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Technical Conservation Group

Technical Paper 3

Energy modelling analysis of a traditionally built Scottish tenement flat

Prepared for Historic Scotland by Changeworks

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Glossary

BRE	Building Research Establishment
BREDEM	BRE Domestic Energy Model
EPC	Energy Performance Certificate
NHER	National Home Energy Rating
RdSAP	Reduced data SAP
SAP	Standard Assessment Procedure
SBEM	Standard Building Energy Model
SEDBUK	Seasonal Efficiency of Domestic Boilers in the United Kingdom

1 Executive summary

Changeworks tested four different energy-modelling methodologies in relation to a traditionally built Georgian tenement flat in central Edinburgh. The results demonstrated that each software model will generate a different result, depending on the content and amount of the data sets. As a general rule, the more detailed the data sets, the more accurate the energy model.

In terms of construction dates, most energy modelling software systems group construction dates into bands that broadly correspond with changes in Building Standards, allowing a reasonable degree of accuracy. However, everything built before 1919 (or 1900 depending on the software model) is grouped into a single category ('Pre-1919' or 'Pre 1900'). This makes inaccuracies more likely when modelling the energy efficiency of older housing, due to the wide range of building types, local construction methods, materials, built forms and so on. This is an important point, showing an in-built generic approach to most energy modelling of older housing.

Some software models assume incorrect building sizes, not taking into account the larger room sizes common in older housing. This immediately weakens the subsequent energy rating assigned to the property. In addition, built forms such as tenemental flats have a relatively low 'floor/external wall area' ratio: some software packages were not sufficiently sensitive to adapt to this scenario, and thus generated a higher-than-expected energy efficiency rating.

Some software packages take no account of local climate data, which again can lead to unrealistic energy ratings (regardless of the age of the property) depending on the geographic location of the property.

Within these software models, some data sets are more flexible than others, allowing pre-set values to be over-written. The user can thereby manually 'construct' the build type (for example) in order to create a more accurate energy model. Other models, however, contain only fixed values, which may sometimes be inaccurate, particularly in relation to older traditionally built housing.

Such generic treatments and in-built inflexibilities of these software models predispose older housing to less accurate energy efficiency ratings (both up and down) than their actual efficiency might be. The actually property surveyed for this research achieved reasonably high energy ratings, however as shown by the subsequent analysis, the property's true energy efficiency and the software accuracy are far from clear-cut.

Looking to the future, with the emergence of **Energy Performance Certificates** (**EPCs**), it seems likely the software package behind them (**Reduced data Standard Assessment Procedure** or **RdSAP**) will become the main model by which the energy efficiency of domestic properties is rated. Other programmes such as **National Home Energy Rating** (**NHER**) may well become less common. Furthermore, as concluded by this research, there is a case for the development of a new software package to provide a truly accurate energy efficiency model for older, traditionally built, Scottish housing.

2 Scope of work

This research took place following a request from Historic Scotland, to inform their wider *Energy Modelling in Traditional Scottish Housing* research programme. Changeworks was asked to assess the applicability and accuracy of existing energy modelling software in relation to older, traditionally built housing.

The work carried out for this research project comprised the following:

- A technical survey of a traditionally built tenement flat in central Edinburgh;
- Subsequent generation of energy models using the following nationally-recognised energy assessment tools:
    - **National Home Energy Rating** (**NHER**)
    - **Standard Assessment Procedure** (**SAP**)
    - **Reduced data Standard Assessment Procedure** (**RdSAP**); which generated an **Energy Performance Certificate** (**EPC**);
- Analysis of the results, and commentary of both the processes and the results.

2.1 Property specifications

The technical energy survey confirmed the following property specifications:

- **Property characteristics** (built form, age of construction and location): the property is a top-floor Georgian (1820s) tenement flat, with an acceptable standard of insulation and three exposed walls. Despite being in a very urban, central situation, being a top-floor flat there is little sheltering. The property has a North-South orientation, with the main living space facing South.

- **Dimensions** (floor areas, floor room heights and exposed wall perimeters / wall areas): large floor areas and window areas per room; high ceilings in comparison to more recently built properties.

- **Building fabric** (wall construction, roof construction, floor construction, insulation, window types): uninsulated and ‘hard-to-treat’ external sandstone walls, albeit thick (600mm); large, single-glazed sash-and-case windows, half of which have reasonable draught proofing; non-exposed floor.

- **Heating and hot water** (primary and secondary heating systems, controls and hot water systems): Reasonably new (post-1998) standard boiler (Potterton Suprima 50L) with an average seasonal efficiency of 78.1%[1] (despite not being a condensing boiler, which is the most efficient type available); fully controllable heating system (timer, thermostatic radiator valves and a room thermostat); well-insulated hot water tank.

Of the three exposed walls, the gable end wall is exposed and partially adjoined to the neighbour’s loft space, and part of the South-facing wall is exposed internally into the stair well. Internally, the property consists of eight rooms in total (three bedrooms, box room, lounge, kitchen, bathroom and hallway). The loft is insulated to a depth of 200mm.

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[1] Source: Seasonal Efficiency of Domestic Boilers in the United Kingdom (SEDBUK) database (www.sedbuk.com).

3 Energy modelling

3.1 Software overview

Typical energy rating software datasets have varying degrees of detail on such items as:

- Property characteristics (built form, age of construction and location)
- Dimensions (floor areas, floor room heights and exposed wall perimeters/areas)
- Building fabric (wall construction, roof construction, floor construction, insulation, window types)
- Heating and hot water (primary and secondary heating systems, controls and hot water systems)

Some levels of analysis also include details of ventilation and fixed appliances.

All of the following stated programmes use a 'standard heating regime' model to calculate the fuel use. This relates both to the heating period and the demand temperatures. The weekday heating period is nine hours: two hours in the morning / seven hours in the evening during the week, and sixteen hours per day at the weekend. The demand temperature in this model is 21^{o}C in zone 1 (the main living area, usually the lounge) and 18^{o}C in the rest of the home.

The number of people staying in the property is theoretical, and is determined by the property size.

3.2 Energy modelling methodology

For this research, data was collected and processed using three **National Home Energy Rating** (**NHER**) programmes:

1. **NHER AutoEvaluator v4.1** (at two different levels of analysis)
2. **NHER Surveyor v4.1** (at two different levels of analysis)
3. **NHER Evaluator v4.1**

All of the above programmes use **SAP 2001** and **BREDEM 12** (see below).

The data collected was also used for a **Reduced data SAP** (**RdSAP**) dataset, and processed using software to produce an **Energy Performance Certificate** (**EPC**; see below). At the time of processing the survey data there was no Scottish version of the software available; an English training version was substituted, and data had to be adjusted in order to make a reasonable comparison with the **NHER** model. Details of these adjustments can be found at *Appendix 1*.

3.3 SAP, BREDEM and NHER

The **SAP** (**Standard Assessment Procedure**) is a manual worksheet calculation, and the Government's energy rating based on energy used in the home to provide heating and hot water only. It does not take account of electrical use for lighting[2] and appliances,

[2] The latest version, **SAP 2005**, now takes lighting into account. The **NHER** software used in the analysis for this report used the earlier version, **SAP 2001**.

or the effect of climate variation throughout the UK. The **SAP** score rates a property from 1 to 120[3], with one being a very energy inefficient property.

The core of the **BREDEM** (**Building Research Establishment Domestic Energy Model**) model is a two-zone, variable base, 'degree day' calculation of space heating demand. Over the last decade this has been supplemented by algorithms for estimating ventilation rates in dwellings, water heating use, fuel use from cooking and lighting and appliances, the effects of controls on heating system performance and internal temperatures, and the effects of conservatories or sun-spaces.

The **NHER** (**National Home Energy Rating**) is an energy label based upon total annual running costs per square metre (under standard occupancy conditions) that can predict energy running costs and CO_2 emissions. It is expressed on a scale of 0 (poor) to 10 (excellent). Annual CO_2 emissions and running costs (based on a standard heating pattern) are estimated. There are various levels of **NHER** analysis – Level 0, 0 enhanced, 1, 2 and 3. The assumptions and standards contained within **NHER** were set by National Energy Services.

As mentioned previously, three **NHER** programmes were used to process the survey data: **AutoEvaluator**, **Surveyor** and **Evaluator**.

3.3.1 NHER AutoEvaluator

AutoEvaluator is used for stock profiling databases, with a level of analysis of NHER Levels 0 to 1. It is usually used in conjunction with another programme, **NHER Probase**, where the data is held centrally. **Microsoft Access** is also needed. **AutoEvaluator** datasets are used predominantly for the social sector housing sector as the data can be collated from a variety of sources (as opposed to a single energy survey as is required for the other **NHER** programme, **Surveyor**, which is used solely for existing buildings). The data can start as a limited dataset, held on a spreadsheet or database, to be added and updated to. It has the capacity to 'batch process' data from an entire housing stock, and is ideal for 'cloning' data (e.g. multiple properties with similar characteristics).

Level 0 is the simplest level analysis and a very limited dataset, only requiring fifteen data items. No details are needed on the dimensions or fabric of the property. Such details are assumed by the age of construction, built form, number of storeys and number of rooms. Social landlords usually have Level 0 information on their stock in various databases. Level 0 data can be added to, but will not take into account an entire Level 1 dataset: this is known as Level 0 enhanced.

At Level 1, up to 73 data items are needed, and analysis can be made for the Scottish Housing Quality Standard compliance.

AutoEvaluator is currently being superseded by **Auto Assessor** (alongside **Stock Assessor**, which is replacing **Probase**), and will have the capacity to hold an **RdSAP** dataset to create **EPCs**. It will also be compliant with the latest version of **SAP** (**SAP 2005**). As **EPCs** will become the market and industry standard, energy rating software is being redesigned to take this into account.

[3] **SAP 2001**, the version used in the **NHER** analysis, used the 1 to 120 scale. **SAP 2005**, however, uses 1 to 100.

3.3.2 NHER Surveyor

NHER Surveyor software is used on existing dwellings and can generate NHER certificates and reports on a property-by-property basis, i.e. it cannot batch process like **AutoEvaluator**. Only qualified NHER site surveyors and site assessors can collect data for **Surveyor**. Processing, analysis and certification can only be carried out by a NHER site assessor.

There are 3 levels of analysis:

- Level 1 – this is the lowest level a certificate can be issued with. There are up to 100 data items required. This is different, but very similar to Level 1 on **AutoEvaluator**. The main differences being that certain fixed appliances (compact florescent light bulbs and cookers) are included and some building fabrics can be 'user defined' by stating actual U-values as opposed to those defaulted into the programme. Data on extensions (one only) are also included, as are conservatories.

- Level 2 – the main difference is that details are collected and measurements are made of each opening (window or door). This requires far more time at both the survey and processing. More details on the heating and hot water system, ventilation, zoning (main living area), exposure and floor construction are required.

- Level 3 – this is the same as Level 2 with the addition of occupancy data. The heating regime can be altered from the standard regime to however the occupant uses their heating. This may vary from one person staying in the property using their heating one hour a day at 15^{o}C, to a family of ten using the heating for 24 hours at 30^{o}C (although each of these extremes should be used with caution). The only difference at this level of analysis will be in the running costs.

Surveyor, too, will be superseded to provide capacity to hold a **RdSAP** dataset to create **EPCs**, and will be compliant with **SAP 2005**.

3.3.3 NHER Evaluator

NHER Evaluator has all the features of **Surveyor** plus extra facilities. The addition of a U-value calculator allows the user to create from scratch the composite U-value for a wall, floor or roof. For existing buildings this would not normally be used, with the exception of:

- abnormal property shapes (e.g. circular or triangular)
- non-traditional wall constructions
- properties with multiple extensions

Whilst **AutoEvaluator** and **Surveyor** will calculate the zone 1 fraction (main living area in the dwelling) by the entire floor area, **Evaluator** requires the actual floor and exposed area of zone 1 to be measured.

3.4 RdSAP and EPCs

Energy Performance Certificates (**EPCs**) are a legal requirement for domestic property sales in Scotland from 1 December 2008, and for all new tenancies from 4 January 2009.

The Building Standards Department in the Scottish Government decided that an entire **SAP** dataset would be too much data to collect for an **EPC**, so **RdSAP** was created. As yet, a Scottish version of the software is unavailable. The dataset, however is public[4]. Despite the name there are a considerable number of data items. In some ways certain data items have been simplified (e.g. floor and wall construction), but in others additional data is required (e.g. where the loft insulation is located, capacity for two extensions).

The U-values (the heat loss coefficients) have been fixed, which will have an affect on non-traditional housing or properties which are insulated beyond the recognised standard specification.

For existing domestic property, **EPCs** will be produced by members of professional organisations, institutions or other bodies whose members have an understanding of buildings / energy issues. Each provider will be part of a 'Protocol' agreement, i.e. professional bodies that have in place a code of conduct / disciplinary procedures and procedures to monitor and audit their membership. These are known as the Protocol Organisations[5].

Different software will be available, depending on the Protocol the user has an agreement with[6]. The functions of different software will vary. These may include:

- Export facilities from databases;
- Handheld data collection;
- Batch processing;
- Cloning.

Other software will only facilitate manual data entry. All **EPCs** will be produced on-line.

The **EPC** has an easy-to-understand A-G rating (like those found on appliances) for both energy efficiency and carbon emissions.

EPCs will also be required for non-domestic property sales and rentals. These **EPCs** will be generated using a separate program the **Standard Building Energy Model** (**SBEM**).

A sample **EPC** can be found at *Appendix 2*.

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[4] www.projects.bre.co.uk/sap2005/pdf/SAP2005_9-82.pdf

[5] A full list of these bodies identified by the Scottish Government to carry out EPC work is available from www.sbsa.gov.uk/european_issues/epcprotocols.htm

[6] A full list of software providers is available from http://projects.bre.co.uk/SAP2005/pdf/RdSAP2005_9-80_software.pdf

4 Data requirements

The following tables 1 to 6 detail the data requirements for each of the programmes outlined above.

Table 1 (below) explores the property detail requirements.

Property details data requirement	AutoEvaluator Level 0	AutoEvaluator Level 1	Surveyor Level 1	Surveyor Level 2	Evaluator	RdSAP
Reference	x	x				x
Full address			x	x		x
Postcode	x	x	x	x	x	x
Degree Day Region	x	x	x	x	x	
Built form	x	x	x	x	x	x
Dwelling age	x	x	x	x	x	x
Dwelling age (main dwelling)			x	x	x	x
Dwelling age (1 x extension)			x	x	x	x
Dwelling age (2 x extensions)						x
No of storeys	x	x	x	x	x	
Storey number of flat *			x	x	x	x
No of rooms (inc. hall)	x	x	x	x	x	
No. of habitable rooms						x
No. of heated habitable rooms						x
Roof rooms (yes / no)		x				
Flat type	x	x				
Site Exposure		x		x	x	
Dwelling Exposure		x		x	x	
Height above sea level (user specific)				x	x	
Terrain type (user specific)				x	x	x
Wind speed (user specific)				x	x	
Floor plan drawing			x	x	x	
Photographic / documentary evidence						x

* Applies to flats and maisonettes only
** Is generated from the postcode

Table 1: Data requirements for property details

As can be seen above, built form, dwelling age, number of storeys and number of rooms are always required throughout all levels of analysis.

Postcodes are required to provide details on local climate data, which will affect the ratings. **SAP**, however does not use local weather data (unlike **NHER**). Therefore, two identical properties, one in London and the other in Shetland, would score the same **SAP**, but the London property would have a higher **NHER**[7].

[7] The Edinburgh tenement surveyed for this research was modelled using **Surveyor** at Level 2. Had the property been situated in London, the **NHER** score would be 7.5 as opposed to 7.2 (Edinburgh). Had the property been situated in the Shetlands, the **NHER** would drop to 6.2.

Table 2 (below) details the building fabric / envelope requirements.

Data requirement	**AutoEvaluator Level 0**	**AutoEvaluator Level 1**	**Surveyor Level 1**	**Surveyor Level 2**	**Evaluator**	**RdSAP**
Wall type (main dwelling)		x	x	x	x	x
Wall type (internal heat loss wall)			x	x	x	
Wall type (1 x extension)			x	x	x	x
Wall type (2 x extensions)					x	x
Wall type (alternative wall)						x
Wall thickness			x	x	x	
User specific wall U-value			x	x	x	
Wall U-value calculator					x	
Roof type		x	x	x	x	x
Roof type (1 x extension)			x	x	x	x
Roof type (2 x extension)					x	x
User specific roof U-value			x	x	x	
Roof U-value calculator					x	
Floor construction		x		x	x	x
Floor construction (1 x extension)				x	x	x
Floor construction (2 x extensions)					x	x
Floor U-value calculator					x	
Loft insulation (over all average amount)		x	x	x	x	
Loft insulation depth (main wall)						x
Loft insulation depth (1 x extension)						x
Loft insulation depth (2 x extensions)						x
Loft insulation location (e.g. joists)						x
Roof room insulation description						x
Roof room insulation depth						x
Wall insulation (amount)		x			x	
Wall insulation (description)						x
Floor insulation (amount)		x		x	x	
Floor insulation (description)						x
Dry lining (tick box)			x	x	x	
External cladding (tick box)			x	x	x	
Flat floor exposure	x	x				x
Flat roof exposure	x	x				
Flat wall exposure	x	x				
Window frame type		x	x	x	x	
Window glazing type		x	x	x	x	
Proportion double / multiple glazing		x				x
Multiple glazing description						x
Draught proofing (windows)		x		x	x	
Draught proofing (doors)		x		x	x	
All openings (windows, doors etc) measurements ***				x	x	x
All openings orientation				x	x	
All openings location (e.g. main wall, extension etc …) ***				x	x	x

Double glazing thickness				x	x	

* Applies to flats and maisonettes only
** Stone walls only
*** Applies to RdSAP in some cases

Table 2: Data requirements for building fabric

As should be noted above, Level 0 analysis requires no details of the building fabric (apart from the floor, roof and wall exposure details which are required for flats and maisonettes[8]). These items default to the building standards relevant to the date of construction.

[8] The programme will assume that detached properties have four walls exposed, semi-detached and end-terraces have three walls exposed, and mid-terraces have two walls exposed.

Similarly Table 3 (below), detailing dimensional data requirements, shows that these are not required for a Level 0 analysis. This will be defaulted from the property age band, built form, number of storeys and number of rooms as stated before.

Data requirement	**AutoEvaluator Level 0**	**AutoEvaluator Level 1**	**Surveyor Level 1**	**Surveyor Level 2**	**Evaluator**	**RdSAP**
Conservatory area			x	x	x	x
Conservatory exposed perimeter			x	x	x	x
Conservatory glazing			x	x	x	x
Conservatory height (half storey levels)						x
Floor areas		x	x	x	x	x
Floor areas (main house)						x
Floor areas (1 x extension)			x	x	x	x
Floor areas (2 x extension)					x	x
Zone 1 area					x	
Average floor room heights		x	x	x	x	
Floor room height (main house)						x
Floor room height (1 x extension)						x
Floor room height (2 x extensions)						x
Upper exposed floor area		x	x	x	x	
Exposed wall area		x				
Exposed wall perimeter *			x	x	x	
Exposed wall perimeter of each floor						x
Exposed wall perimeter of each floor (1 x extension)				x	x	x
Exposed wall perimeter of each floor (2 x extensions)						x
Internal heat loss wall perimeter **				x	x	x
Zone 1 heat loss wall perimeter					x	
Roof area		x	x	x	x	
Window area		x				
Window area description (e.g typical)						x
Glazed door area		x				
Solid door area		x				

* Lowest floor except basements and mid terrace with passage.

** Flats and maisonettes only

Table 3: Data requirements for dimensions

Table 4 (below) details the requirements for heating and hot water.

Data requirement	AutoEvaluator Level 0	AutoEvaluator Level 1	Surveyor Level 1	Surveyor Level 2	Evaluator	RdSAP
Primary heating fuel	x	x	x	x	x	x
Primary heating type	x	x	x	x	x	x
Primary heating system details	x	x	x	x	x	x
Primary heating controls		x	x	x	x	x
SEDBUK boiler database look up			x	x	x	x
Extended primary heating system data				x	x	
Secondary heating system	x	x	x	x	x	x
Secondary heating controls		x				
Extended secondary heating system data				x	x	
Water heating type	x	x	x	x	x	x
Water heating fuel	x	x	x	x	x	x
Cylinder size (litres)		x		x	x	
Cylinder size (small, medium of large)			x			x
Cylinder stat		x	x	x	x	x
Cylinder insulation type		x		x	x	x
Cyllnder insulation thickness		x		x	x	x
Extended water heating data				x	x	
Pipe insulation		x		x	x	
Solar panels (tick box)			x			x
Solar panel size				x	x	
Photovoltaic array (tick box)						x
Wind turbine (tick box)						x
Fraction CHP		x				

Table 4: Data requirements for heating and hot water

All of the above require at least one heating system (primary system). Only one other system can be included (secondary system) and these can only be room heaters. In the instance where there are two central heating systems present, the predominant heating system takes precedence. If there is no heating in the dwelling, electric heaters are defaulted to.

For a boiler system, the minimum data requirements (Level 0) are its fuel and whether it is old or new. At a higher and more accurate level of analysis, if the boiler's manufacturer's name, model and number are available, they can be looked up on a national database called SEDBUK (Standard Efficiency of Domestic Boilers in the United Kingdom, www.sedbuk.com) to give the annual seasonal efficiency. The latter is usually only the case for boilers manufactured after 1997[9].

[9] Boilers manufactured after 1997 have a minimum efficiency standard and the manufacturer have to declare the efficiency.

Table 5 (below) shows the requirements for ventilation.

Data requirement	**AutoEvaluator Level 0**	**AutoEvaluator Level 1**	**Surveyor Level 1**	**Surveyor Level 2**	**Evaluator**	**RdSAP**
LSO pressure results if available				x	x	
Loft hatch present				x	x	
Loft hatch draught proofed				x	x	
No of chimneys		x	x	x	x	x
No of flues		x		x	x	
Stairs into zone 1		x		x	x	
No of extractor fans		x		x	x	
Mechanical ventilation		x	x	x	x	x
Mechanical ventilation heat recovery (%)		x	x	x	x	
Mechanical ventilation (extract only or balanced)						x

Table 5: Data requirements for ventilation

It is worth noting under NHER convention, airbricks count as flues and balanced flues (including fan assisted) are not included in the count.

Miscellaneous items are shown in Table 6 (below).

Data requirement	**AutoEvaluator Level 0**	**AutoEvaluator Level 1**	**Surveyor Level 1**	**Surveyor Level 2**	**Evaluator**	**RdSAP**
Low energy light bulbs (as a % of all light fittings)		x	x	x	x	x
Cooker type			x	x	x	
Electricity meter type						x
Mains gas availability						x

Table 6: Data requirements for miscellaneous items

It is assumed that low energy light bulbs and cookers are fixed appliances.

5 Results

Processing the data through different NHER software, as detailed in Tables 7 and 8 (below) and in *Appendix 3*, shows that:

- The NHER result varies from 6.1 to 7.5, with an average result of 6.8;
- The SAP result varies from 59 to 70;
- The estimation of CO_2 emissions range from 6.1 to 8.3 tonnes per annum;
- The estimated running costs varies between £895 and £1,248 per annum;
- The estimated energy usage varies between 22,974 KWh and 31,503 KWh per annum.

	NHER AutoEvaluator		NHER Surveyor		NHER Evaluator
	Level 0	**Level 1**	**Level 1**	**Level 2**	**Level 2**
NHER	6.6	6.1	6.7	7.2	7.5
SAP	63	59	61	67	70
CO_2	6.1	8.3	7.6	7.0	6.6
Costs per annum	£895	£1,242	£1,238	£1,134	£1,076
KWh (total, per annum)	27,308	37,475	34,419	30,225	28,641
KWh (heating & hot water, per annum)	22,974	31,503	29,558	25,085	24,863

Table 7: Results using different NHER software and levels of analysis

	Average result
NHER	6.8
SAP	64
CO_2	7.1
Costs per annum	£1,119
KWh (total, per annum)	31,614
KWh (heating & hot water, per annum)	26,797

Table 8: Average NHER result combining all methodologies

As there is no Scottish version of the **RdSAP** software available, the English and Welsh version of the software – which has been used in Scotland for training purposes – was used for the analysis. The theoretical **EPC** for the property surveyed is included at *Appendix 4*. Table 9 (below) shows the **RdSAP** results.

	Result	Notes
Banding	D	
Energy Efficiency Rating (RdSAP)	63	
Environmental Impact Rating	57	
CO_2 emissions (tonnes per annum)	5.6	(Includes heating, hot water and lighting - does not include appliances)
Costs per annum	£863	(Includes heating, hot water and lighting - does not include appliances)
kWH (total, per annum)	33,513	
kWH (heating & hot water, per annum)		Breakdown not available

Table 9: Results using RdSAP

6 Commentary on results

6.1 NHER and SAP results

Without dimension details at Level 0 analysis, **NHER AutoEvaluator** underestimated the property size as being 100.6 m^2, as opposed to 130.4 m^2 as measured during the survey. This explains the low predicted CO_2 emissions, running costs and energy usage at this analysis compared to the other methods[10].

As loft insulation details were available, they were entered on Level 0 analysis, as this is optional. Had this not been input, the programme would default to the building regulations of the period. As there were no standards in the time of construction in the early 19th century, then it would be assumed as none as opposed to 200 mm. The **NHER** would therefore be 4.2, the **SAP** would be 44, a CO_2 prediction of 9.3 tonnes per annum, running costs prediction of £1,254 per annum and annual energy usage of 43,726 KWh. This shows the significance placed on loft insulation as a means of improving energy efficiency of a property.

As dimensional data was introduced to make a Level 1 dataset on **NHER AutoEvaluator**, the ratings lower.

When more data was introduced into the **NHER Surveyor** dataset, the ratings begin to increase as the assumptions were narrowed. This can be attributed to the inclusion of more accurate heating data, ventilation and building fabric, particularly the windows.

The ratings further increased as the information was input into **NHER Evaluator**. Additional information that was required about the dimensions of the main living area and internal heat loss wall is more favourable for the assessment than that assumed by **NHER Surveyor**.

In short, the different energy ratings present a wide range of results. NHER ratings vary by 1.4; annual CO_2 emission predictions vary by 2.2 tonnes; annual running cost predictions vary by £353; and annual energy use predictions vary by 8,529 kWh.

6.2 RdSAP results

The **RdSAP** rating of 63 would appear to compare well with the average **SAP** of 64 across all five NHER programmes, but this is deceiving, as the **SAP** in the **NHER** programmes is scored out of 120 (SAP 2001) whilst the **RdSAP** is scored out of 100 (**SAP 2005**).

The CO_2 emissions predicted by **RdSAP** are lower than that of any of the **NHER** estimations, but this figure only accounts for heating, hot water and lighting and so does not present the whole picture.

In terms of the energy banding generated by the **RdSAP**, the property surveyed for this report achieved a banding of D. The expected energy banding for a new build property

[10] Furthermore, the programme assumes that the shape of the property is square and that each wall length is approximately 10 metres (i.e. square root of 100 metres). **AutoEvaluator** will then assume that the exposed wall perimeter is around 30 metres, as the NHER surveyor stated that there are three walls exposed.

would be B. Energy Saving Trust monitoring indicates that the average domestic property in England would score a rating between the bands of E and F.

7 Conclusions

At level 0 analysis, the **NHER** software estimated the size of the property to be around three-quarters of the actual size. In the absence of data on dimensions, this was an estimation based on the built form, property age, number of storeys and number of rooms. Strip the **NHER** model to its bare assumptions and it does not expect rooms to be of such size as this typical Edinburgh tenement.

NHER analysis results increase as more accurate data is introduced, giving an energy rating ranging from 6.1 to 7.5. The data range varies from programme to programme. As more detailed analysis was carried out, the energy rating increased. However, the results from the different NHER programmes showed a wide range of results, making it difficult to confirm the true accuracy of any one result by itself.

The property in question has a lot in its favour (e.g. solar gains, reasonable gas central heating system, loft insulation, thermal mass of the external walls) but one would not expect such a high result (i.e. **NHER** 7.5) when using such a high degree of accuracy. Listing and cost issues aside, there are still many potential improvements which could be made, for example: topping up loft insulation to a depth of 270-300mm, low-emissivity double glazing, a condensing boiler system, solar panels (for water heating and / or electricity generation), and internal wall insulation. In summary, it would appear that NHER can over-estimate an existing building's energy performance, and such a high result should be questioned.

RdSAP, on the other hand, can underestimate an existing building's performance. The building may have a U-value that exceeds the default values. Properties that exceed the building regulations will be under-rated, e.g. under **RdSAP** a wall can either be internally or externally insulated, but not both.

New build properties use different software to measure the property's energy performance: these do not have fixed values for the building's characteristics. Therefore, it would be assumed that new build ratings are more precise than those carried out on existing properties using **RdSAP** and **NHER** (assuming they detail how the property was actually built).

The lack of consideration of local climate data by **SAP** can present misleading energy ratings. As mentioned previously, while the tenement flat in question achieved an **NHER Surveyor** (Level 2) energy rating of 7.2, the same property in London would have been rated at 7.5 and the same property in Shetland would have been rated at 6.2. **SAP**, meanwhile, would allocate the same rating regardless of location.

(Another point worth noting – although not applicable to the actual property tested for this research – is the discrepancies between U-values predicted by some software packages and U-values established by in-situ testing for some building elements. Previous testing carried out by Historic Scotland in collaboration with Changeworks for their Energy Heritage project[11] measured the U-value of a basement-level concrete floor at 3.6, however **NHER Surveyor** has an in-built default U-value of 0.4 for the same floor, while **RdSAP** assumes a U-value of 1.2 for a concrete floor. These are considerable differences, which would affect the accuracy of any subsequent energy efficiency rating.

[11] The full Energy Heritage report can be found at www.changeworks.org.uk/uploads/83096-EnergyHeritage_online1.pdf

Similarly, while not necessarily being directly applicable to the property tested for this research, it should be noted that the relatively low ‘floor/external wall area’ ratio of most tenement flats is not accurately accounted for by some software packages. Again, this can lead to distorted energy ratings which may not be fully representative of the actual property.)

As this report shows, by using a large dataset through **NHER**, the tenement flat in question almost reaches the ratings required for new build properties; the accuracy of this result should be questioned. **RdSAP**, on the other hand, showed a result further away from that expected from a new build property. The **EPC**, in turn, gave the property in question an energy efficiency banding of D, which is above average when compared with the present average rating of domestic properties in England. It should also be noted that the **EPC** predicted the maximum energy efficiency banding possible for the property in question (following various improvement measures) to be a C.

The most common **NHER** rating for domestic properties in Scotland is 7[12], which is defined as ‘good’ in terms of energy efficiency by the Scottish Government[13]. 7 is also the mean **NHER** rating for tenements – the highest mean **NHER** rating of any Scottish dwelling type[14]. The property in question achieved an average **NHER** rating of 6.8; it could therefore be taken from this that the property is almost ‘good’ in terms of energy efficiency. However, it also raises the question of whether an **NHER** of 7 is truly indicative of an energy efficient property.

7.1 Future developments

It may be that there will be a trend towards using **RdSAP** for existing housing, with the building’s energy performance rating restricted by the dataset and set values.

It might be a valuable exercise to carry out a detailed study of typical traditional Scottish housing – particularly tenements – to reinforce the findings from this one Edinburgh tenement flat. Either existing data could be collected, or new data gathered through site surveys.

There also seems to be a case for further research into U-values of typical Scottish domestic properties, rather than continuing to rely on the current default values based on construction and age bands.

A Scottish-specific energy model could be designed, taking into account the unique property types such as tenements that are common across Scotland but nonexistent elsewhere in the UK. This could incorporate dimensional data of typical building archetypes, particularly tenements. It is the opinion of the authors that **NHER** and **SAP** can be more accurate for traditional properties built between the 1930s and 1970s, where more data is available, than for older (pre-1919) traditionally built Scottish housing.

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[12] Source: *Scottish House Condition Survey – Key Findings 2005/06* (The Scottish Government, 2007).
[13] *Ibid*. **NHER** ratings are divided into three energy efficiency bandings: 0-2 = ‘Poor’; 3-6 = ‘Moderate’; 7-10 = ‘Good’.
[14] *Ibid*.

Appendix 1: The RdSAP modelling process

A Scottish version of **RdSAP** software was not available at the time of surveys and preparing this report. It is anticipated that there will be a version by 1 December 2008, in time for the implementation of **EPCs** in the rental sector on 4th January 2009. The data was therefore processed using an English and Welsh version, used for the Building Research Establishment's (BRE) accreditation courses and designed by Quest software.

The main differences between the software designed for England and Wales and the software designed for Scotland are the programme defaults for wall U-values and building regulations. To overcome this, the available software had to be manipulated to:

i. achieve a wall U-value of the 1.3 W/m^2K baseline, and
ii. make the correct assumptions on window areas.

i. In the English and Welsh version used for this research, the U-Value for a sandstone wall of the same period as the surveyed property is 2.1 W/m^2K. The software contained no wall U-values that could be substituted to achieve the 1.3 W/m^2K baseline. However, in the software a 1967-1975 cavity wall had a default U-value of 1.6 W/m^2K, and a 1976-1982 cavity wall had a U-value of 1.0 W/m^2K. In order to achieve an accurate U-value for the surveyed property wall, therefore, the surveyor 'created' two exposed walls using these two cavity wall default values, in order to achieve an average of the baseline. The exposed wall perimeters were halved, and one half assigned to each of these categories: one as a main wall and the other, an extension.

ii. In **RdSAP**, window areas are calculated by the age of the property and the exposed wall perimeters unless they are "much more than typical" or "much less than typical". If they fall into either of these categories, they have to be input manually. As the property surveyed for this research was built well before the above age bands, the actual measurements were input.

It is anticipated that the results generated for this research will be very close to those generated by the Scottish version of the software. It should however be noted that the Scottish version will use an updated version of the software, **RdSAP 9.82** (as opposed to **RdSAP 9.80** which was used for this exercise).

Appendix 2: Sample Energy Performance Certificate

Energy Performance Certificate

Address of dwelling and other details

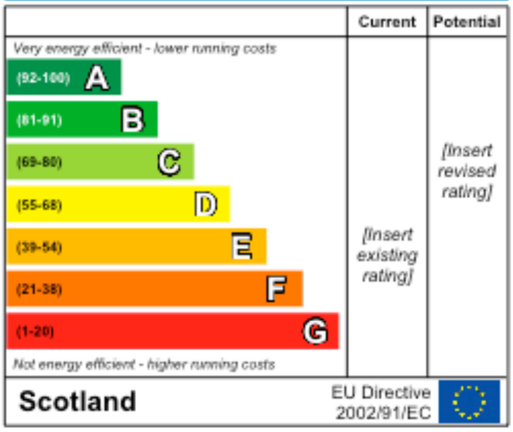
100 Any Street,
Anyvillage,
Anywhere,
XY1 Z2

Dwelling type:	*[e.g. Detached house]*
Name of protocol organisaton:	*[if applicable, otherwise N/A]*
Membership number:	*[if applicable, otherwise N/A]*
Date of certificate:	
Total floor area:	
Main type of heating and fuel:	*[e.g. air-source heat pump, electric]*

This dwelling's performance rating(s)

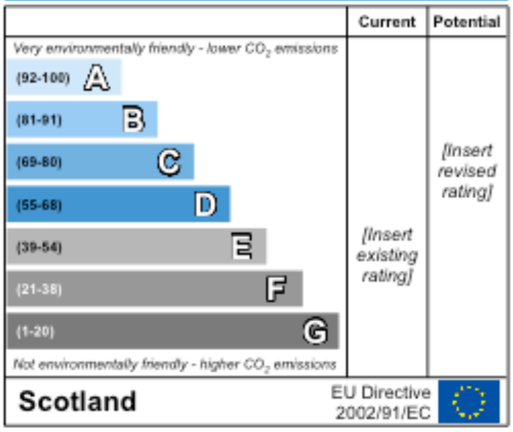
This dwelling has been assessed using the *[insert methodology calculaton tool e.g. SAP]*
Its performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs* and environmental impact based on carbon dioxide (CO_2) emissions. Carbon dioxide is a greenhouse 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.

Environmental 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 m² of floor area: *[insert in kWh/m² per year]*

Approximate current CO_2 emissions: *[insert in kg/m² 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 table(s) above.

1. *[e.g. Fit 100% low energy lighting]*
2.
3.

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

[A full energy report is appended to this certificate]*

* Requirement for dwellings subject to 'Single Survey' - optional for Scottish building regulations

Appendix 3: NHER modelling results

Figure i: NHER results

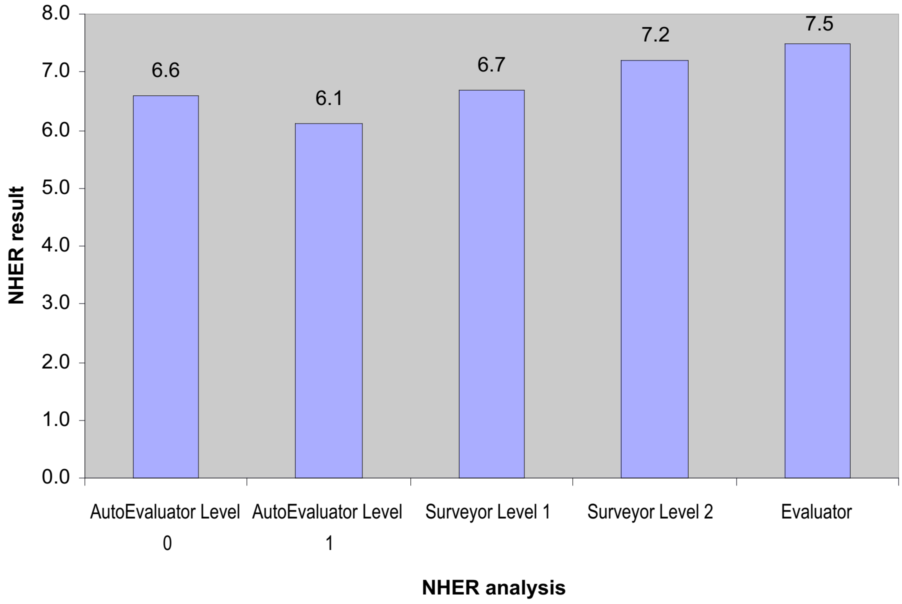


Figure ii: SAP results

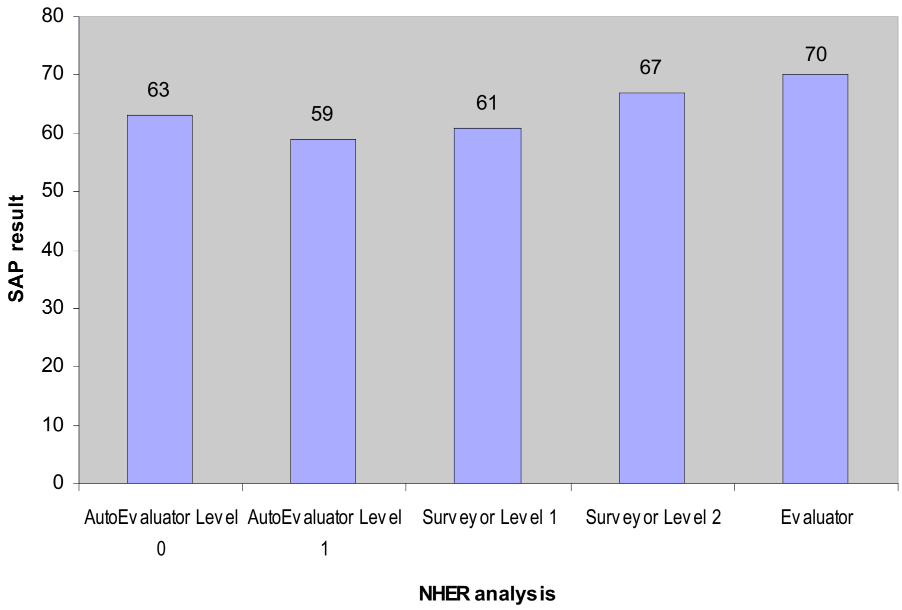


Figure iii: Estimated annual running costs

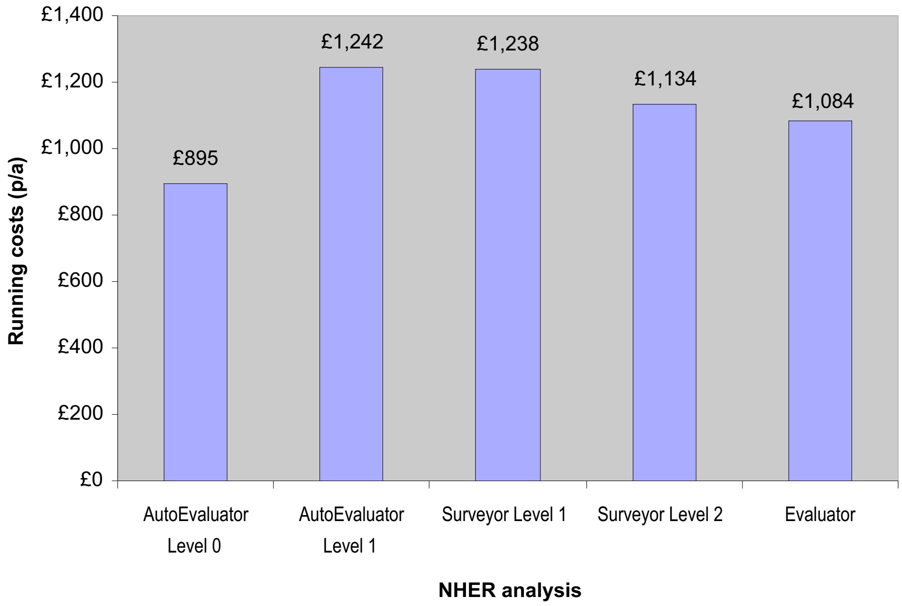


Figure iv: Estimated annual CO_2 emissions

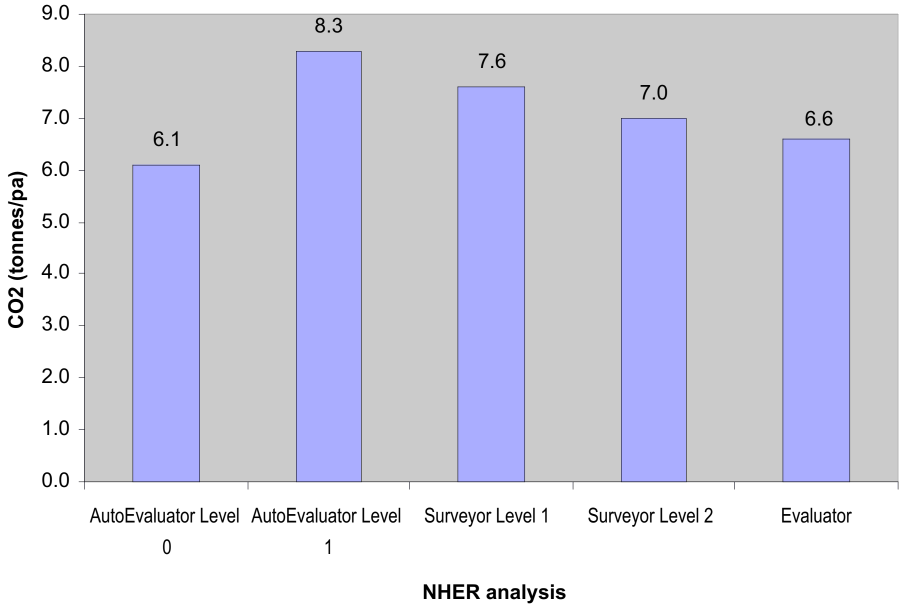
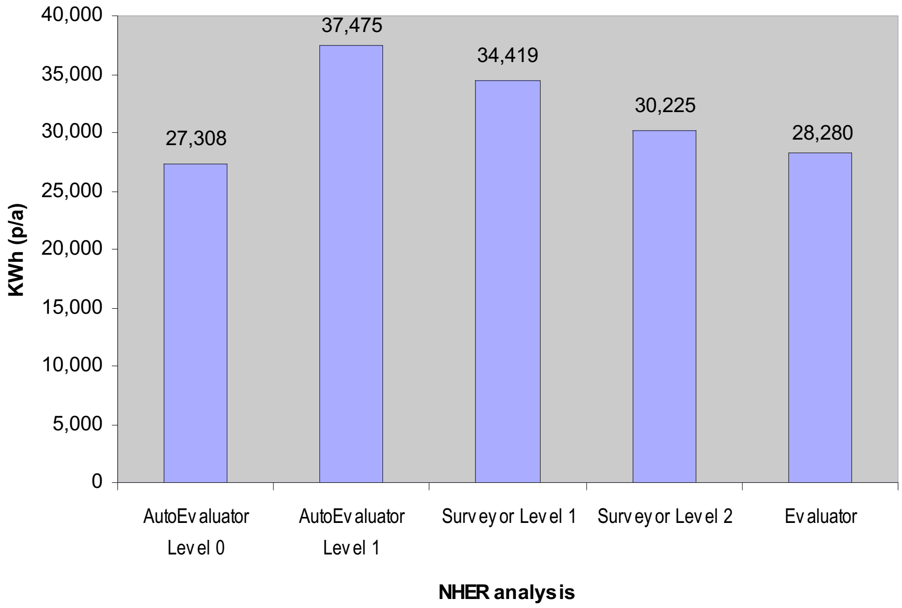


Figure v: Estimated annual energy usage



Appendix 4: Theoretical Energy Performance Certificate for surveyed property

The following Energy Performance Certificate was produced using the English and Welsh version of the RdSAP software; as such it should be considered theoretical only.

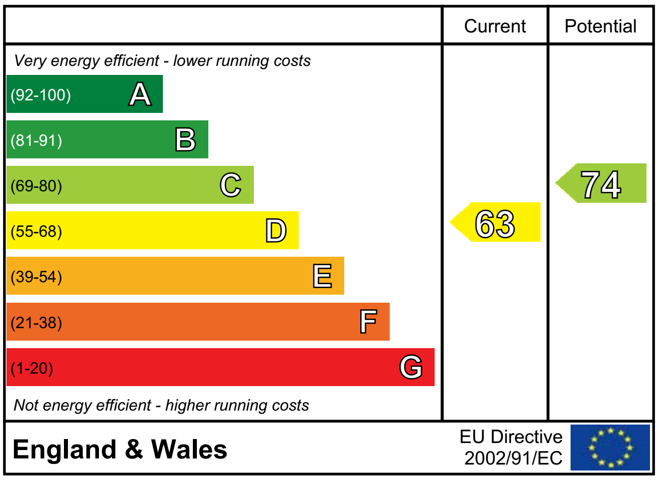
Energy Performance Certificate

For Training Purposes Only

34 (3f1) Lauriston Place Edinburgh EH3 9EZ	Dwelling type: Top-floor flat Date of assessment: 29 August 2008 Date of certificate: 22 October 2008 Reference number: 5502-1113-3220-7424-1883 Total floor area: 130 m²

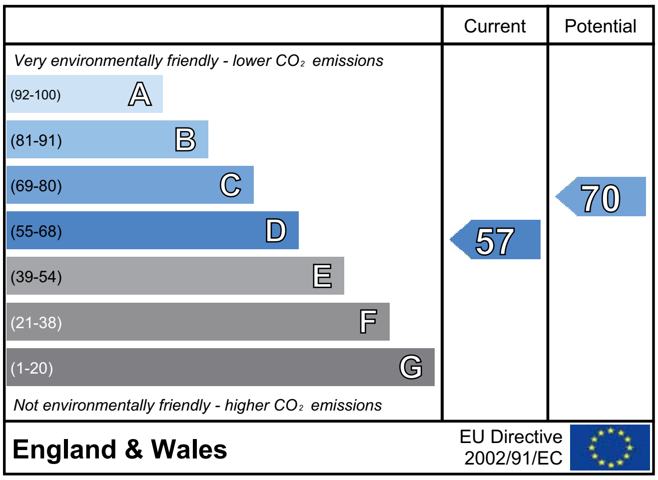
This home's performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (CO_2) emissions.

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 will be.

Environmental Impact Rating (CO_2)



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.

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

	Current	Potential
Energy use	257 kWh/m² per year	183 kWh/m² per year
Carbon dioxide emissions	5.6 tonnes per year	4.0 tonnes per year
Lighting	£86 per year	£63 per year
Heating	£652 per year	£470 per year
Hot water	£125 per year	£109 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 saving recommendations will evolve.

To see how this home can achieve its potential rating please see the recommended measures.

Remember to look for the energy saving recommended logo when buying energy efficient product. It's a quick and easy way to identify the most energy efficient products on the market.
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

About this document

The Energy Performance Certificate for this dwelling was produced following an energy assessment undertaken by a qualified assessor, accredited by ???, to a scheme authorised by the Government. This certificate was produced using the RdSAP 2005 assessment methodology and has been produced under the Energy Performance of Buildings (Certificates and Inspections)(England and Wales) Regulations 2007. A copy of the certificate has been lodged on a national register.

Assessor's accreditation number:	GARY232323
Assessor's name:	Gary Pearson
Company name/trading name:	???
Address:	???
Phone number:	???
Fax number:	
E-mail address:	
Related party disclosure:	

If you have a complaint or wish to confirm that the certificate is genuine

Details of the assessor and the relevant accreditation scheme are on the certificate. You can get contact details of the accreditation scheme from our website at together with details of their procedures for confirming authenticity of a certificate and for making a complaint.

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. The average energy efficiency rating for a dwelling in England and Wales is band E (rating 46).

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 building. Different methods of calculation are used for homes and for other buildings. Details can be found at www.communities.gov.uk/epbd

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 every day measures that will save money, improve comfort and reduce the impact on the environment, such as:

- 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.

Visit the Government's website at www.communities.gov.uk/epbd to:

- Find how to confirm the authenticity of an energy performance certificate.
- Find how to make a complaint about a certificate or the assessor who produced it.
- Learn more about the national register where this certificate has been lodged.
- Learn more about energy efficiency and reducing energy consumption.

Recommended measures to improve this home's energy performance
For Training Purposes Only

34 (3f1) Lauriston Place
Edinburgh
EH3 9EZ

Date of certificate: 22 October 2008
Reference number: 5502-1113-3220-7424-1883

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.

Elements	Description	Current performance	
		Energy Efficiency	Environmental
Walls	Cavity wall, as built, no insulation (assumed) Cavity wall, as built, partial insulation (assumed)	Poor Average	Poor Average
Roof	Pitched, 200 mm loft insulation	Good	Good
Floor	(other premises below)	-	-
Windows	Single glazed	Very poor	Very poor
Main heating	Boiler and radiators, mains gas	Good	Good
Main heating controls	Programmer, room thermostat and TRVs	Average	Average
Secondary heating	Room heaters, mains gas	-	-
Hot water	From main system	Good	Good
Lighting	Low energy lighting in 63% of fixed outlets	Good	Good
Current energy efficiency rating		D 63	
Current environmental impact (CO_2) rating			D 57

Recommendations

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.

Lower cost measures (up to £500)	Typical savings per year	Performance ratings after improvement Energy efficiency	Environmental
1 Cavity wall insulation	£138	C 70	D 65
2 Low energy lighting for all fixed outlets	£19	C 71	D 66
Sub-total	**£157**		
Higher cost measures			
3 Replace boiler with Band A condensing boiler	£64	C 74	C 70
Total	**£221**		
Potential energy efficiency rating		C 74	
Potential environmental impact (CO_2) rating			C 70

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.

4 Replace single glazed windows with low-E double glazing	£58	C 76	C 73
Enhanced energy efficiency rating		C 76	
Enhanced environmental impact (CO_2) rating			C 73

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

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 Cavity wall insulation

Cavity wall insulation, to fill the gap between the inner and outer layers of external walls with an insulating material, reduces heat loss. The insulation material is pumped into the gap through small holes that are drilled into the outer walls, and the holes are made good afterwards. As specialist machinery is used to fill the cavity, a professional installation company should carry out this work, and they should carry out a thorough survey before commencing work to be sure that this type of insulation is right for this home. They should also provide a guarantee for the work and handle any building control issues. Further information can be obtained from National Cavity Insulation Association (http://dubois.vital.co.uk/database/ceed/cavity.html).

2 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.

Higher cost measures (typically over £500 each)

3 Band A condensing boiler

A condensing boiler is capable of much higher efficiencies than other types of boiler, meaning it will burn less fuel to heat this property. This improvement is most appropriate when the existing central heating boiler needs repair or replacement, but there may be exceptional circumstances making this impractical. Condensing boilers need a drain for the condensate which limits their location; remember this when considering remodelling the room containing the existing boiler even if the latter is to be retained for the time being (for example a kitchen makeover). Building Regulations apply to this work, so your local authority building control department should be informed, unless the installer is registered with a competent persons scheme[1], and can therefore self-certify the work for Building Regulation compliance. Ask a qualified heating engineer to explain the options.

About the further measures to achieve even higher standards

Further measures that could deliver even higher standards for this home

4 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 Regulations apply to this work, so either use a contractor who is registered with a competent persons scheme[1] or obtain advice from your local authority building control department.

[1] For information on competent persons schemes enter "existing competent person schemes" into an internet search engine or contact your local Energy Saving Trust advice centre on 0800 512 012.

Reduced Data SAP 2005 Input Data Summary

34 (3f1) Lauriston Place		Located in:	England & Wales
Edinburgh		Date of assessment:	29 August 2008
EH3 9EZ		Date of certificate:	22 October 2008
		UPRN:	1234512345
		Reference number:	5502-1113-3220-7424-1883

Language

ENGLISH

Property overview

Dwelling type:	Flat	Main property age:	1967 - 1975
Built form:		Extension 1 age:	1976 - 1982
Habitable rooms:	4	Perimeters and areas:	Internal
Heated habitable rooms:	4		

Main property construction

Lowest floor	area = 65.2	room height = 3.15	perimeter = 19.35
Wall construction	Cavity with insulation as built		
Roof construction	Pitched, insulation at joists which is 200 mm thick		

Extension 1 construction

Lowest floor	area = 65.2	room height = 3.15	perimeter = 19.35
Wall construction	Cavity with insulation as built		
Roof construction	Pitched, insulation at joists which is 200 mm thick		

Windows

Area of windows:	More than typical
Double glazing:	None
Measured windows:	6
Window 1	Single glazed in the main property with an area of 2.42
Window 2	Single glazed in the main property with an area of 4.84
Window 3	Single glazed in the main property with an area of 0.71
Window 4	Single glazed in extension 1 with an area of 2.64
Window 5	Single glazed in extension 1 with an area of 2.9
Window 6	Single glazed in extension 1 with an area of 2.42

Shelter factors (flats and maisonettes only)

Floor number:	3	Flat corridor:	Unheated
Floors in block:	4	Heat loss floor:	Other flat below
Sheltered wall length:	6.2 m		

Space heating and controls

Database Reference No:	8575 - Potterton Suprima 50L: gas:regular:non-condensing:wall mount:BF:fan:no pilot
Heat emitter:	
Boiler flue type:	Balanced flue
Boiler fan type:	Fan assisted
Main heating controls:	2106 - BOILER SYSTEM WITH RADIATORS OR UNDERFLOOR HEATING, Programmer, room thermostat and TRVs
Secondary heating:	603 - Gas (including LPG) room heater, Gas fire, open flue, 1980 or later (open fronted), sitting proud of, and sealed to, fireplace
Secondary heating fuel:	1 - Gas, mains gas

Water heating and cylinder

Water heating:	901 - From main heating system		
Water heating fuel:	1 - Gas, mains gas		
Solar panel:	No	Immersion type:	
Cylinder present:	Yes		
Cylinder size:	Normal	Cylinder insulation type:	Factory applied
Cylinder insulation:	50 mm	Cylinder thermostat:	Yes

Miscellaneous

Open fireplaces:	0	Photovoltaic cells:	0%
Ventilation type:	Natural	Low energy lights:	63%
Electricity meter:	Single	Main gas supply:	Yes

Measures

Selected:
Cavity wall insulation (B)
Low energy lights (E)
Upgrade boiler, same fuel (I)
Double glazing (O)

Cancelled:

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