of a new dwelling with Section 6 (Energy) of the Scottish Building Standards. The same methodology must be used to produce an Energy Performance Certificate (EPC) on completion of new dwellings and other property types. The current version (at April 2010) is SAP 2005.

Within SAP 2005 there are three separate but related calculations:

i. The SAP calculation: this predicts both energy consumption and CO_2 emissions per m^2; the latter is termed the Environmental Impact (EI) rating.

ii. The Target Energy Rating (TER) calculation: this also measures CO_2 emissions per m^2, but for a *notional dwelling*. This notional dwelling has the same floor area as the actual property being surveyed but uses default property specifications (U-values, glazing area, infiltration rates etc.) and service efficiencies, as defined in Section 6 of the Building Standards. As the name suggests, this calculation is used to set a target that a new dwelling has to meet in order to comply with Building Standards.

iii. The Design Energy Rating (DER) calculation: this is based on the actual property specifications, and differs slightly from the EI in that the calculations assume some defaults from Section 6. (For example, the DER assumes that 10% of space heating is from a secondary source and will default to electricity as the fuel source in the absence of a manual input, whereas the EI will reflect the actual fuel source. The TER, by comparison, always assumes 10% of secondary heating is electrical.)

The SAP work sheet has 12 sections:

1. Overall dimensions (this gives use assumptions and dwelling volume)
2. Ventilation and air infiltration rates

3. Heat loss through the building fabric, thermal bridges and air loss
4. Hot water demand (based on floor area and implied occupancy rates)
5. Incidental heat gains from the hot water system, appliances and lighting
6. Solar gains
7. Average temperature calculation in the absence of heating (this then defines the heat input needed)
8. An accounting for the contribution made by the heat gains in section 5 (but ignoring those which raise the temperature above 18 / 21ºC)
9. Total energy requirements (based on system efficiencies)
10. Multiplication of the above by the energy cost
11. SAP rating and band
12. EI rating and band

Like all assessment methodologies, SAP is constantly evolving and the forthcoming 2009 version of SAP will further refine the thermal bridging calculation, and take account of the impact of thermal mass in evening out air temperatures.

The algorithms in SAP are defined on behalf of the UK Government by the Building Research Establishment, and there are a number of different software providers, all of which have to be approved by the UK Government.

4.2 Reduced data SAP (RdSAP) and Energy Performance Certificates (EPCs)

RdSAP is the National Calculation Methodology for existing dwellings for all parts of the UK. It was developed in recognition of that fact that a SAP assessment is a desk-based exercise, undertaken with the benefit of a full understanding of the dwelling's geometry and the fabric and service attributes, which is not possible on a short inspection visit to a property.

RdSAP is the methodology used for surveying and issuing EPCs for existing domestic properties. As the name implies, it is a reduced dataset of a full SAP. It has been designed to cope with common generic housing types, but by definition it is more limited than SAP in terms of the actual numerical data that can be added. The data is not therefore as sensitive as a full SAP, and default U-values are used depending on age and location. Changeworks' survey form for RdSAP data collection is included at Appendix 4.

As the Bothy is not currently habitable RdSAP does not deem it to be a residential property, so no formal certification could be produced. The RdSAP data was therefore processed using two pieces of software that can be used off-line: ECMK EPC Reporter and NHER Stock Assessor. Theoretical EPCs were produced using EPC Reporter.

Like SAP, RdSAP programs are provided by a number of approved software suppliers.

4.3 National Home Energy Rating (NHER)

There are two stand-alone NHER software packages for domestic properties: Stock Assessor and Plan Assessor. (Both of these supersede earlier NHER models that were used in Changeworks' 2008 report for Historic Scotland, Energy modelling analysis of a traditionally built Scottish tenement flat.)

4.3.1 NHER Stock Assessor

Stock Assessor has two main functions as a tool for modelling energy ratings:

i. Stock analysis: in this function, the data requirements can range from a limited dataset, where no dimensional data is required, through to a full RdSAP dataset. This is generally used for assessing a social landlord's whole-stock compliance with the Scottish Housing Quality Standard[1] and as a fuel poverty indicator[2].

ii. EPCs: in this function, if the software user is a member of the NHER Protocol for conducting domestic EPC surveys, this would enable the RdSAP data to be used to generate an EPC.

Over and above the RdSAP dataset, Stock Assessor takes into account locality elements (i.e. geographical location, height above sea level, wind speed and site exposure) to provide an NHER rating.

4.3.2 NHER Plan Assessor

Plan Assessor is used primarily for new buildings, but can also be used for analysis of existing buildings. It uses a full SAP dataset, but has additional data requirements relating to the characteristics of the main living area, heating controls, lighting, cooking appliances and ventilation. Information can also be entered on the occupant's pattern of use of heating and appliances, which would affect the estimated running costs but not the energy ratings.

4.4 Simplified Building Energy Model (SBEM)

SBEM is the National Calculation Methodology for new non-domestic and existing non-domestic properties for the whole of the UK, and for generating Public Display Certificates for large public buildings in Scotland. Despite its mainly non-domestic applications, SBEM can include domestic dwellings as a building use. The current version (at April 2010) is SBEM v.3.5a.

SBEM has some parallels with SAP, but where SAP takes a holistic view of a dwelling over a whole year, SBEM takes a zoned view of buildings on a month-by-month basis. A building is defined as a set of zones, which are determined by the use of the particular zone, access to natural daylight and services. A single zone can contain more than one room, and a single room can contain more than one zone, although in the case of the Bothy they are coincident.

A key part of SBEM is the set of databases that define the activities in different spaces in different building classes[3]. One standard activity must be assigned to each space in the building.

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[1] The Scottish Housing Quality Standard (SHQS) defines what constitutes acceptable good quality social housing. The Standard must be met by 2015, and includes minimum standards for energy efficiency.

[2] A household is in fuel poverty if, in order to maintain a satisfactory heating regime, it would be required to spend more than 10% of its total income on fuel.

[3] The NCM databases can be downloaded from www.ncm.bre.co.uk

The database provides standard assumptions for occupancy, temperature set-points, outdoor air rates and heat gain profiles for each type of space in a building. This means that buildings with the same activity mix will differ only in terms of their geometry, construction, building services and weather location.

There are two ways of inputting information into SBEM, either through iSBEM (a free online tool) or through commercial applications. For this project a commercial system was used, Space Manager (v.2.59).

Space Manager is an object-orientated database developed in Scandinavia, where it is market dominant. Every historic building owned by the Swedish state has been modelled using this software, along with most universities and many major corporate, local government and health sector buildings. The particular benefit of Space Manager is that the database is graphically built, so once the external envelope is calibrated it is very accurate, and it is considerably simpler and quicker than numerical data entry.

The main outputs from SBEM are narrower than those from SAP:

- It does not predict fuel costs
- It only provides energy and CO_2 ratings per m^2, not for the whole building
- It produces an EI band but not a SAP rating
- The EI rating is not expressed as a number, merely by the position of an arrow on a chart

The chart numbering is fixed between 0 and 100**. It is important to note that 0 is the best rating and 100 the worst, unlike SAP where the higher the number the more efficient the building, and where the ratings can go into negative figures** (as is the case for the baseline results for the Bothy).

4.5 Building Simulation Model (BSM)

There are a number of competing Building Simulation Modelling tools available. Many of these have their origins in the ESP-r tool, which was developed by Strathclyde University to allow an in-depth appraisal of the factors that influence the energy and environmental performance of buildings. ESP-r is the tool used for this report.

ESP-r attempts to simulate the real world as rigorously as possible, and to a level that is consistent with current best practice. It allows the designer to explore the complex relationships between a building's form, fabric, air-flow, plant and control. Simple models and operating regimes can be extended incrementally to encompass the simultaneous solution of fabric (1/2/3D), air flow, electrical power, embedded renewable energy systems, plant system components, indoor air quality and lighting assessments. Building and flow simulations can be undertaken at frequencies of one minute to one hour, and system simulations can be from fractions of a second to an hour.

The output is an interactive analysis module. It can be used to provide many different views of simulation results, undertake a variety of performance appraisals, and explore the interactions between assessment domains. An Integrated Performance View can be created, which summarises performance over a range of relevant criteria. The range of analyses is essentially unrestricted, and data can be exported to other analysis and graph tools.

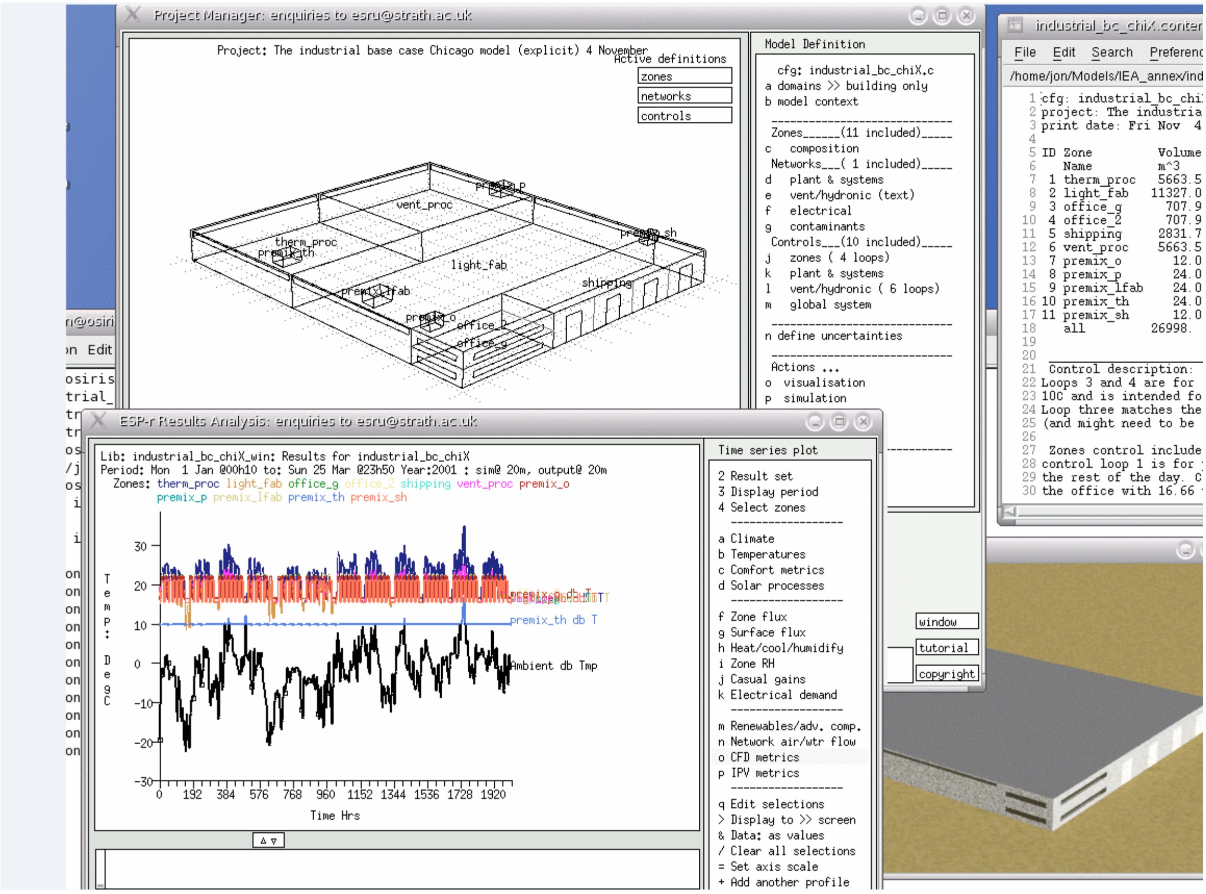


Fig. 3 A sample output page from ESP-r

In addition to state-of-the-art standard simulation features, ESP-r has powerful capability to simulate many innovative or leading technologies including daylight utilisation, natural ventilation, Combined Heat & Power generation, photovoltaic facades, multi-gridding (2D and 3D conduction) and control systems. However, its specialist features require detailed knowledge by the user, and the results may not be readily accessible without this knowledge. Although robust and increasingly used for consulting, ESP-r retains much of the look and feel of a research tool, and lacks the extensive databases associated with commercial tools.

5 Results

5.1 Baseline results (annual figures)

Software programme	kWh / m^2	Total kWh	CO_2 / m^2 (kg)	Total CO_2 (kg)	Fuel costs
NHER Plan Assessor	1,406	88,806	434	27,421	£4,337
NHER Stock Assessor	1,167	73,762	355	22,455	£2,743
NHER RdSAP only	1,068	67,501	268	16,962	£2,746
RdSAP	989	62,485	247	15,605	£1,887
SAP	1,879	118,698	491	31,306	£2,197
SBEM	1,002	69,138	328	22,625	n/a
BSM	1,194	82,386	353	24,347	n/a
Averages	1,244	80,397	354	22,960	£2,782

Baseline building data		
Building element	**U-value**	**Size (m^2)**
External walls (ground floor)	1.25	59.35
External walls (first floor)	1.15	64.30
Roof	2.30	31.59
Shaft to rooflight	2.30	2.12
Suspended floor	3.60	11.70 (perimeter 9.9m)
Solid floor	3.60	19.89 (perimeter 14.1m)
Openings:		
Windows (North)	5.50	6.20
Windows (South)	5.50	2.70
Door (North)	2.75	1.89
Rooflight (adjusted as per BR442)	5.90	0.54
Ground to ceiling		2,700 mm
Ground ceiling to 1st-floor ceiling		2,925 mm
Services information	**Description**	**Performance**
Heating main source:	Open fires (coal)	32%
Controls	None	
Heat emitters	None	
Heating secondary source:	Electric fires	100%
Controls	None	
Heat emitters	None	
Water heating:	Main system (coal)	32%
Controls	None	
Storage	84l (trad. 100l tank)	
Insulation	25mm loose jacket	
Pipework	Uninsulated	
Cylinder thermostat	None	
Air infiltration		
Chimneys	2	
Flues	0	
Fans	0	
Air Change Rate	2.75 / hour	

5.2 Post-improvement results (annual figures)

Software programme	kWh / m²	Total kWh	CO_2 / m² (kg)	Total CO_2 (kg)	Fuel costs
NHER Plan Assessor	309	24,639	33	2,106	£1,118
NHER Stock Assessor	545	34,456	36	2,262	£1,374
NHER RdSAP only	460	29,065	16	994	£1,375
RdSAP	429	27,107	17	1,074	£873
SAP	398	25,117	15	963	£519
SBEM	477	32,913	118	8,135	n/a
BSM	n/a	n/a	n/a	n/a	n/a
Averages	436	28,883	39	2,589	£1,052

Post-improvement building data		
Building element	**U-value**	**Size (m²)**
External walls (area weighted)	0.86	123.65
Roof	0.16	31.59
Shaft to rooflight	0.16	2.12
Suspended floor	0.20	11.70 (perimeter 9.9m)
Solid floor	0.32	19.89 (perimeter 14.1m)
Openings:		
Windows (North)	1.80	6.20
Windows (South)	1.80	2.70
Door (North)	1.85	1.89
Rooflight (adjusted as per BR442)	1.75	0.54
Ground to ceiling		2,700 mm
Ground ceiling to 1st-floor ceiling		2,925 mm
Services information	**Description**	**Performance**
Heating main source:	Log boiler	60%
Controls	Programmer + TRVs	
Heat emitters	Radiators	
Heating secondary source:	Log burning stove	65%
Controls	None	
Heat emitters	None	
Water heating:	Main system	
Controls	Programmer + TRVs	60%
Storage	140l	
Insulation	50mm factory-applied	
Pipework	Insulated	
Cylinder thermostat	Yes	
Air infiltration		
Chimneys	0	
Flues	1	
Fans	MVHR (Vent Axia HR250)	
SFP	3	
Efficiency	70%	
Air Change Rate	0.66 / hour	

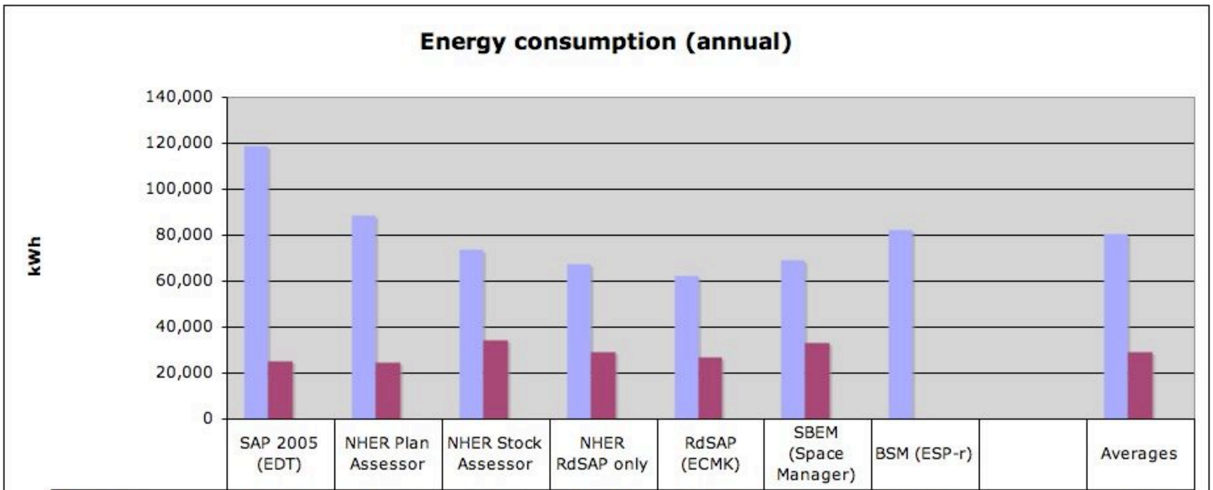
5.3 Energy Performance Certificate results

	Baseline	Post-improvement
EPC band	G	E

6 Analysis by area

As the tables in section 5 show, there is a broad spread of results, both pre- and post-improvement. This is not unexpected, as the different software programmes require varying levels of detail and make differing assumptions. This makes reliance on any one software programme less robust, as in some instances the difference between the highest and lowest predictions is considerable. This section examine these variations in more detail.

6.1 Energy consumption



	SAP 2005 (EDT)	NHER Plan Assessor	NHER Stock Assessor	NHER RdSAP only	RdSAP (ECMK)	SBEM (Space Manager)	BSM (ESP-r)		Averages
Baseline	118,698	88,806	73,762	67,501	62,485	69,138	82,386		80,397
Post-improvement	25,117	24,639	34,456	29,065	27,107	32,913			28,883
Improvement	79%	72%	53%	57%	57%	52%			62%

The chart above shows a wide spread of predictions, with the highest (SAP 2005) predicting nearly twice as much pre-improvement energy consumption as the lowest (RdSAP). The average annual predicted energy consumption of the Bothy in its current state is 80,397 kWh. This is many times higher than the national average for a property of a similar age and build. However this is a relatively meaningless measurement as the property is derelict and has not benefited from the installation of a relatively modern heating and hot water system. Post-improvement, the energy consumption drops to an average of 28,883 kWh. Despite this 62% improvement, this remains rather high. This is mainly due to the fact that the post-improvement U-values, while very much better than currently, still fall short of Building Standards requirements for a new-build property.

Pre-improvement energy use **Post-improvement energy use**

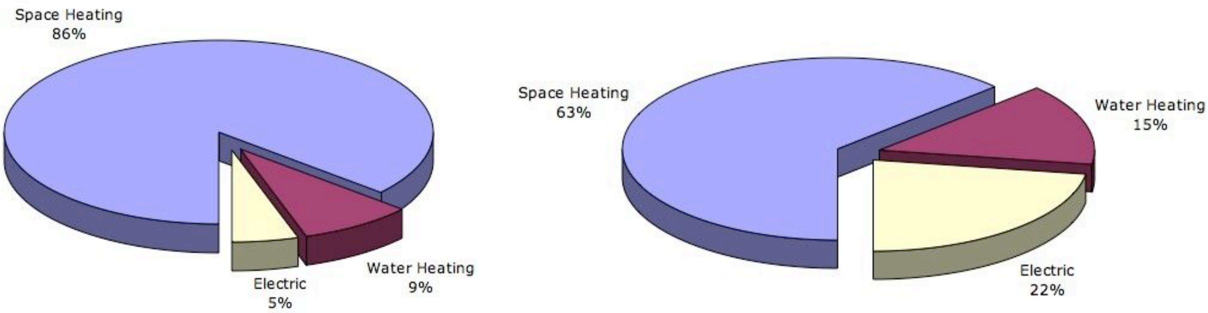
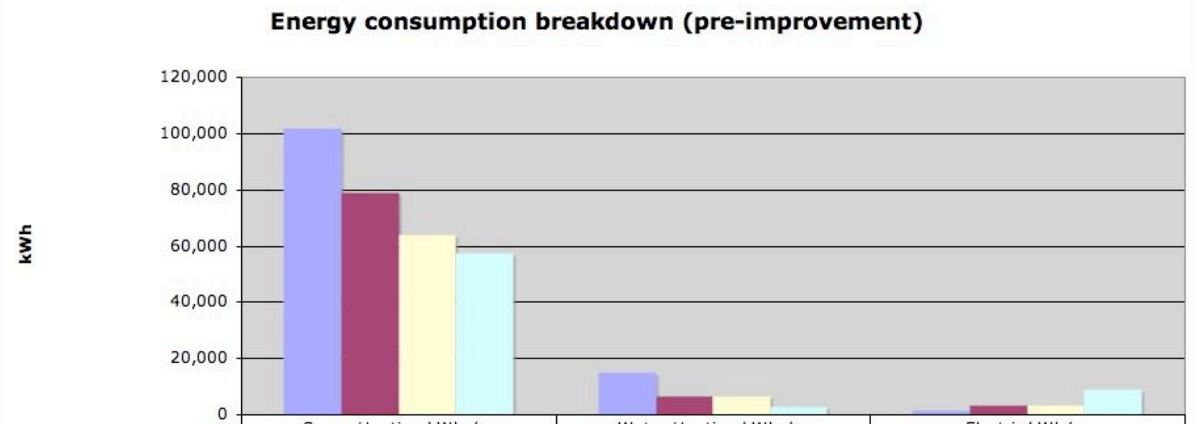


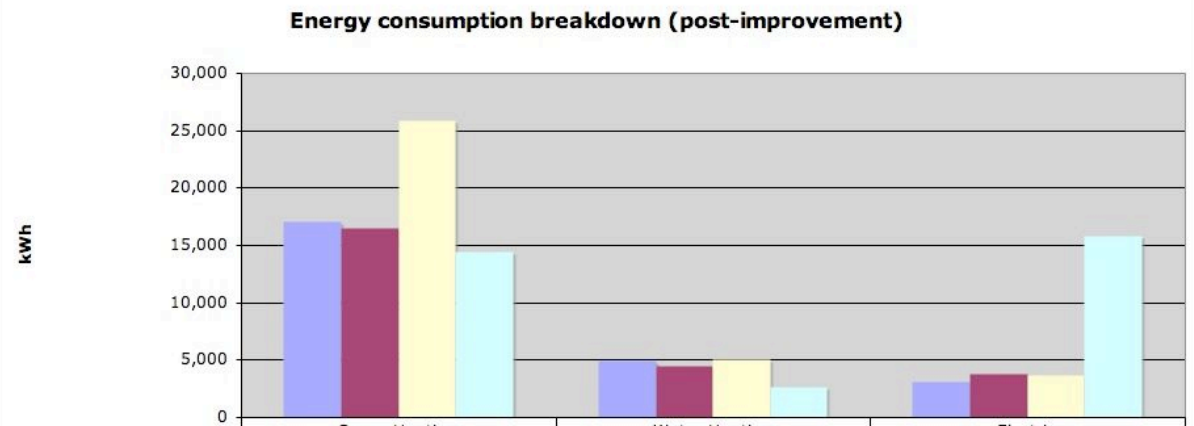
Fig. 4 Breakdown of energy use pre- and post-improvement (average predictions)

These pie charts represent an average of the software predictions (excluding RdSAP and BSM). These show that space heating accounts for a smaller proportion of energy use post-improvement (due to improved insulation and airtightness). The higher proportion of energy use subsequently allocated to water heating and in particular electricity could strengthen the case for on-site electricity generation, which otherwise would carry a significant carbon load.

The SAP-based software programmes were consistent when measuring water heating and lighting energy use, but less so when assessing space heating, as the tables below show. SAP 2005 predicted the highest pre-improvement energy use for space heating (102,013 kWh), but post-improvement it also predicted the greatest reduction. NHER Stock Assessor predicted the lowest figure pre-improvement (63,903 kWh) but also the smallest reduction. SBEM predicted a significantly higher electricity load post-improvement. The reasons for these variations are covered in section 7.

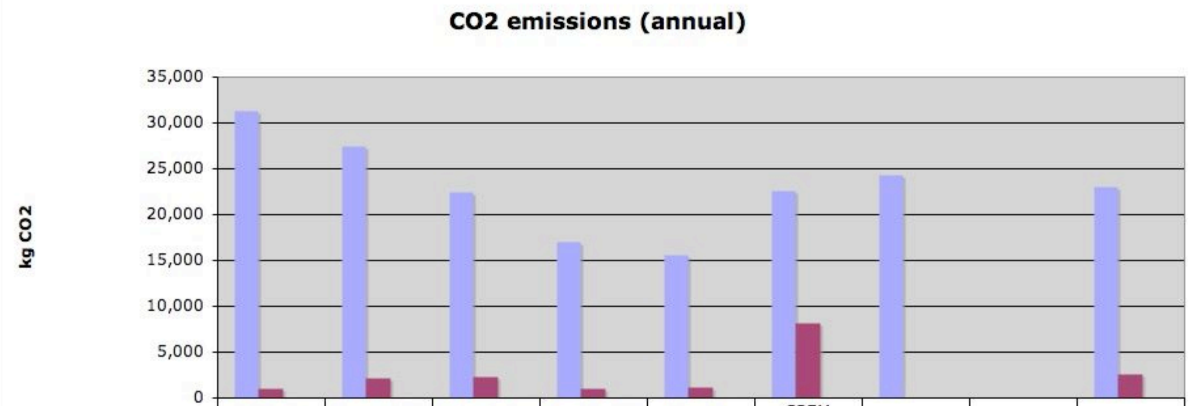


	Space Heating kWhr/yr	Water Heating kWhr/yr	Electric kWh/yr
SAP 2005	102,013	15,098	1,589
NHER Plan Assessor	78,945	6,583	3,278
NHER Stock Assessor	63,903	6,582	3,277
SBEM	57,385	2,766	8,988



	Space Heating	Water Heating	Electric
SAP 2005	17,085	4,966	3,066
NHER Plan Assessor	16,445	4,417	3,750
NHER Stock Assessor	25,828	5,000	3,628
SBEM	14,482	2,633	15,798

6.2 CO_2 emissions



	SAP 2005 (EDT)	NHER Plan Assessor	NHER Stock Assessor	NHER RdSAP only	RdSAP (ECMK)	SBEM (Space Manager)	BSM (ESP-r)		Averages
Baseline	31,306	27,421	22,455	16,962	15,605	22,625	24,347		22,960
Post-improvement	963	2,106	2,262	994	1,074	8,135			2,589
Improvement	97%	92%	90%	94%	93%	64%			88%

Again, there is a wide spread of results. SAP is again the highest, predicting emissions nearly double those indicated by RdSAP, which was again the lowest. The predicted average annual CO_2 emissions are almost 23 tonnes for the property as a whole. Post-improvement, this drops dramatically to an average of 1.48 tonnes (**excluding the SBEM prediction**, as explained below). This drop is far greater than the drop in energy consumption, and can be attributed to replacing coal with biomass as the primary fuel.

While SAP predicts the highest baseline emissions (31,306 $kgCO_2$), it also predicts the greatest reduction (97%) and lowest emissions (963 $kgCO_2$) post-improvement.

The SBEM prediction for post-improvement emissions (8,135 $kgCO_2$) is extremely high in comparison with all other modelling programmes. The reason for this is almost certainly that SBEM assumes a greater use of electricity (mainly for the proposed heat recovery ventilation system) than the other programmes. This is covered in more detail in section 7.4, but the result is that it skews the post-improvement average (an 88% improvement at 2,589 $kgCO_2$); removing SBEM from the equation would change this substantially, giving a 93% improvement to 1,480 $kgCO_2$.

Removing SBEM from the equation may give a more accurate average for the majority of programmes. However the question does arise as to which programme paints a more accurate picture of *actual* CO_2 emissions. If SBEM is recognising electricity usage that the other programmes do not, then it could be argued that its predictions are the more accurate.

On-site electricity generation should be considered in order to lower the CO_2 emissions further.

6.3 Running costs

	SAP 2005 (EDT)	NHER Plan Assessor	NHER Stock Assessor	NHER RdSAP only	RdSAP (ECMK)	SBEM (Space Manager)	BSM (ESP-r)		Averages
Baseline	2,197	4,337	2,743	2,746	1,887				2,782
Post-improvement	519	1,118	1,374	1,375	873				1,052
Improvement	76%	74%	50%	50%	54%				61%

The pre-improvement fuel costs predicted by SAP and RdSAP are reasonably consistent (compared with the energy consumption and CO_2 emissions predictions), however the NHER figures show a far greater variance, with NHER Plan Assessor in particular giving a cost prediction over twice as great as the lowest (RdSAP). The post-improvement predictions are also subject to wide variations. It is not viable to rely on the average figures for these running costs, as explained below.

The main reason for this broad range of cost predictions is the fuel cost assumptions made by the different software models. The NHER programmes use fuel costs from the Sutherland Tables[4], which are regularly updated to reflect the frequent change in fuel prices. At present, NHER rates the per-kWh cost at 3.56p for coal, and 13.59p for electricity. However, SAP assumes a per-kWh cost of 1.91p for coal, and 7.2p for electricity. These figures are considerably lower than current fuel costs (by a factor of around 2), and therefore the fuel cost predictions made by SAP and RdSAP are unreliable.

SAP and NHER Plan Assessor reflect similar levels of fuel cost reduction post-improvement, at around 75%; NHER Stock Assessor and RdSAP also reflect similar reductions to one another, but these are lower, at around 50%.

Neither SBEM nor BSM makes fuel cost predictions.

[4] The Sutherland tables represent average fuel prices for Scotland, and are regularly updated

6.4 Energy efficiency ratings

SAP		
	Pre-improvement	Post-improvement
SAP 2005	-28	44
NHER Plan Assessor	1	46
Notes:	The pre-improvement SAP rating is considerably lower when modelled using SAP 2005. The post-improvement SAP rating is very similar with both programmes.	

RdSAP		
	Pre-improvement	Post-improvement
RdSAP (ECMK)	2	40
NHER Stock Assessor	1	37
NHER RdSAP only	1	37
Notes:	All predictions are similar. However, the slightly higher post-improvement prediction generated by the ECMK programme would raise the property into a higher SAP band, which would be reflected in any EPC. This is covered in more detail in section 7.2.	

SAP band		
	Pre-improvement	Post-improvement
SAP 2005	G	E
NHER Plan Assessor	G	E
RdSAP (ECMK)	G	E
NHER Stock Assessor	G	F
NHER RdSAP only	G	F
Notes:	All programmes rated the property at G pre-improvement. However, the post-improvement predictions range from E to F. The potential impacts of this variation are covered in more detail in section 7.2.	

NHER		
	Pre-improvement	Post-improvement
NHER Plan Assessor	0	4.4
NHER Stock Assessor	0	2.8
NHER RdSAP only	0	2.8
Notes:	All programmes rated the property at 0 pre-improvement; this is the lowest rating possible. However, Plan Assessor gave a significantly higher post-improvement rating than the other programmes.	

None of the post-improvement energy ratings is particularly high. Indeed, all fall well below that would normally be regarded as a 'good' energy efficiency rating. As mentioned previously, this is mainly due to the shortfall in post-improvement U-values compared with current Building Standards requirements. Section 8 covers the further improvements that would be needed in order for the Bothy to meet these Standards.

Theoretical EPC certificates are included at Appendix 2 and Appendix 3.

7 Analysis by software programme

These sections provide more detail on the potential reasons for variance in the results between individual software programmes.

7.1 SAP results

SAP 2005 is designed to allow a direct comparison between dwellings, and as such it makes certain assumptions that cannot be varied. For example, it assumes that living rooms are heated to 21ºC and all other rooms (including circulation space) are heated to 18ºC. In addition, the floor area of the heated space dictates the predictions for hot water demand, lighting requirements and the amount of heat contributed by appliances. As such, SAP 2005 is only an *indicator* of the energy consumption and CO_2 emissions of a dwelling, occupied in one specific way.

(NHER Plan Assessor allows heating patterns to be varied. The standard pattern is 9 hours per day on weekdays rising to 16 hours per day at weekends, with the same temperatures as above. It also has a reduced pattern of 5 hours per day every day, an extended pattern of 16 hours per day every day, and a similar extended pattern for sheltered accommodation but with higher temperatures. The number of occupants can also be altered.)

Each approved SAP assessor should in theory produce the same results (based on the same inputs), although this study showed that this is not the case. Two different assessors input the same information, and produced 2 different sets of SAP results. It is clear that the SAP result is also dependent on the user's experience and understanding of the software. This can make the results more or less accurate. It is also important to note that in this instance, both assessors went somewhat beyond the standard methodology, adjusting some of the otherwise standard inputs (based on their knowledge of the actual building properties and software functions) to generate as accurate a picture as possible.

It is anticipated that SAP 2009 will provide more accurate results for traditional buildings, by virtue of its recognition of the impacts of thermal mass in regulating temperature.

7.2 RdSAP results

The default U-values in RdSAP cannot be altered. This limited the extent to which the survey could be tailored to account for the traditional-build aspects of the Bothy, and means that the survey is based on assumed U-values, that may differ from the actual U-values of the property. The table below shows some of these assumed U-values.

Building element	RdSAP default U-value	
	Pre-improvement	Post-improvement
Wall	1.5	0.6
Roof	2.3	0.16
Floor	1.2	0.5
Window	4.8	2.0
Rooflight	5.1	2.2

Looking at the U-values in section 5 (taken from a combination of architect models and on-site monitoring of traditional properties), it is clear to see that these differ from the U-values assumed by RdSAP.

(Looking ahead to post-improvement energy modelling, this lack of flexibility means that, should the Bothy exceed current Building Standards once it has been improved, RdSAP will not be able to recognise this, as the default U-values cannot be changed.)

As there were two different types of exposed floor (suspended timber in the living room, and solid in the hall and kitchen), the suspended timber living room was treated as the main property and the solid floor as an extension. A test run had revealed that RdSAP treats both floors differently, rating the solid floor as more efficient.

For a typical RdSAP survey the windows are not normally measured, unless they are 'much less or much more than typical' of the building period. The Bothy falls into the 'Before 1919' category, for which there is not a definite window-to-wall area ratio. The windows were therefore measured as an enhancement to the RdSAP restrictions.

As the RdSAP data was processed using two software applications (NHER Stock Assessor and ECMK EPC Reporter), both sets of RdSAP results can be compared. It had been assumed that as both applications use the same dataset and calculations, the results would be very similar, if not identical. However, this was not the case, as the following table illustrates.

RdSAP rating	ECMK EPC Reporter generated a baseline rating of 2, while the NHER Stock Assessor rating was 1. Post-improvement, ECMK EPC Reporter generated a rating of 40, while the NHER Stock Assessor rating was 37. These differences may seem insignificant, but the higher post-improvement rating of ECMK EPC Reporter places the property in a higher EPC band (E rather than F), which could impact on its marketability, grant eligibility for energy efficiency improvements, and potential future legislative requirements[5]
Energy consumption	ECMK EPC Reporter estimates 7% lower energy consumption than NHER Stock Assessor, both at baseline and post-improvement
CO_2 emissions	ECMK EPC Reporter estimates 8% lower CO_2 emissions than NHER Stock Assessor, both at baseline and post-improvement

(No comparison can be made on running costs, as NHER EPC accreditation would be needed to obtain further EPC results.)

7.3 NHER results

As the property was modelled using two different pieces of NHER software (Stock Assessor which used a reduced dataset, and Plan Assessor which used a more detailed dataset), both sets of results can be compared.

[5] In the future, owners of properties falling into the lowest EPC bands may be required to make energy efficiency improvements to the building before it can be sold or re-let

Unlike Stock Assessor (which incorporates RdSAP), Plan Assessor allows building fabric characteristics to be altered, and there are no fixed U-Values. This allows for a more accurate rating of a property.

With both Plan Assessor and Stock Assessor, the figures for energy usage, CO_2 emissions and annual running costs include all appliance use in addition to heating, hot water and lighting (SAP and RdSAP do not include appliance use).

There are differences in the estimated energy rating, energy consumption, CO_2 emissions and the running costs, as follows.

NHER rating	Both sets of results confirmed that the baseline NHER result was the poorest possible (0.0) and that the baseline SAP / RdSAP rating was 1. However, the post-improvement ratings show a considerable variance: 4.2 with Plan Assessor, compared with 2.8 for Stock Assessor. This variance is not surprising, however, due to the U-value limitations of Stock Assessor
Energy consumption	Stock Assessor estimates 17% lower baseline energy consumption than Plan Assessor. However, post-improvement this situation is reversed, with Plan Assessor estimating 29% lower energy consumption than Stock Assessor. Comparing the results pre- and post-improvements, Plan Assessor predicts a 72% reduction, while Stock Assessor predicts a 53% reduction
CO_2 emissions	Stock Assessor estimates 18% lower baseline CO_2 emissions than Plan Assessor. Post-improvement this situation is reversed (as with the energy consumption predictions), and Plan Assessor estimates 7% lower CO_2 emissions than Stock Assessor. It is significant to note that these figures do not correspond with the energy consumption. Comparing the results pre- and post-improvements, Plan Assessor and Stock Assessor both predict similar reductions in CO_2 emissions (92% and 90% respectively)
Fuel cost	Stock Assessor estimates 37% lower baseline fuel costs compared to Plan Assessor. Post-improvement the situation is again reversed, and Plan Assessor estimates 19% lower running costs compared to Stock Assessor. Comparing the results pre- and post-improvements, Plan Assessor predicts a 74% reduction, while Stock Assessor predicts a 50% reduction (these predictions are in line with those for energy consumption)

These results raise questions in relation to the accuracy of these models, as it would be expected that predictions of energy consumption and CO_2 emissions would correspond with one another.

Both Plan Assessor and Stock Assessor use up-to-date fuel costs, derived from the (October 2009) Sutherland Tables.

7.4 SBEM results

There are five key areas where SBEM differs from SAP:

i. Thermal mass: SAP 2005 does not take thermal mass into account when assessing a building, so it is unable to factor in the smoothing-out effect that this has on the impact of changes in external air temperature and the responsiveness of heating / cooling systems.

ii. Thermal bridging: the way in which thermal bridging can be included in iSBEM assessments could lead to inaccuracies, if different zones are combined rather than measured individually (as commonly happens when using iSBEM).

iii. Hot water use: SBEM and SAP use different calculations for hot water use, which will generate different predictions.

iv. Cooling: Unlike SAP, SBEM calculates the impact of over-heating and a cooling load, although this is not included in the overall energy and CO_2 figures if (as in the case of the Bothy) no cooling system is present.

v. Ventilation: SAP and SBEM treat different types of ventilation system differently. SAP ignores intermittent extract fans and attributes a lower energy requirement to a whole house compared to SBEM (see below for more details).

SBEM also deals with heating systems in a very different way to SAP. While SAP assumes that the primary and secondary heating systems are always 90% and 10% (respectively) of the total heating load, SBEM can allocate a different heat source to each zone so the heating split can be very different. In the case of the unimproved Bothy, the entire upper floor has electric heating: SBEM would therefore recognise electricity as accounting for c.50% of the heating load, but SAP's default secondary heating assumptions would only allocate it as 10% of the heating load.

(In a deliberate exercise to assess the impact of the above, the baseline SBEM model was re-run to mimic SAP's 90%-10% split, with coal accounting for 90% and electricity 10%. This increased the predicted overall energy consumption from 1,002 to 1,310 $kWh/m^2/yr$ (nearly 25%), and CO_2 emissions from 22.6 to 27.4 tonnes per year (nearly 20%). These figures can be seen in the table at Appendix 1.)

The SBEM calculation of the initial improvements proposed for the Bothy has a much higher CO_2 prediction than the SAP-based assessments. This is almost certainly due to the way in which SBEM treats mechanical ventilation systems. The initial Bothy improvements include the installation of a Vent-Axia HR250 whole-house ventilation system, which operates continuously, extracting air from the kitchen and bathroom and providing positive ventilation air into the circulation areas (having recovered the heat from the extracted air). The SBEM technical manual confirms the difficulty of attributing energy for fans, pumps, and controls to the different end-uses (heating, cooling, and ventilation). As a result, SBEM has calculated that this system would account for 44% of the Bothy's post-improvement energy load, at around 12,000 kWhr/yr; as this load is electric, it therefore has high associated CO_2 emissions. SAP, by contract, predicts an energy load of only 638kWh/yr for this system. Neither software programme allows such systems to be tailored beyond a certain point. It is therefore unclear whether either calculation can be said to be accurate in this instance.

SBEM assumed a greater use of electricity post-improvement (for reasons explained above), meaning that the predicted CO_2 emissions were higher than those of the other software programmes.

The EPC generated by SBEM is based on CO_2 emissions only, and is also non-domestic. It cannot therefore be compared meaningfully with the other EPCs.

7.5 BSM results

The calculation methodology behind a BSM model differs radically from the various assessment tools as described above, in that each component in a buildings fabric can be accurately modelled in terms of thermal transmissivity, hygroscopicity and density. This means it cannot readily be compared directly with the other modelling tools in this report.

Heating systems are placed within the building and the heating regime (times and temperatures) set. A series of calculations is then undertaken on a variable time frame (generally every 10-60 minutes) over a full year, to determine the internal air and surface temperatures relative to external conditions.

This provides a massive amount of data, identifying cold or hot spots within the building as well as providing the information needed to determine a comfort index (the average of air and surface temperatures). This comfort index recognises, for example, that a relatively cool room with a radiant heat source (such as a log burning stove) can be very comfortable.

A detailed comfort analysis is beyond the remit of this report. However, in order to provide a meaningful comparison to the other software models, the heating regime was assumed to match SAP, and the BSM results were distilled down to show an overall heat demand for Bothy a) unimproved, and b) post-improvement (with additional improvements identified to achieve compliance with Building Standards; see section 8).

The table below shows the results of the BSM modelling alongside those of the other software programmes, for space heating only.

Software programme	**Space heating, unimproved (kWh/yr)**	**Space heating, improved to comply with current Building Standards (kWh/yr)**
SAP 2005	102,013	10,411
NHER Stock Assessor	63,903	Not re-modelled
NHER Plan Assessor	78,945	Not re-modelled
SBEM	57,385	8,141
BSM	82,386	14,214
Averages	76,926	10,922

These results show that the BSM system is closest to NHER Plan Assessor in its modelling of the unimproved Bothy. When modelling the improvements needed to meet current Building Standards, the BSM results for the Bothy’s space heating demand are significantly higher than either SAP or SBEM predictions.

Again, until the Bothy has been improved, occupied and monitored it is not possible to determine which model is the most accurate. However, the BSM system is considerably more detailed than the other programmes included in this report, which could point to a greater likelihood of increased accuracy.

7.6 Other issues affecting accuracy

- The software programmes used in this exercise assume an efficiency of 60% for a biomass boiler system, and in the absence of a detailed specification this default figure was used in the calculation of the initial improvements. However, significantly more efficient biomass boilers exist, and these would result in significantly reduced predictions for energy consumption, CO_2 emissions and fuel costs. In subsequent calculations (see section 8) a 92% efficient boiler was identified and modelled.

- The assumptions regarding U-values, fuel type, fuel costs, occupancy patterns and heating patterns have already been mentioned. The importance of recognising these assumptions cannot be overstated, however, in particular the occupancy and heating patterns. The way the occupants behave and use energy can have a dramatic effect on energy consumption, CO_2 emissions and fuel costs: an occupant with a highly efficient behaviour pattern could feasibly use less energy living in the un-improved Bothy than an occupant with a highly extravagant behaviour pattern living in the improved Bothy.

- There is an assumption that comfort levels are dictated by actual air temperatures. However, heat is transmitted in a number of ways (radiation, convection and conduction), meaning that comfort can often be achieved in a relatively cool room by being situated close to a heat source (e.g. a wood-burning stove, or a sunny window).

- The energy saving realised by energy efficiency improvements is often only around half that predicted; this is known as the Rebound Effect or Reduction Factor[6], and there are a number of contributory factors. These include a ‘comfort take’ – where occupants may heat the property to higher temperatures than previously – and the inherent inaccuracies in most savings predictions, as demonstrated by this report. This reduction factor makes it even more important to monitor the actual energy use in the Bothy once the improvements have been implemented and it is occupied. Monitoring will allow the actual energy consumption to be compared with that predicted by the various software programmes, and can have the added benefit of raising the occupants’ awareness which in turn can lead to lower energy use. (The use of a biomass system can further enhance this; see section 9.1.3 for more details).

[6] A significant amount of research has been carried out in this area, however a relevant starting point can be found in *Review of differences between measured and theoretical energy savings for insulation measures* (Glasgow Caledonian University, 2006)

8 Achieving compliance with Building Standards

On completion of the initial results and analysis, it became apparent that the planned suite of improvements to the Bothy was not sufficient to comply with the new-build energy requirements of the current Building Standards.

Historic Scotland was keen to be able to use this study to demonstrate compliance, as well as to assess how accurately each programme performs (the final conclusions regarding the latter aim cannot be fully determined until the improvements to the Bothy are complete and have been measured on site). The calculations were therefore re-examined to identify further improvements that would allow the Bothy to achieve compliance. The following changes were identified:

- Wall insulation: An additional 25mm of insulating board (Calistherm) was modelled. The U-values were recalculated, taking as a starting point the on-site wall U-value measurement.

- Heating: A biomass (log) boiler rated at 92% efficiency was identified (rather than the default assumption of 60% efficiency made by many of the software programmes).

- Electricity: The whole-house MVHR ventilation system was removed, in favour of intermittent extract fans (which can reduce the predicted electricity load considerably in many of the software programmes).

Using SAP 2005, the above improvements added onto the existing suite of proposed improvements would enable the Bothy to comply with current Building Standards.

However, these improvements would not be sufficient for the Bothy to comply with the new Building Regulations that come into effect on 1 October 2010. Additional improvements would be needed to meet these new standards: a solar water heating system, for example (with panels fitted to the South-facing roof), would enable the Bothy to meet these new standards under SAP.

9 Conclusions

The wide range of results, and their lack of consistency, makes it difficult to rely on the outputs of any one software programme in isolation. It is not clear which programme provides the most accurate (i.e. close to reality) results. The accuracy of any software model is limited considerably by the ‘human element’: on the one hand, the knowledge and experience of the software user, and on the other hand, the way in which occupants behave and use energy.

Having a number of different software predictions, and knowing what assumptions lie behind those predictions, allows for a more accurate and thorough understanding of a building’s energy use and its associated costs and emissions. The number of assumptions made by some of these software programmes can reduce their accuracy significantly.

Energy Performance Certificates are a relative but blunt indicator of energy use. They do not provide a full picture, particularly for older properties which heat and cool in different ways to modern buildings. However, they currently act as the UK-wide baseline for energy rating when selling and letting properties, which makes them a very important tool.

The improvement measures to be applied to the Bothy are not sufficient to bring the energy consumption down in line with new-build Building Standards, and as such the post-improvement predictions do not give particularly high ratings to the property. (There are however no regulatory requirements for any improvements to be made to any building that remains unaltered and in its original use.)

This raises a question in terms of cost-effectiveness, value for money and replicability of the proposed improvements. Given the number of traditional buildings in Scotland and the rest of the UK, it becomes important to find widely replicable improvement measures, which are affordable (and in many cases there may be a limit in terms of acceptable disruption).

The current, unimproved state of the Bothy means that it is relatively easy to achieve an 80% CO_2 saving, as its baseline performance was so poor. However, most traditional properties have been significantly altered over the years with modern heating systems, loft insulation and replacement glazing giving a much better baseline, making it all the harder to achieve an 80% CO_2 reduction. Again, this becomes important when assessing replicability.

It is clear that there is a pressing need to provide cost-effective and practical models for the physical improvement of traditional buildings. In order for traditionally constructed buildings such as the Garden Bothy to achieve high ratings for energy efficiency and environmental impact, it is likely that a significant investment will have to be made in terms of fabric upgrades and renewable energy installations. (It is important to note, however, that most energy efficiency rating tools do not take account of the broader environmental strengths – embodied energy, build quality, etc. – of many traditionally constructed buildings.) Improving and re-using buildings in this way will maximise the inherently sustainable qualities of traditional buildings and the existing investment in energy and materials that they embody.

Detailed monitoring of the Bothy’s energy consumption is strongly recommended, to allow an accurate picture to be built up and to assess which of the software predictions proved most accurate. More widely, considerable further *in-situ* monitoring would seem to be required to test the calibration of each of the programmes.

9.1 CO_2 reduction options

A suite of improvement measures has been proposed for the Bothy. This short section provides additional brief comments for consideration in the property's upgrading.

9.1.1 Glazing

When considering improvements to single-glazed windows in traditional buildings, draughtproofing is often advocated over additional glazing. Both have their place, however it is important to be aware of the impact of single glazing both in terms of heat loss and air movement. Single glazing has a very poor U-value (around 5.5[7]), and recent research has shown that around three-quarters of the heat lost through a single-glazed window is lost through the glass[8] (although clearly this proportion will vary depending on the fit of the window into the frame). When warm air hits a large area of very cold glazing, it will cool and drop; this causes air movement that could be misinterpreted as a draught (see diagram below). For this reason it is important to consider additional glazing layers as well as draughtproofing.

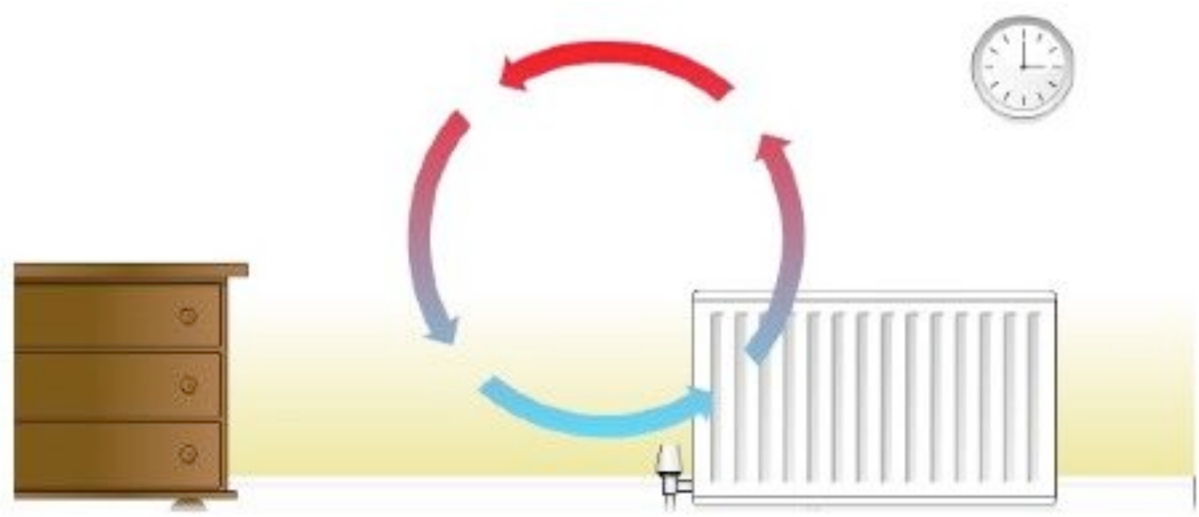


Fig. 5 A convection current[9]

9.1.2 Electricity and CO_2 emissions

While lighting and appliances, including cooking, typically account for 17% of an average home's energy consumption[10], they account for nearly a third of its CO_2 emissions[11] since they mainly run off electricity which has very high associated emissions. As such, they provide a good opportunity to cut emissions, particularly where items need replacing in any case. Low-energy lighting (e.g. LEDs or CFLs) and efficient appliances could make a considerable difference to the Bothy's electricity use.

9.1.3 Energy generation

[7] Energy Heritage: A guide to improving energy efficiency in traditional and historic homes (Changeworks, 2008)
[8] Technical Paper 1: Thermal performance of traditional windows (Historic Scotland, 2008)
[9] www.bbc.co.uk
[10] Sources: ECUK 2007 & MTP
[11] *Ibid*

The relatively high costs associated with installing most renewable energy systems would be offset to varying degrees by lower running costs, grant assistance for installations, and recently-introduced financial incentives. The Feed-In Tariff, introduced in April 2010, pays renewable electricity generators for the clean energy they produce; a similar system, the Renewable Heat Incentive, will be introduced for renewable heat generators in April 2011.

The following is a brief summary of the clean energy options for the Bothy (detailed technical guidance can be found in Renewable Heritage: A guide to microgeneration in traditional and historic homes (Changeworks, 2009)). More information can also be found in the *Dumfries House Estate: Renewable Energy Options Appraisal* (Sgurr Energy, 2010).

Biomass would seem to be a strong contender for heating the Bothy. Its rural location should negate any concerns over particulate emissions; there are plentiful local wood supplies and there may be potential for the estate woodland to be used as fuel; the cottage was constructed with fireplaces and chimneys that could house stoves and flues, while the outbuildings could house a larger boiler system and fuel store. In addition, the hands-on approach needed for a biomass system is likely to help raise awareness of energy use and behaviour: regular loading up of a biomass boiler or stove highlights how quickly fuel is being used and how much fuel is left (in contrast with a modern electric system, for example, where the fuel source is invisible and supply is dictated by flicking a switch). This awareness is likely to reduce the Rebound Effect referred to previously (see section 6.4).

The South-facing roof, unobtrusively facing onto fields and woods (and assuming no overshadowing from trees), presents a suitable site for **solar** panels, for either water heating or electricity generation. Solar water heating is considerably cheaper than photovoltaics (PV), and if there is sufficient hot water demand they could present a good opportunity. However, as the fossil fuel options for this off-gas property have high associated emissions, there is a potentially greater CO_2 saving to be made from generating renewable electricity via PV.

The heat source options for a **heat pump** are air, ground and water. There is a small water source nearby (Back Burn) although a site assessment would be necessary to determine whether it is suitable for a water source heat pump; the surrounding land would allow a borehole or trench system to be installed for a ground source heat pump; an air source heat pump could also be introduced, and would cost less, although this would have more of an impact in terms of visibility and noise. However, the insulation and airtightness of the Bothy would have to be considerably improved for any heat pump to function efficiently. Behavioural issues would also need to be addressed to ensure efficient performance (e.g. not opening windows or doors too often, not turning the system off and on frequently, etc.). The installation of a heat pump would strengthen the case for introducing other renewable energy systems (PV, wind or hydro) to generate the electricity needed to run the heat pump.

The Bothy's location is rural and relatively exposed, so there may be potential for a mast-mounted **wind** turbine. However, a more detailed site assessment would be necessary to identify suitable sites for a turbine and any potential physical barriers (trees, buildings, hills, etc.) to wind flow over the site, and ideally a 12-month on-site wind speed monitoring period.

The only water source in the area is a small stream, which appears to run through relatively flat land. A low-head **hydro** turbine may be a viable option, however this would depend on the head and flow of the stream, which may be insufficient. Again a detailed site assessment would be necessary.

Appendix 1
Full results spreadsheets

Dumfries House Garden Bothy - Energy modelling results **Base Data as agreed with Historic Scotland 16.03.10**

	kWh / m² / year	kWh / year	CO_2 / m² / year (kg)	CO_2 / year (kg)	Annual running costs	SAP	RdSAP	SAP band	E I	E I band	NHER	DER / BER	TER	Space Heating kWhr/yr	Water Heating kWhr/yr	Lighting + Pumps kWhr/yr	Price Coal (Heating and Water) per kWhr	Price Electricity (Secondry heating) per kWhr	Price Electricity (lights and pumps) per kWhr
NHER Stock Assessor	1,167	73,762	355.42	22,455	£2,743	N/A	1	G	1	G	0.0	N/A	N/A	87% 63,903	9% 6,582	4% 3,277	3.56	13.49	13.49
NHER rdSAP only *	1,068	67,501	268.47	16,962	£2,746	N/A	1	G	1	G	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RdSAP (ECMK)	989	62,485	247.00	15,605	£1,887	N/A	2	G	1	G	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SAP 2005	1,879	118,698	491.23	31,306	£2,197	-28	N/A	G	-33	G	N/A	495.15	40.35	86% 102,013	13% 15,098	1% 1,589	1.91	7.21	7.21
NHER Plan Assessor	1,406	88,806	434.02	27,421	£4,337	1	N/A	G	1	G	0.0	N/A	N/A	89% 78,945	7% 6,583	4% 3,278	3.56	13.49	13.49
																	Equipment	Auxilary	
SBEM (re-run to mimic SAP)	1,310	90,390	397.70	27,441	N/A	N/A	N/A	N/A	N/A	G	N/A	397.70	28.90	87% 78,639	3% 2,712	8% 7,231	2% 1,808	0% 0	
SBEM (Space Manager)	1,002	69,138	327.90	22,625	N/A	N/A	N/A	N/A	N/A	G	N/A	327.90	28.90	83% 57,385	4% 2,766	10% 6,914	3% 2,074	0% 0	
BSM (ESP-r) **	1,194	82,386	352.86	24,347	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	82,386	N/A	N/A	N/A	N/A	

* The previous table records the NHER results that use a different methodology. RdSAP only estimates for heating, hot water and lighting, The energy use, emissions and running costs estimated for Stock Assessor will therefore be less.

79,874 Average Space Heating Requirement

** The ESP-r tool out puts a total heat demand (410 w/m2). The figure above takes this demand and multiplies it by 90% x 32% (efficiency of coal fires) + 10% x 100%. (electrical efficiency). The same logic is used for the carbon footprints.

Building Data	U-values	Size m2	Perimeter
External Walls (Ground)	1.25	59.35	
External Walls (First Floor)	1.15	64.30	
Roof	2.30	31.59	
Shaft to Rooflight	2.30	2.12	
Suspended Floor	3.60	11.70	9.9m
Solid Floor	3.60	19.89	14.1m
Openings:			
Windows North	5.50	6.20	
Windows South	5.50	2.70	
Door North	2.75	1.89	
Rooflight, Adjusted as per BR442	5.90	0.54	
Ground to Ceiling		2700mm	
Grd Ceiling to 1st Floor Ceiling		2925mm	

Services Information	Discription	Performance	
Heating Main Source:	Open Fires	32%	Coal
Controls	None		
Heat Emitters	None		
Heating Secondary Source	Electrical Fires	100%	
Controls	None		
Heat Emitters	None		
Water Heating	Main System	32%	Coal
Controls	None		
Storage	84lites (trad 110 litre tank)		
Insulation	25 mm loose jacket		
Pipework	Uninsulated		
Cylinder Stat	None		

Air Infiltration	
Chimneys	2
Flues	0
Fans	0
Air Change Rate	2.75/hr

The NHER Plan Assessor and Stock Assessor both default to 50% for water heating efficiency with a back boiler

Total Area of External Envelope 200.29 **1.98** Average U Value

Regulation Compliance Back Stop Values	U-values	Size m2	Perimeter
External Walls	0.20	119.19	
Roof	0.16	31.59	
Shaft to Rooflight	0.16	2.12	
Floor	0.22	31.59	
Openings (25% of floor area)	1.50	15.80	
Total Area of External Envelope		200.29	
Average U Value		0.30	

Services Information	Discription	Performance	
Heating Main Source:	Open Fires	65%	Anthracite
Controls	Programmer + room Stats + TRVs		
Heat Emitters	None		
Heating Secondary Source	Electrical Fires	100%	
Controls	Manual		
Heat Emitters	Convector / radiant		
Water Heating	Dual Emmersion + 4m2 solar panels		
Controls	None		
Storage	150 litres		
Insulation	50 mm loose jacket		
Pipework	Insulated		
Cylinder Stat	Yes		

Air Infiltration	
Chimneys	0
Flues	1
Fans	3 or 4 depending on floor area
Air Inlitration Rate	10m3/hr/m2

These values are used to set the TER in SAP 2005

Dumfries House Garden Bothy - Energy modelling results **Improvement Data as advised 23.03.10**

	kWh / m^2 / year	kWh / year	CO_2 / m^2 / year (kg)	CO_2 / year (kg)	Annual running costs	SAP	RdSAP	SAP band	E I	E I band	NHER	DER / BER	TER	Space Heating kWhr/yr	Water Heating kWhr/yr	Lighting + Pumps kWhr/yr	Price Coal (Heating and Water) per kWhr	Price Electricity (Secondry heating) per kWhr	Price Electricity (lights and pumps) per kWhr
NHER Stock Assessor	545	34,456	35.80	2,262	£1,374	N/A	37	F	88	B	2.8	N/A	N/A	75% 25,828	15% 5,000	11% 3,628	3.56	13.49	13.49
NHER rdSAP only *	460	29,065	15.74	994	£1,375	N/A	37	F	88	B	2.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
RdSAP (ECMK)	429	27,107	17.00	1,074	£873	N/A	40	E	87	B	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SAP 2005	398	25,117	15.25	963	£519	44	N/A	E	88	B	N/A	16.35	10.78	68% 17,085	20% 4,966	12% 3,066	2.20	7.21	7.21
NHER Plan Assessor	309	24,639	33.34	2,106	£1,118	46	N/A	E	88	B	4.4	N/A	N/A	67% 16,445	18% 4,417	15% 3,750	2.95	13.49	13.49
																	Equipment	Auxilary	
SBEM (Space Manager)	477	32,913	117.90	8,135	N/A	N/A	N/A	N/A	N/A	G	N/A	117.90	41.70	44% 14,482	8% 2,633	3% 987	6% 1,975	39% 12,836	

* The previous table records the NHER results that use a different methodology. RdSAP only estimates for heating, hot water and lighting, The energy use, emissions and running costs estimated for Stock Assessor will therefore be less.

18,460 Average Space Heating Requirement

Building Data	U-values	Size m2	Perimeter	Services Information	Discription	Performance		Air Infiltration	
External Walls (Area Weighted)	0.86	123.65		Heating Main Source:	Log Boiler	60%	Logs	Chimneys	0
				Controls	Programmer, TRV's			Flues	1
Roof	0.16	31.59		Heat Emitters	Radiators			Fans	MVHR Vent Axia HR 250
Shaft to Rooflight	0.16	2.12						SFP	3
Suspended Floor	0.20	11.70	9.9m	Heating Secondary Source	Log Burning Stove	65%	Logs	Efficiency	70%
Solid Floor	0.32	19.89	14.1m	Controls	None			Air Change Rate	0.66/hr
Openings:				Heat Emitters	None				
Windows North	1.80	6.20							
Windows South	1.80	2.70		Water Heating	Main System	60%	Logs		
Door North	1.85	1.89		Controls	Programmer, TRV's				
Rooflight, Adjusted as per BR442	1.75	0.54		Storage	140 Litre				
Ground to Ceiling		2700mm		Insulation	50 mm factory applied				
Grd Ceiling to 1st Floor Ceiling		2925mm		Pipework	Insulated				
				Cylinder Stat	Yes				

Total Area of External Envelope	200.29		**0.70**	Average U Value

Percentage Improvements	Before kW/yr/M2	After kW/yr/M2	Improve-ment		Before CO2/yr/m2	After CO2/yr/m2	Improve-ment
NHER Stock Assessor	1,167	545	53.30%		355.42	35.80	89.93%
NHER rdSAP only *	1,068	460	56.94%		268.47	15.74	94.14%
RdSAP (ECMK)	989	429	56.62%		247.00	17.00	93.12%
EDT - SAP 2005	1,879	398	78.82%		491.23	15.25	96.90%
NHER Plan Assessor	1,406	309	78.02%		434.02	33.34	92.32%
Space Manager (SAP Inputs)	1,310	477	63.59%		397.70	117.90	70.35%
Space Manager (True SBEM)	1,002	477	52.40%		327.90	117.90	64.04%
ESP-r BSM (Heating Only)	N/A	N/A	N/A		N/A	N/A	N/A
Average	1,260	442	64.91%		360.25	50.42	86.00%

Dumfries House Garden Bothy - Energy modelling results **Compliant Improvements as agreed with HS 11.05.2010**

	kWh / m² / year	kWh / year	CO_2 / m² / year (kg)	CO_2 / year (kg)	Annual running costs	SAP	RdSAP	SAP band	E I	E I band	NHER	DER / BER	TER	Space Heating kWhr/yr	Water Heating kWhr/yr	Lighting + Pumps kWhr/yr	Price Coal (Heating and Water) per kWhr	Price Electricity (Secondry heating) per kWhr	Price Electricity (lights and pumps) per kWhr
SAP 2005	237	14,961	7.75	490	£396	57	N/A	D	94	A	N/A	8.84	10.78	70% 10,411	23% 3,410	8% 1,171	2.20	7.21	7.21
																	Equipment	Auxilary	
SBEM (Space Manager)	207	14,283	28.70	1,980	N/A	N/A	N/A	N/A	N/A	B	N/A	28.70	26.30	57% 8,141	18% 2,571	7% 1,000	12% 1,714	7% 1,000	
BSM (ESP-r) **	206	14,214	5.15	355	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	14,214	N/A	N/A	N/A	N/A	

* The previous table records the NHER results that use a different methodology. RdSAP only estimates for heating, hot water and lighting, The energy use, emissions and running costs estimated for Stock Assessor will therefore be less.

8,209 Average Space Heating Requirement

** The ESP-r tool out puts a total heat demand (182 w/m2). The figure above takes this demand and multiplies it by 90% x 92% (efficiency of log burning boiler) + 10% x 65%. (wood burn stove default efficiency). The same logic is used for the carbon footprints.

Building Data	U-values	Size m2	Perimeter	Services Information	Discription	Performance		Air Infiltration	
External Walls (Area Weighted)	0.78	123.65		Heating Main Source:	Log Boiler	92%	Logs	Chimneys	0
				Controls	Programmer, TRV's			Flues	1
Roof	0.16	31.59		Heat Emitters	Radiators			Fans	2 intermitten extract fans
Shaft to Rooflight	0.16	2.12						SFP	Default
Suspended Floor	0.20	11.70	9.9m	Heating Secondary Source	Log Burning Stove	65%	Logs	Efficiency	Default
Solid Floor	0.32	19.89	14.1m	Controls	None			Air Change Rate	n/a
Openings:				Heat Emitters	None				
Windows North	1.80	6.20							
Windows South	1.80	2.70		Water Heating	Main System	92%	Logs		
Door North	1.85	1.89		Controls	Programmer, TRV's				
Rooflight, Adjusted as per BR442	1.75	0.54		Storage	140 Litre				
Ground to Ceiling		2700mm		Insulation	50 mm factory applied				
Grd Ceiling to 1st Floor Ceiling		2925mm		Pipework	Insulated				
				Cylinder Stat	Yes				

Total Area of External Envelope	200.29	0.65	Average U Value

Percentage Improvements	Before	After	Improve-ment	Before	After	Improve-ment
	kW/yr/M2	kW/yr/M2		CO2/yr/m2	CO2/yr/m2	
EDT - SAP 2005	1,879	237	87.39%	491.23	7.75	98.42%
Space Manager (SAP Inputs)	1,310	207	84.20%	397.70	28.70	92.78%
Space Manager (True SBEM)	1,002	207	79.34%	327.90	28.70	91.25%
ESP-r BSM (Heating Only)	1,194	206	82.75%	352.86	5.15	98.54%
Average	1,346	214	84.09%	392.42	17.58	95.52%

Appendix 2
Baseline EPC

(This EPC is hypothetical only)

Energy Performance Certificate

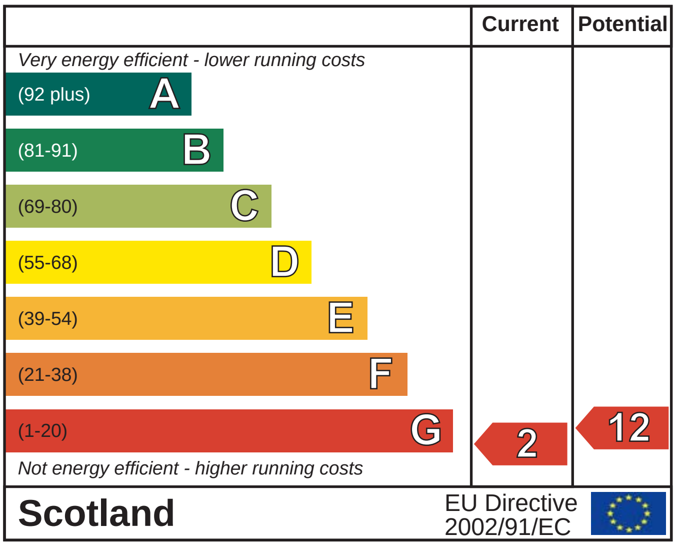
Address of dwelling and other details

Garden Bothy	Dwelling type:	Detached house
Dumfries House	Name of approved organisation:	Ecmk Ltd
Cumnock	Membership number:	
KA18 2NJ	Date of certficate:	01 March 2010
	Reference Number:	0000-0000-0000-0000-0000
	Total floor area:	63 m^2
	Main type of heating and fuel:	Room heaters, coal

This dwelling's performance ratings

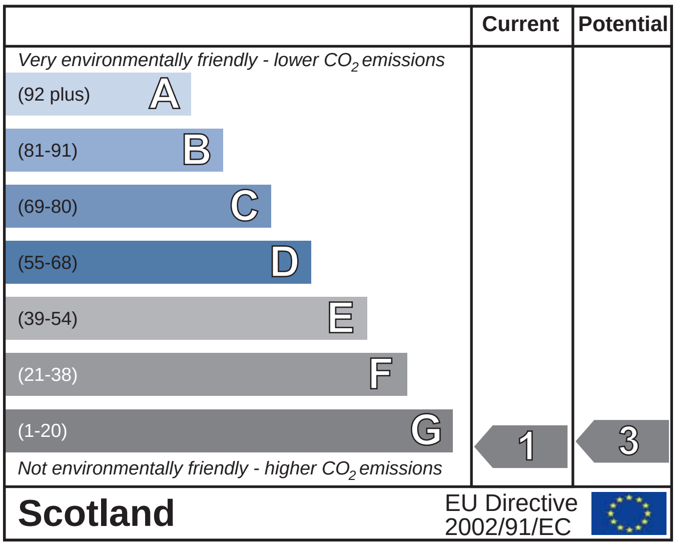
This dwelling has been assessed using the RdSAP 2005 methodology. Its performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (CO_2) emissions. CO_2 is a greenhouse gas that contributes to climate change.

Energy Efficiency Rating



The energy efficiency rating is a measure of the overall efficiency of a home. The higher the rating the more energy efficient the home is and the lower the fuel bills are likely to be.

Environment Impact (CO_2) Rating



The environmental impact rating is a measure of a home's impact on the environment in terms of carbon dioxide (CO_2) emissions. The higher the rating the less impact it has on the environment.

Approximate current energy use per square metre of floor area: 989 kWh/m^2 per year

Approximate current CO_2 emissions: 247 kg/m^2 per year

Cost effective improvements

Below is a list of lower cost measures that will raise the energy performance of the dwelling to the potential indicated in the tables above.

1. Increase loft insulation to 270 mm
2. Increase hot water cylinder insulation
3. Low energy lighting for all fixed outlets

A full energy report is appended to this certificate

Information from this EPC may be given to Energy Saving Trust to provide advice to householders on financial help available to improve home energy efficiency.

For advice on how to take action and to find out about offers available to help make your home more energy efficient, call **0800 512 012** or visit **www.energysavingtrust.org.uk/myhome**

N.B. THIS CERTIFICATE MUST BE AFFIXED TO THE DWELLING AND NOT BE REMOVED UNLESS IT IS REPLACED WITH AN UPDATED VERSION

Energy report

The Energy Performance Certificate and Energy Report for this dwelling were produced following an energy assessment undertaken by a member of Ecmk Ltd. This is an organisation which has been approved by the Scottish Ministers. The certificate has been produced under the Building (Scotland) Amendment Regulations 2006 and a copy of the certificate and this energy report have been lodged on a national register.

Assessor's name:
Company name/trading name:
Address:

Phone number:
Fax number:
E-mail address:
Related party disclosure: I am not related to the buyer nor seller

Estimated energy use, carbon dioxide (CO_2) emissions and fuel costs of this home

	Current	Potential
Energy use	989 kWh/m^2 per year	814 kWh/m^2 per year
Carbon dioxide emissions	16 tonnes per year	13 tonnes per year
Lighting	£67 per year	£33 per year
Heating	£1492 per year	£1273 per year
Hot water	£328 per year	£236 per year

Based on standardised assumptions about occupancy, heating patterns and geographical location, the above table provides an indication of how much it will cost to provide lighting, heating and hot water to this home. The fuel costs only take into account the cost of fuel and not any associated service, maintenance or safety inspection. This certificate has been provided for comparative purposes only and enables one home to be compared with another. Always check the date the certificate was issued, because fuel prices can increase over time and energy savings recommendations will evolve.

About the building's performance ratings

The ratings on the certificate provide a measure of the building's overall energy efficiency and its environmental impact, calculated in accordance with a national methodology that takes into account factors such as insulation, heating and hot water systems, ventilation and fuels used.

Not all buildings are used in the same way, so energy ratings use 'standard occupancy' assumptions which may be different from the specific way you use your home.

Buildings that are more energy efficient use less energy, save money and help protect the environment. A building with a rating of 100 would cost almost nothing to heat and light and would cause almost no carbon emissions. The potential ratings in the certificate describe how close this building could get to 100 if all the cost effective recommended improvements were implemented.

About the impact of buildings on the environment

One of the biggest contributors to global warming is carbon dioxide. The way we use energy in buildings causes emissions of carbon. The energy we use for heating, lighting and power in homes produces over a quarter of the UK's carbon dioxide emissions and other buildings produce a further one-sixth.

The average household causes about 6 tonnes of carbon dioxide every year. Adopting the recommendations in this report can reduce emissions and protect the environment. You could reduce emissions even more by switching to renewable energy sources. In addition there are many simple everyday measures that will save money, improve comfort and reduce the impact on the environment. Some examples are given at the end of this report.

Summary of this home's energy performance related features

The following is an assessment of the key individual elements that have an impact on this home's performance rating. Each element is assessed against the following scale: Very poor / Poor / Average / Good / Very good.

Element	Description	Current performance	
		Energy Efficiency	Environmental
Walls	Sandstone, as built, no insulation (assumed)	Poor	Poor
Roof	Pitched, no insulation	Very poor	Very poor
Floor	Suspended, no insulation (assumed)	-	-
Windows	Single glazed	Very poor	Very poor
Main heating	Room heaters, coal	Poor	Very poor
Main heating controls	No thermostatic control of room temperature	Poor	Poor
Secondary heating	Room heaters, electric	-	-
Hot water	From main system, no cylinderstat	Very poor	Very poor
Lighting	No low energy lighting	Very poor	Very poor
Current Energy efficiency rating		G 2	
Current environmental impact (CO_2) rating			G 1

Low and zero carbon energy sources

These are sources of energy (producing or providing electricity or hot water) which emit little or no carbon dioxide into the atmosphere.There are none applicable to this home.

Recommended measures to improve this home's energy performance

The measures below are cost effective. The performance ratings after improvement listed below are cumulative, that is they assume the improvements have been installed in the order that they appear in the table. However you should check the conditions in any covenants, warranties or sale contracts, and whether any legal permissions are required such as a building warrant, planning consent or listed building restrictions.

Lower cost measures (up to £500)	Typical savings per year	Performance ratings after improvement	
		Energy Efficiency	Environmental
1 Increase loft insulation to 270 mm	£269	G 9	G 2
2 Increase hot water cylinder insulation	£57	G 11	G 3
3 Low energy lighting for all fixed outlets	£19	G 12	G 3
Total	£345		
Potential Energy efficiency rating		G 12	
Potential environmental impact (CO_2)rating			G 3

Further measures to achieve even higher standards

The further measures listed below should be considered in addition to those already specified if aiming for the highest possible standards for this home. Some of these measures may be cost-effective when other building work is being carried out such as an alteration, extension or repair. Also they may become cost-effective in the future depending on changes in technology costs and fuel prices. However you should check the conditions in any covenants, warranties or sale contracts, and whether any legal permissions are required such as a building warrant, planning consent or listed building restrictions.

4 Solar water heating	£70	G 14	G 4
5 Replace single glazed windows with low-E double glazing	£89	G 17	G 7
6 50 mm internal or external wall insulation	£441	F 36	F 23
7 Solar photovoltaic panels, 2.5 kWp	£172	E 46	F 28
8 Wind turbine	£50	E 50	F 30
Enhanced Energy efficiency rating		E 50	
Enhanced environmental impact (CO_2)rating			F 30

Improvements to the energy efficiency and environmental impact ratings will usually be in step with each other. However, they can sometimes diverge because reduced energy costs are not always accompanied by a reduction in carbon dioxide (CO_2) emissions.

About the cost effective measures to improve this home's performance ratings

If you are a tenant, before undertaking any work you should check the terms of your lease and obtain approval from your landlord if the lease either requires it, or makes no express provision for such work.

Lower cost measures (typically up to £500 each)

These measures are relatively inexpensive to install and are worth tackling first. Some of them may be installed as DIY projects. DIY is not always straightforward, and sometimes there are health and safety risks, so take advice before carrying out DIY improvements.

1 Loft insulation

Loft insulation laid in the loft space or between roof rafters to a depth of at least 270 mm will significantly reduce heat loss through the roof; this will improve levels of comfort, reduce energy use and lower fuel bills. Insulation should not be placed below any cold water storage tank, any such tank should also be insulated on its sides and top, and there should be boarding on battens over the insulation to provide safe access between the loft hatch and the cold water tank. The insulation can be installed by professional contractors but also by a capable DIY enthusiast. Loose granules may be used instead of insulation quilt; this form of loft insulation can be blown into place and can be useful where access is difficult. The loft space must have adequate ventilation to prevent dampness; seek advice about this if unsure. Further information about loft insulation and details of local contractors can be obtained from the National Insulation Association (www.nationalinsulationassociation.org.uk). It should be noted that building standards may apply to this work.

2 Hot water cylinder insulation

Increasing the thickness of existing insulation around the hot water cylinder will help to maintain the water at the required temperature; this will reduce the amount of energy used and lower fuel bills. An additional cylinder jacket or other suitable insulation layer can be used. The insulation should be fitted over any thermostat clamped to the cylinder. Hot water pipes from the hot water cylinder should also be insulated, using pre-formed pipe insulation of up to 50 mm thickness, or to suit the space available, for as far as they can be accessed to reduce losses in summer. All these materials can be purchased from DIY stores and installed by a competent DIY enthusiast.

3 Low energy lighting

Replacement of traditional light bulbs with energy saving recommended ones will reduce lighting costs over the lifetime of the bulb, and they last up to 12 times longer than ordinary light bulbs. Also consider selecting low energy light fittings when redecorating; contact the Lighting Association for your nearest stockist of Domestic Energy Efficient Lighting Scheme fittings.

About the further measures to achieve even higher standards

Further measures that could deliver even higher standards for this home. You should check the conditions in any covenants, planning conditions, warranties or sale contracts before undertaking any of these measures.If you are a tenant, before undertaking any work you should check the terms of your lease and obtain approval from your landlord if the lease either requires it, or makes no express provision for such work.

4 Solar water heating

A solar water heating panel, usually fixed to the roof, uses the sun to pre-heat the hot water supply. This will significantly reduce the demand on the heating system to provide hot water and hence save fuel and money. The Solar Trade Association has up-to-date information on local installers and any grant that may be available or call 0800 512 012 (Energy Saving Trust). Building regulations may apply to this work.

5 Double glazing

Double glazing is the term given to a system where two panes of glass are made up into a sealed unit. Replacing existing single-glazed windows with double glazing will improve comfort in the home by reducing draughts and cold spots near windows. Double-glazed windows may also reduce noise, improve security and combat problems with condensation. Building standards may apply to this work, so it is best to obtain advice from your local authority building standards department.

6 Internal or external wall insulation

Solid wall insulation involves adding a layer of insulation to either the inside or the outside surface of the external walls, which reduces heat loss and lowers fuel bills. As it is more expensive than cavity wall insulation it is only recommended for walls without a cavity, or where for technical reasons a cavity cannot be filled. Internal insulation, known as dry-lining, is where a layer of insulation is fixed to the inside surface of external walls; this type of insulation is best applied when rooms require redecorating and can be installed by a competent DIY enthusiast. External solid wall insulation is the application of an insulant and a weather-protective finish to the outside of the wall. This may improve the look of the home, particularly where existing brickwork or rendering is poor, and will provide long-lasting weather protection. Further information can be obtained from the National Insulation Association (www.nationalinsulationassociation.org.uk). It should be noted that planning permission might be required and that building standards may apply to this work.

7 Solar photovoltaic (PV) panels

A solar PV system is one which converts light directly into electricity via panels placed on the roof with no waste and no emissions. This electricity is used throughout the home in the same way as the electricity purchased from an energy supplier. The British Photovoltaic Association has up-to-date information on local installers who are qualified electricians and on any grant that may be available, or call 0800 512 012 (Energy Saving Trust). Planning restrictions may apply in certain neighbourhoods and you should check this with the local authority. Building regulations may apply to this work, so it is best to obtain advice from your local authority building standards department and from a suitably qualified electrician.

8 Wind turbine

A wind turbine provides electricity from wind energy. This electricity is used throughout the home in the same way as the electricity purchased from an energy supplier. The British Wind Energy Association has up-to-date information on suppliers of small-scale wind systems and any grant that may be available, or call 0800 512 012 (Energy Saving Trust). Wind turbines are not suitable for all properties. The system's effectiveness depends on local wind speeds and the presence of nearby obstructions, and a site survey should be undertaken by an accredited installer. Planning restrictions and/or building regulations may apply and you should check this with the local authority.

What can I do today?

Actions that will save money and reduce the impact of your home on the environment include:

- Ensure that you understand the dwelling and how its energy systems are intended to work so as to obtain the maximum benefit in terms of reducing energy use and CO_2 emissions.
- If you have a conservatory or sunroom, avoid heating it in order to use it in cold weather and close doors between the conservatory and dwelling.
- Check that your heating system thermostat is not set too high (in a home, 21°C in the living room is suggested) and use the timer to ensure you only heat the building when necessary.
- Make sure your hot water is not too hot - a cylinder thermostat need not normally be higher than 60°C.
- Turn off lights when not needed and do not leave appliances on standby. Remember not to leave chargers (e.g. for mobile phones) turned on when you are not using them.
- Close your curtains at night to reduce heat escaping through the windows.
- If you’re not filling up the washing machine, tumble dryer or dishwasher, use the half-load or economy programme. Minimise the use of tumble dryers and dry clothes outdoors where possible.

Appendix 3
Post-improvement EPC

(This EPC is hypothetical only)

Energy Performance Certificate

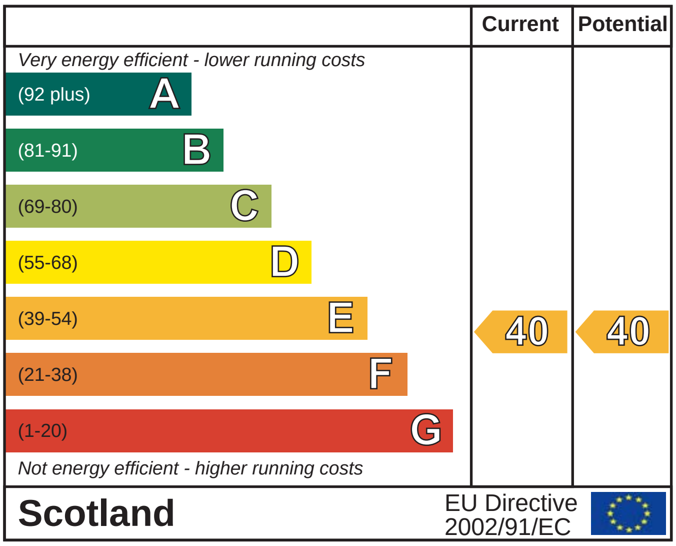
Address of dwelling and other details

Garden Bothy Dumfries House Cumnock KA18 2NJ	Dwelling type:	Detached house
	Name of approved organisation:	Ecmk Ltd
	Membership number:	
	Date of certficate:	29 March 2010
	Reference Number:	0000-0000-0000-0000-0000
	Total floor area:	63 m^2
	Main type of heating and fuel:	Boiler and radiators, wood logs

This dwelling's performance ratings

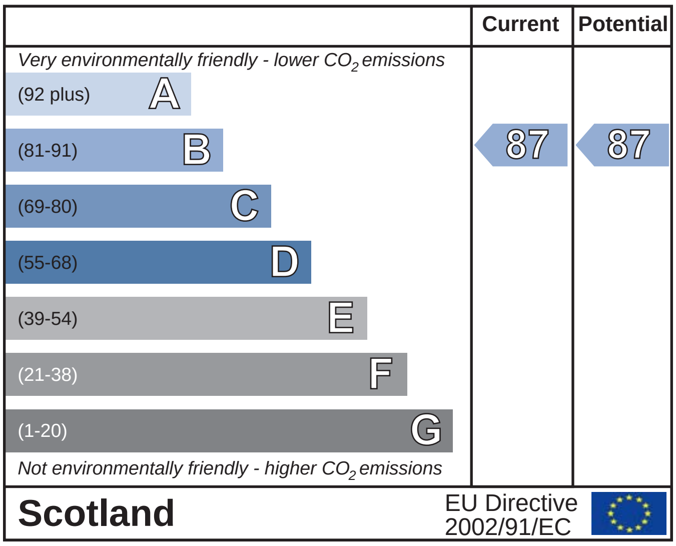
This dwelling has been assessed using the RdSAP 2005 methodology. Its performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (CO_2) emissions. CO_2 is a greenhouse gas that contributes to climate change.

Energy Efficiency Rating



The energy efficiency rating is a measure of the overall efficiency of a home. The higher the rating the more energy efficient the home is and the lower the fuel bills are likely to be.

Environment Impact (CO_2) Rating



The environmental impact rating is a measure of a home's impact on the environment in terms of carbon dioxide (CO_2) emissions. The higher the rating the less impact it has on the environment.

Approximate current energy use per square metre of floor area: 429 kWh/m^2 per year

Approximate current CO_2 emissions: 17 kg/m^2 per year

Cost effective improvements

Below is a list of lower cost measures that will raise the energy performance of the dwelling to the potential indicated in the tables above.

Not applicable

A full energy report is appended to this certificate

Information from this EPC may be given to Energy Saving Trust to provide advice to householders on financial help available to improve home energy efficiency.

For advice on how to take action and to find out about offers available to help make your home more energy efficient, call **0800 512 012** or visit **www.energysavingtrust.org.uk/myhome**

N.B. THIS CERTIFICATE MUST BE AFFIXED TO THE DWELLING AND NOT BE REMOVED UNLESS IT IS REPLACED WITH AN UPDATED VERSION

Energy report

The Energy Performance Certificate and Energy Report for this dwelling were produced following an energy assessment undertaken by a member of Ecmk Ltd. This is an organisation which has been approved by the Scottish Ministers. The certificate has been produced under the Building (Scotland) Amendment Regulations 2006 and a copy of the certificate and this energy report have been lodged on a national register.

Assessor's name:
Company name/trading name:
Address:

Phone number:
Fax number:
E-mail address:
Related party disclosure: I am not related to the buyer nor seller

Estimated energy use, carbon dioxide (CO_2) emissions and fuel costs of this home

	Current	Potential
Energy use	429 kWh/m^2 per year	429 kWh/m^2 per year
Carbon dioxide emissions	1.1 tonnes per year	1.1 tonnes per year
Lighting	£34 per year	£34 per year
Heating	£668 per year	£668 per year
Hot water	£171 per year	£171 per year

Based on standardised assumptions about occupancy, heating patterns and geographical location, the above table provides an indication of how much it will cost to provide lighting, heating and hot water to this home. The fuel costs only take into account the cost of fuel and not any associated service, maintenance or safety inspection. This certificate has been provided for comparative purposes only and enables one home to be compared with another. Always check the date the certificate was issued, because fuel prices can increase over time and energy savings recommendations will evolve.

About the building's performance ratings

The ratings on the certificate provide a measure of the building's overall energy efficiency and its environmental impact, calculated in accordance with a national methodology that takes into account factors such as insulation, heating and hot water systems, ventilation and fuels used.

Not all buildings are used in the same way, so energy ratings use 'standard occupancy' assumptions which may be different from the specific way you use your home.

Buildings that are more energy efficient use less energy, save money and help protect the environment. A building with a rating of 100 would cost almost nothing to heat and light and would cause almost no carbon emissions. The potential ratings in the certificate describe how close this building could get to 100 if all the cost effective recommended improvements were implemented.

About the impact of buildings on the environment

One of the biggest contributors to global warming is carbon dioxide. The way we use energy in buildings causes emissions of carbon. The energy we use for heating, lighting and power in homes produces over a quarter of the UK's carbon dioxide emissions and other buildings produce a further one-sixth.

The average household causes about 6 tonnes of carbon dioxide every year. Adopting the recommendations in this report can reduce emissions and protect the environment. You could reduce emissions even more by switching to renewable energy sources. In addition there are many simple everyday measures that will save money, improve comfort and reduce the impact on the environment. Some examples are given at the end of this report.

Summary of this home's energy performance related features

The following is an assessment of the key individual elements that have an impact on this home's performance rating. Each element is assessed against the following scale: Very poor / Poor / Average / Good / Very good.

Element	Description	Current performance	
		Energy Efficiency	Environmental
Walls	Sandstone, with internal insulation	Good	Good
Roof	Pitched, 250 mm loft insulation	Good	Good
Floor	Suspended, insulated	-	-
Windows	Fully double glazed	Good	Good
Main heating	Boiler and radiators, wood logs	Poor	Very good
Main heating controls	Programmer, TRVs and bypass	Poor	Poor
Secondary heating	Room heaters, wood logs	-	-
Hot water	From main system	Poor	Very good
Lighting	Low energy lighting in all fixed outlets	Very good	Very good
Current Energy efficiency rating		E 40	
Current environmental impact (CO_2) rating			B 87

Low and zero carbon energy sources

These are sources of energy (producing or providing electricity or hot water) which emit little or no carbon dioxide into the atmosphere.The following are provided for this home:

- Biomass main heating
- Biomass secondary heating

Recommended measures to improve this home's energy performance

None

Further measures to achieve even higher standards

The measures listed below should be considered if aiming for the highest possible standards for this home. Some of these measures may be cost-effective when other building work is being carried out such as an alteration, extension or repair. Also they may become cost-effective in the future depending on changes in technology costs and fuel prices. However you should check the conditions in any covenants, warranties or sale contracts, and whether any legal permissions are required such as a building warrant, planning consent or listed building restrictions.

Higher cost measures (over £500)	Typical savings per year	Performance ratings after improvement	
		Energy Efficiency	Environmental
1 Solar water heating	£46	E 43	B 87
2 Solar photovoltaic panels, 2.5 kWp	£172	E 54	A 99
3 Wind turbine	£50	D 58	A 100
Enhanced Energy efficiency rating		D 58	
Enhanced environmental impact (CO_2)rating			A 100

Improvements to the energy efficiency and environmental impact ratings will usually be in step with each other. However, they can sometimes diverge because reduced energy costs are not always accompanied by a reduction in carbon dioxide (CO_2) emissions.

About the cost effective measures to improve this home's performance ratings

Not applicable

About the further measures to achieve even higher standards

Further measures that could deliver even higher standards for this home. You should check the conditions in any covenants, planning conditions, warranties or sale contracts before undertaking any of these measures.If you are a tenant, before undertaking any work you should check the terms of your lease and obtain approval from your landlord if the lease either requires it, or makes no express provision for such work.

1 Solar water heating

A solar water heating panel, usually fixed to the roof, uses the sun to pre-heat the hot water supply. This will significantly reduce the demand on the heating system to provide hot water and hence save fuel and money. The Solar Trade Association has up-to-date information on local installers and any grant that may be available or call 0800 512 012 (Energy Saving Trust). Building regulations may apply to this work.

2 Solar photovoltaic (PV) panels

A solar PV system is one which converts light directly into electricity via panels placed on the roof with no waste and no emissions. This electricity is used throughout the home in the same way as the electricity purchased from an energy supplier. The British Photovoltaic Association has up-to-date information on local installers who are qualified electricians and on any grant that may be available, or call 0800 512 012 (Energy Saving Trust). Planning restrictions may apply in certain neighbourhoods and you should check this with the local authority. Building regulations may apply to this work, so it is best to obtain advice from your local authority building standards department and from a suitably qualified electrician.

3 Wind turbine

A wind turbine provides electricity from wind energy. This electricity is used throughout the home in the same way as the electricity purchased from an energy supplier. The British Wind Energy Association has up-to-date information on suppliers of small-scale wind systems and any grant that may be available, or call 0800 512 012 (Energy Saving Trust). Wind turbines are not suitable for all properties. The system's effectiveness depends on local wind speeds and the presence of nearby obstructions, and a site survey should be undertaken by an accredited installer. Planning restrictions and/or building regulations may apply and you should check this with the local authority.

What can I do today?

Actions that will save money and reduce the impact of your home on the environment include:

- Ensure that you understand the dwelling and how its energy systems are intended to work so as to obtain the maximum benefit in terms of reducing energy use and CO_2 emissions.
- If you have a conservatory or sunroom, avoid heating it in order to use it in cold weather and close doors between the conservatory and dwelling.
- Check that your heating system thermostat is not set too high (in a home, 21°C in the living room is suggested) and use the timer to ensure you only heat the building when necessary.
- Make sure your hot water is not too hot - a cylinder thermostat need not normally be higher than 60°C.
- Turn off lights when not needed and do not leave appliances on standby. Remember not to leave chargers (e.g. for mobile phones) turned on when you are not using them.
- Close your curtains at night to reduce heat escaping through the windows.
- If you're not filling up the washing machine, tumble dryer or dishwasher, use the half-load or economy programme. Minimise the use of tumble dryers and dry clothes outdoors where possible.

Appendix 4
Changeworks' RdSAP data collection form

RdSAP v9.82 – EPC data collection

PROPERTY ADDRESS	
Postcode:	UPRN: Surveyor's name: Date of survey: Property owner:

PROPERTY DETAILS	
Tenure	Owner occupier ☐ Private rented ☐ Local authority ☐ Housing association ☐ Tied / other ☐
Transaction type	Marketed sale ☐ Non-marketed sale ☐ Rental (social) ☐ Rental (private) ☐ Not sale or rental ☐
Built form	House ☐ Bungalow ☐ Flat ☐ Maisonette ☐
Detachment	Detached ☐ Semi-detached ☐ Mid-terrace ☐ Enclosed mid-terrace ☐ End-terrace ☐ Enclosed end-terrace ☐
Main property age	Pre 1919 ☐ 1919-29 ☐ 1930-49 ☐ 1950-64 ☐ 1965-75 ☐ 1976-83 ☐ 1984-91 ☐ 1992-98 ☐ 1999-2002 ☐ 2003-07 ☐ Post 2007 ☐
Main room in roof age (if applicable)	Pre 1919 ☐ 1919-29 ☐ 1930-49 ☐ 1950-64 ☐ 1965-75 ☐ 1976-83 ☐ 1984-91 ☐ 1992-98 ☐ 1999-2002 ☐ 2003-07 ☐ Post 2007 ☐
Extension age (if applicable)	Pre 1919 ☐ 1919-29 ☐ 1930-49 ☐ 1950-64 ☐ 1965-75 ☐ 1976-83 ☐ 1984-91 ☐ 1992-98 ☐ 1999-2002 ☐ 2003-07 ☐ Post 2007 ☐
Extension room in roof age (if applicable)	Pre 1919 ☐ 1919-29 ☐ 1930-49 ☐ 1950-64 ☐ 1965-75 ☐ 1976-83 ☐ 1984-91 ☐ 1992-98 ☐ 1999-2002 ☐ 2003-07 ☐ Post 2007 ☐
2nd Extension age	Pre 1919 ☐ 1919-29 ☐ 1930-49 ☐ 1950-64 ☐ 1965-75 ☐ 1976-83 ☐ 1984-91 ☐ 1992-98 ☐ 1999-2002 ☐ 2003-07 ☐ Post 2007 ☐
2nd Extension room in roof age (if applicable)	Pre 1919 ☐ 1919-29 ☐ 1930-49 ☐ 1950-64 ☐ 1965-75 ☐ 1976-83 ☐ 1984-91 ☐ 1992-98 ☐ 1999-2002 ☐ 2003-07 ☐ Post 2007 ☐

FLATS & MAISONETTES ONLY		
Corridor type	No corridor ☐ Heated corridor ☐ Unheated corridor ☐	
	If Unheated corridor:	Length of sheltered wall ______ m
Storey no.		
No. floors in block		
Heat loss upper floor type	Above another dwelling ☐ Above partially heated space ☐ Above unheated space ☐ Fully exposed ☐ Ground floor ☐	

DWELLING DETAILS	
No. of habitable rooms	
No. of habitable heated rooms	
Measurements	Internal ☐ External ☐

Main dwelling dimensions

Floor	Floor area (m^2)	Room height (m)	Heat loss perimeter (m)
Room in roof		**N/A**	**N/A**
+3			
+2			
+1			
Lowest floor			

Extension dimensions (if applicable) *Use extended data, if more than one extension*			
Floor	Floor area (m^2)	Room height (m)	Heat loss perimeter (m)
Room in roof		**N/A**	**N/A**
+3			
+2			
+1			
Lowest floor			
2nd extension dimensions			
Floor	Floor area (m^2)	Room height (m)	Heat loss perimeter (m)
Room in roof		**N/A**	**N/A**
+3			
+2			
+1			
Lowest floor			
Conservatory	No conservatory ☐ Separated, no fixed heaters ☐ Separated, fixed heaters ☐ Not separated ☐		
Non-separated conservatory (if applicable)			
Floor area (m^2)			
Double glazed	Yes ☐ No ☐		
Glazed perimeter (m)			
Room height	1 storey ☐ 1.5 storey ☐ 2 storey ☐ 2.5 storey ☐ 3 storey ☐		

DWELLING FABRIC	
WALLS	
Main wall construction	Stone (sandstone) ☐ Stone (granite or whinstone) ☐ Solid brick ☐ Cavity ☐ Timber frame ☐ System built ☐ Cob ☐
Main wall insulation type	Filled cavity ☐ External ☐ Internal ☐ As built ☐ Unknown ☐
Extension wall construction	Stone (sandstone) ☐ Stone (granite or whinstone) ☐ Solid brick ☐ Cavity ☐ Timber frame ☐ System built ☐ Cob ☐
Extension wall insulation	Filled cavity ☐ External ☐ Internal ☐ As built ☐ Unknown ☐
2nd extension wall construction	Stone (sandstone) ☐ Stone (granite or whinstone) ☐ Solid brick ☐ Cavity ☐ Timber frame ☐ System built ☐ Cob ☐
2nd extension wall insulation	Filled cavity ☐ External ☐ Internal ☐ As built ☐ Unknown ☐
Alternative wall construction	Stone (sandstone) ☐ Stone (granite or whinstone) ☐ Solid brick ☐ Cavity ☐ Timber frame ☐ System built ☐ Cob ☐
Alternative wall insulation type	Filled cavity ☐ External ☐ Internal ☐ As built ☐ Unknown ☐
Area of alternative wall	________ m^2
Alternative wall part of	Main ☐ Extension 1 ☐ Extension 2 ☐

ROOF	
Main roof construction	Pitched (slate or tiles), access to loft ☐ Pitched (thatch) ☐ Pitched (slate or tiles), no access ☐ Flat ☐ Another dwelling above ☐
Main roof insulation location	None ☐ Joists ☐ Rafters ☐ Flat roof insulation ☐ Unknown ☐
Main roof insulation depth	12mm ☐ 25mm ☐ 50mm ☐ 75mm ☐ 100mm ☐ 150mm ☐ 200mm ☐ 250mm ☐ >=300mm ☐ Don't know ☐
Main roof room insulation	Unknown ☐ No insulation ☐ Flat ceiling only ☐ All elements ☐
Main roof room insulation depth	12mm ☐ 25mm ☐ 50mm ☐ 75mm ☐ 100mm ☐ 150mm ☐ 200mm ☐ 250mm ☐ >=300mm ☐ Don't know ☐
Extension roof construction	Pitched (slate or tiles), access to loft ☐ Pitched (thatch) ☐ Pitched (slate or tiles), no access ☐ Flat ☐ Another dwelling above ☐
Extension roof insulation location	None ☐ Joists ☐ Rafters ☐ Flat roof insulation ☐ Unknown ☐
Extension roof depth	12mm ☐ 25mm ☐ 50mm ☐ 75mm ☐ 100mm ☐ 150mm ☐ 200mm ☐ 250mm ☐ >=300mm ☐ Don't know ☐
Extension roof room insulation	Unknown ☐ No insulation ☐ Flat ceiling only ☐ All elements ☐
Extension roof room insulation depth	12mm ☐ 25mm ☐ 50mm ☐ 75mm ☐ 100mm ☐ 150mm ☐ 200mm ☐ 250mm ☐ >=300mm ☐ Don't know ☐
2nd extension roof construction	Pitched (slate or tiles), access to loft ☐ Pitched (thatch) ☐ Pitched (slate or tiles), no access ☐ Flat ☐ Another dwelling above ☐
2nd extension roof insulation location	None ☐ Joists ☐ Rafters ☐ Flat roof insulation ☐ Unknown ☐
2nd extension roof depth	12mm ☐ 25mm ☐ 50mm ☐ 75mm ☐ 100mm ☐ 150mm ☐ 200mm ☐ 250mm ☐ >=300mm ☐ Don't know ☐
2nd extension roof room insulation	Unknown ☐ No insulation ☐ Flat ceiling only ☐ All elements ☐
Extension roof room insulation depth	12mm ☐ 25mm ☐ 50mm ☐ 75mm ☐ 100mm ☐ 150mm ☐ 200mm ☐ 250mm ☐ >=300mm ☐ Don't know ☐
WINDOWS AND DOORS	
Window glazing area	Typical ☐ More than typical ☐ Much more than typical (i.e. use extended data form) ☐ Less than typical ☐ Much less than typical (i.e. use extended data form) ☐
% multiple glazing	__________%
Multiple glazing type	Double, pre 2003 ☐ Double, post or during 2003 ☐ Double, unknown date ☐ Secondary glazing ☐ Triple glazing ☐
FLOORS	
Floor construction	Solid ☐ Suspended timber ☐ Suspended, not timber ☐ Unknown ☐
Floor insulation	Unknown ☐ As built ☐ Retro-fitted ☐
Extension floor insulation	Solid ☐ Suspended timber ☐ Suspended, not timber ☐ Unknown ☐
Extension floor insulation	Unknown ☐ As built ☐ Retro-fitted ☐
2nd extension floor insulation	Solid ☐ Suspended timber ☐ Suspended, not timber ☐ Unknown ☐
2nd extension floor insulation	Unknown ☐ As built ☐ Retro-fitted ☐

VENTILATION	
No. of open fire places	
Mechanical ventilation	Yes ☐ No ☐ If yes, is it … Extract only ☐ Balanced ☐

HEATING AND HOT WATER			
Primary heating system	Main heating fuel		
	Code	____________ (using tables provided)	
	For boilers only	Brand name	
		Model	
		ID	
		Flue type	Open ☐ Room sealed ☐
		Ignition type	Auto-ignition ☐ Permanent pilot light ☐
		Fanned flue	Yes ☐ No ☐
	Heating emitter	Radiators ☐ Underfloor heating ☐	
	If community heating …	Please state fuel type __________________	
Primary heating controls	Code	____________ (using tables provided)	
Secondary heating	Code	____________ (using tables provided)	
Water heating	Code	____________ (using tables provided) If immersion system: On-peak immersion ☐ Off-peak immersion ☐ Dual immersion ☐	
	Hot water tank size	No cylinder ☐ No access ☐ Normal (90-130 litres) ☐ Medium (131-170 litres) ☐ Large (>170 litres) ☐	
	Hot water tank insulation type	No insulation ☐ Jacket ☐ Spray foam ☐	
	Hot water tank insulation thickness	12mm ☐ 25mm ☐ 38mm ☐ 50mm ☐ 80mm ☐ 100mm ☐ 125mm ☐ 160mm ☐	
	Hot water tank thermostat present	Yes ☐ No ☐	
Renewables present	Solar water heating	Yes ☐ No ☐	
	Wind turbine	Yes ☐ No ☐	
	Photo-voltaics	Yes ☐ No ☐ if yes: PV area as a percentage of roof area ____%	

MISC	
Is mains gas supply available?	Yes ☐ No ☐
Electricity meter type	Single ☐ Dual ☐ 24 hours ☐ Unknown ☐
Terrain	Dense urban ☐ Low rise urban or suburban ☐ Rural ☐
Low energy lighting	Percentage of fixed outlets with CFLs ____%

SKETCH PLAN & NOTES

Notes:

EXTENDED DATA

Excessive or minimal window area

Measured windows

Window	Area (m^2)	Glazing type *	Location/Element **

* unknown date double, single, double pre 2003, double post or during 2003, secondary
** main house wall, extension wall (identified if more than one), internal heat loss wall, main roof, extension roof (identified if more than one)

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