Technical Paper 17

HISTORIC SCOTLAND
ALBA AOSMHOR

Green Deal, Energy Company Obligation and traditional buildings

Stuart Hay, Nicholas Heath & Gary Pearson

CHANGEWORKS

The views expressed in the research report(s) presented in this Historic Scotland Technical Paper are those of the authors and do not necessarily represent the views of Historic Scotland or the Scottish Government.

This Technical Paper is available as web publication for free download from the Historic Scotland website:
www.historic-scotland.gov.uk/technicalpapers

This Technical Paper should be quoted as:
Historic Scotland Technical Paper 17

ISBN 978 1 84917 125 0

This paper was published by Historic Scotland, an executive agency of the Scottish Government.

You can contact us at:

Historic Scotland
Conservation Directorate
Longmore House
Salisbury Place
Edinburgh EH9 1SH

Phone 0131 668 8600
Email hs.conservationgroup@scotland.gsi.gov.uk
Web www.historic-scotland.gov.uk/conservation

v1.1

We welcome your comments

If you have any comments or queries about our Technical Papers or would like to suggest topics for future papers, please do get in touch with us either by email at hs.conservationgroup@scot.gov.uk or by phone on 0131 668 8660.

Historic Scotland Technical Paper 17

Green Deal, Energy Company Obligation and traditional buildings

Stuart Hay, Nicholas Heath & Gary Pearson

Contents

Introduction

by Historic Scotland

This Technical Paper, a reworking of the earlier material issued in Technical Paper 16, seeks to further update homeowners and building professionals on some of the considerations when planning Green Deal measures in older buildings. This is a new retrofit area in terms of scope and aspiration and as such the guidance and associated regulations for Green Deal providers and the subsequent procurement chain is still evolving. This new paper, complementary to Technical Paper 16, looks in more depth at the developing range of measures and financial structures that govern the delivery of the Green Deal as well as considerations regarding the provision of measures under the ECO funding stream.

In a report of this nature there are a range of variables, and it does not seek to be definitive, nor could it be so. One key variable in the delivery of the ECO finance is the price of CO_2 paid by the Utility Companies. This price varies: DECC's official estimate of future costs of meeting the Carbon Emissions Reduction Obligation was £77.00 per tonne of CO_2 in 2012, however ECO brokerage auctions have seen this figure rise to more than £120.00 per tonne in March 2013. For the purposes of this report, both figures were modelled to provide a comparison giving both a base and a current ceiling.

The properties used by Historic Scotland in Technical Paper 16 have still been used, but an additional property (a granite cottage in Aberdeenshire) has been included in the modelling, following refurbishment work commissioned by a private owner where cost control and monitoring were a high priority. In order to explore fully the potential for Green Deal measure in traditional buildings, some interventions in the properties are virtually modelled: that is, they were modelled using the building's key characteristics, and not actually installed. The relevant Refurbishment Case Studies should be consulted for details of the actual measures installed and the measured improvements. The measures described in this paper are also considered in more technical detail in The Historic Scotland Short Guide 1 "Fabric Improvements for energy efficiency in traditional buildings".

It should also be noted that the building modelling software for the Green Deal, RdSAP, is itself being adjusted and tuned to the evolving needs of the Green Deal. A Technical Paper will be issued in due course that discusses RdSAP in more depth and its use on older traditionally built structures and considers areas for further improvement. For example, at present biomass is fully modelled by RdSAP but with assumed efficiency levels that are in reality exceeded by many systems, and as such the figures given in this report are conservative. This has implications for owners planning retrofit work in rural areas where biomass might be a viable option.

While this report suggests that the range of measure that can be funded for installation in older properties is limited, it must also be borne in mind that this will also be the case for much of the housing stock. The cost and commitment required for home refurbishment is considerable, wherever you live - in a modern or a traditionally built home.

Executive Summary

by Changeworks

This report analysed three traditional property types common across urban and rural Scotland, modelling comprehensive upgrade packages and identifying opportunities for financial support through the Green Deal and Energy Company Obligation (ECO). Most calculations were made prior to the activation of these finance streams (January 2013); some details may therefore be subject to change.

It was found that, for these three properties, the Green Deal would only meet a relatively small proportion (c.20%) of the capital costs without subsidy.

ECO, the subsidy designed to work alongside the Green Deal, meets a further proportion (c.40%) of the costs for only one of the properties. However, between 20% and 40% (depending on the ECO price) of the capital costs would still require alternative funding, unless: a) the cost of the measures could be reduced (this may be difficult in the short to medium term); b) some measures were withdrawn from the upgrade package; or c) the

levels of ECO were considerably increased from current prices. This is based both on the Department of Energy and Climate Change (DECC)'s initial estimated costs of CO_2 at £77 per tonne, and on recent ECO brokerage auctions that have seen prices around £120 per tonne. DECC's estimate seems likely to be an underestimate, as more support is likely to be needed to fully fund these projects without a householder (or other) contribution. Changes in the price of CO_2 may allow greater convergence towards a fundable package, but even with the current high at around £120, there still remains a gap in funding that for many householders could prove hard to meet.

No ECO would be available for either of the other two properties through the Carbon Emissions Reduction stream (CERO), as the solid wall insulation specified fails to meet the U-value requirement (0.30 or less) of the ECO legislation. Failure to access ECO for solid wall insulation means that no other measures would be able to access this stream of ECO. It also leaves one of the most expensive measures without support.

ECO may be available through the other streams – Home Heating Cost Reduction Obligation (HHCRO) and Carbon Saving Communities Obligation (CSCO) – given the right householder situation. However it is notable that the largest stream of ECO – and the one designed to address hard-to-treat housing – is of limited applicability for these properties.

Higher-specification solid wall insulation may meet the minimum U-value requirement of ECO. However based on recent research some such materials may be of questionable suitability for traditional mass masonry walls.

Glazing improvements also tend to be among the most expensive upgrade options, particularly in Scottish traditional housing where window sizes can be considerable. However, no ECO subsidy is likely to be available unless Building Standards performance levels are exceeded, and where ECO is available the levels will be negligible. This further restricts the subsidy opportunities for traditional households.

ECO subsidy levels will be very sensitive to the make-up of the upgrade package. Measures with high savings will be important to include in order to make higher-cost measures viable. Biomass boiler systems in particular are not likely to be subsidised by ECO. However they will receive benefits via the Renewable Heat Incentive. Overall, there are limitations in how the RdSAP software models these systems and assessors would benefit from more flexibility in specifying system efficiencies and fuel types beyond the narrow range of defaults available.

Traditional properties, particularly those on the gas network, may be less attractive for installers, as utility companies may focus on subsidising easier/cheaper-to-treat property types off the gas network where greater CO_2 savings can be created at a lower cost.

Where a Green Deal loan is taken out over the maximum lifetime of 20 years, at interest rates suggested in recent Government publications the total interest repayable is likely to be approximately equal to the loan sum. These relatively high interest rates may be off-putting to some consumers, and limit the total amount that may be borrowed through a Green Deal loan.

The measures qualifying for Green Deal finance without subsidy are typically low-cost upgrades. Given the small sums involved it is unlikely that Green Deal loans will be taken out to cover these measures by the majority of bill payers, with the exception of those that can't meet the upfront costs. Within some packages these measures may generate 'surplus' Green Deal finance, as they would save more over their lifetime than they cost to install (e.g. loft insulation). Low-cost measures such as loft insulation could therefore provide sufficient savings to support additional borrowing potential under the Green Deal's Golden Rule as well as additional ECO funding. However, it will become increasingly difficult for utility companies to find virgin lofts to insulate, making packages more expensive overtime.

The software tool behind the Green Deal finance calculations, RdSAP, has been enhanced with the introduction of the Green Deal. While some improvements will be noticed, one of the critical weaknesses remains the reliance of most assessors on default U-values. The difference between default and calculated U-values is highlighted in this report (and other research), together with their impact on finance levels available and whether savings are likely to be realised in practice. While calculated U-values may be entered in place of the default figures, there are two considerable barriers to uptake: a) this is only optional, and b) there are specific requirements for entering an additional U-value calculation (see Section 3.3). It seems unlikely these will be entered for the majority of Scottish properties in the near future. The situation would be improved if the use of calculated and *in situ* U-values were facilitated, as the predicted impacts of upgrading traditional buildings would become more accurate. In addition, some measures that are technically compatible with older building fabric are not listed by RdSAP as being eligible; further work is needed to develop wider material/measure selection options for GD and ECO measures.

Significant subsidy is needed if traditional properties are to be retrofitted to make significant CO_2 and running cost savings. The level of ECO available is critical if households are to avoid having to pay upfront costs. In their current form, however it seems unlikely that the Green Deal and ECO alone will provide sufficient subsidy to achieve this, particularly as subsidy opportunities are limited for common wall and window upgrades.

These barriers could to some degree be removed by alleviating the tight restrictions on solid wall insulation and glazing improvements. Relaxing the maximum U-value for solid wall insulation would allow more systems to qualify for ECO, including the less disruptive and lower-cost options such as blown bead insulation. Likewise, removing the U-value restriction of 1.6 on glazing improvements would allow the poor performance of single glazing to be recognised together with the impact of the most likely improvement measures.

The costs of substantial upgrades are shown to be considerable; it is unlikely that many householders will have the means (or motivation) to invest in improving their property's energy efficiency or environmental impact. In conclusion, the costs of measures will have to fall below those identified by Historic Scotland, or the level of ECO will have to rise substantially to see a significant rise in the number of properties insulated.

About the authors

Stuart Hay has led Changeworks consultancy efforts developing a diverse range of energy related projects including development of insulation schemes and innovative approaches to energy conservation in historic buildings and the deployment of micro-renewables in social housing since 2008. His role involves delivery of key aspects the City of Edinburgh Council's Energy Efficiency Strategy. Significant projects include delivering fuel poverty intervention pilot for the Intelligent Energy Europe and research for the eaga charitable Trust and Joseph Rowntree Foundation.

Nicholas Heath is a Senior Consultant at Changeworks, where he has worked since 2006. He has developed and led award-winning research and demonstration projects on energy efficiency and renewable energy in traditional and historic buildings across Scotland, and presented his work with Changeworks internationally. Project partners have included Historic Scotland, the Energy Saving Trust, Consumer Focus Scotland, the Joseph Rowntree Foundation, and various local authorities, housing associations and community organisations. With a background in social housing and sustainable energy, the main focus of his current work is energy performance, retrofit and behavioural issues surrounding older, traditionally built, hard-to-treat housing.

Gary Pearson joined Changeworks in 1998. His current role at Changeworks is Surveyor and Data Analyst, with a focus on hard-to-treat housing. He has conducted energy analysis using a variety of energy rating tools (including NHER, SAP and RdSAP), delivers EPCs and has written detailed reports on energy modelling. This has been carried out on a wide range of domestic properties, from single units to entire housing stocks. Gary has also written reports for a wide range of clients ranging from community groups to the Scottish Government. He is currently leading on the development of Changeworks' Carbon HEART stock analysis tool.

Contents

1. Introduction and context

This report revisits Historic Scotland's Technical Paper 16: Green Deal financial modelling of a traditional cottage and tenement flat, which explored the Green Deal in relation to traditional buildings in early 2012. Technical Paper 16 should be referred to for a more detailed overview of the background and issues surrounding the financing of energy efficiency in traditional buildings. However, significant changes to the Green Deal and Energy Company Obligation (ECO) have been made since then, and the likely funding arena is substantially different. This report therefore provides an up-to-date analysis of the applicability and limitations of the Green Deal and ECO for traditional properties in Scotland. The aim of the research was to assess the overall viability of these finance schemes for traditional properties, where upgrade costs tend to be high and specialist measures may sometimes be needed, and to identify the level of subsidy likely to be available for such upgrades.

Energy and financial modelling and analysis have been applied to a range of traditional property types. For each, key variables are identified and tested to identify the potential availability and impact of financial support through the Green Deal and ECO. Key updates and areas of analysis since Technical Paper 16 are as follows:

- A third property type (a granite cottage) is included, to increase the representation of typical traditional property types in Scotland
- The new version of RdSAP – the Energy Performance Certificate (EPC) software package that will be used for Green Deal Assessments – is used to re-model all property types
- EPC ratings are provided alongside cost and CO_2 impacts for each measure, to inform future minimum energy efficiency standards for housing
- 'In Use Factors' – the fixed percentage reduction applied to predicted savings for all energy efficiency measures funded via the Green Deal
- Measures applied in practice by Historic Scotland are assessed in light of the confirmed list of measures eligible for Green Deal and ECO finance
- Measures are tested against the different streams of ECO
- The likely level of ECO subsidy is identified, and compared against DECC and utility projections, to identify the necessary cost per tonne of CO_2 required for upgrade measures in traditional housing
- The effect of different heating patterns is tested, to identify how occupancy lifestyle will affect the viability of Green Deal finance
- Overall scope for Green Deal and ECO finance is assessed.

It should be noted that this report was prepared shortly before the Green Deal came into active force (January 2013), and some aspects of the Green Deal and ECO are likely to continue to change in the short term, including the price per tonne of carbon saved.

1.1 The Green Deal

The Green Deal[1] is the UK Government's flagship policy to drive an increased uptake in energy efficiency measures. Through the Green Deal, households and business can install energy efficiency measures at no upfront cost (with the possible exception of a one-off cost for the initial assessment). Instead, they will pay for the installation costs through regular payments on their energy bill over a period of up to 25 years. Repayments are tied to the property rather than the occupants. Crucially, the 'Golden Rule' aims to ensure that the repayments do not exceed savings on energy bills as a result of the energy efficiency improvements. This means, in theory, that the householder would not be worse off than previously – however it must be recognised that the repayments are based on predicted rather than actual savings.

Some measures, which do not meet the Golden Rule without support, will still be eligible under the Green Deal. These are expected to receive funding through the Energy Company Obligation (ECO). This includes expensive measures in hard-to-treat housing, and places significant emphasis on solid wall insulation (a contentious issue for traditional buildings in light of recent and ongoing research[2]).

Households interested in the Green Deal will have a Green Deal Assessment carried out on their home by a certified Green Deal assessor. This will include a technical assessment (using RdSAP) to identify suitable upgrade measures, and an occupancy assessment to identify how behaviour could impact on actual savings.

Whilst Green Deal legislation was laid down in late 2012, finance packages will not be available until at least the end of January 2013. Although the Department for Energy and Climate Change (DECC) has published much guidance on the policies, many aspects of the policy are market driven (for example, the interest rates applied to packages or level of ECO funding) and are yet to be confirmed.

---

[1] Green Deal Quick Guides; The Green Deal and Energy Company Obligation: Government Response to the November 2011 Consultation (DECC, 2012); Green Deal Provider Guidance (DECC, 2012); Final Stage Impact Assessment for the Green Deal and Energy Company Obligation (DECC, 2012)

[2] Solid wall insulation in Scotland: Exploring barriers, solutions and new approaches (Changeworks 2012); http://www.changeworks.org.uk/projects/solid-wall-conference/640/

1.2 Energy Company Obligation (ECO)

ECO[3] will operate alongside the Green Deal, placing an obligation on energy companies to reduce the fuel bills of low-income households and to secure CO_2 savings from hard-to-treat housing. The following description (adapted from a recent economic report on ECO[4]) provides a clear outline of the different streams:

'The ECO consists of an obligation to surrender a given number of "ECO Points" between January 2013 and March 2015. Energy companies can earn ECO points [by investing in housing energy efficiency measures] from three schemes:

- ***Carbon Emissions Reduction Obligation** (CERO)][5]: an obligation to reduce lifetime carbon emissions from private households by 20.9 $MtCO_2$ (20.9 million tonnes of carbon dioxide) using a restricted range of relatively expensive insulation measures in harder-to-treat homes (solid wall insulation and "hard to treat" cavity wall insulation) [other measures can be installed alongside one of these measures as part of a package];*
- ***Carbon Saving Communities Obligation** (CSCO): an obligation to reduce emissions by 6.8 $MtCO_2$ by insulating any housing within defined low income areas [the bottom 15% areas of multiple deprivation – data zones in Scotland – although 20% can be delivered in adjoining areas], for which suppliers may use a wide range of insulation measures plus connections to district heating systems; suppliers will be obliged to deliver 15% of their overall CSC to rural, low-income settlements with a population size under 10,000;*
- ***Home Heating Cost Reduction Obligation** (HHCRO)[6]: an obligation to help customers (living in private tenure and in receipt of qualifying benefits) save £4.2 billion on their 'notional' energy bills using the full range of energy efficiency measures [including measures such as loft and cavity insulation, heating upgrades and district heating];*

DECC assumes that energy companies pay the full cost of insulation installed under the HHCRO scheme. Under the [CERO] and CSCO, domestic customers pay some of the costs of their insulation. However, they are eligible for the "Green Deal", whereby they take out a loan which they repay through a surcharge on their electricity bills. Their contribution is capped at a level intended to ensure they save money overall. Energy suppliers pay the rest.'

---

[3] http://www.ofgem.gov.uk/Sustainability/Environment/ECO/Pages/index.aspx; ECO Quick Guide; Energy Companies Obligation (ECO) 2012 - 15: Guidance for Suppliers

[4] The Costs of the Energy Company Obligation (NERA Economic Consulting, 2012)

[5] Also referred to as the **Carbon Reduction Obligation** or **Carbon Saving Obligation**, depending on the source.

[6] Also referred to as the **Affordable Warmth Obligation**, depending on the source.

A full list of eligible measures is included at Section 7. The largest stream is the CERO obligation with an estimated 58% of the total ECO funding. Solid-walled properties are therefore likely to be a focus for this stream, presenting potential opportunities for occupants of traditional housing.

Green Deal Providers are not obliged to let customers know the levels of ECO they are receiving from energy companies for their Green Deal improvement packages. As such it may be difficult to assess the calculations in this report against real-life situations, as Providers may or may not provide this information on request.

1.3 Meeting additional costs

Where costs are not fully met by Green Deal and ECO, the balance must be paid from other sources. This may include self-finance or a bank loan, or could include other subsidy. Under ECO, for example, measures may be jointly funded by a third party such as a local council or Devolved Administration – in Scotland, households may benefit from Scottish Government funding from the Home Energy Efficiency Programmes for Scotland (HEEPS). The following statement has been provided by the Scottish Government for this report:

'In 2013/14 the Scottish Government is spending £79m on tackling fuel poverty and improving the energy efficiency of the housing stock. £60m of this funding will be available to Councils through area-based schemes and it is our intention to lever in at least £120m of ECO funding from utility companies. Scottish Government funding is directed in particular to the private sector and homeowners will be able to benefit from schemes Councils run in their area. In developing schemes to tackle fuel poverty Councils should consider the range of measures needed to improve properties and, by maximising ECO funding from utility companies and Scottish Government funding, ensure any costs to the homeowner are as low as possible. In some cases homeowners may wish to use the Green Deal as an additional funding source.'

2. Key issues

As mentioned in the Introduction, the Green Deal and ECO methodologies have changed considerably in the past 12 months. These changes will affect the calculation processes and the figures provided in Technical Paper 16. This Section outlines the key issues.

2.1 In-use factors

'In-use factors' have been applied to all predicted savings in this report. Within the Green Deal, DECC has decided to apply in-use factors to the savings predicted for different energy efficiency measures[7], effectively lowering the assumed CO_2 and financial savings. This is intended to make projections more accurate, accounting for increasing research showing that actual savings tend to be lower than those predicted. In-use factors will be applied to all measures installed through the Green Deal. Each measure has a different factor applied, as shown in the following table.

[7] How the Green Deal will reflect the in-situ performance of energy efficiency measures (DECC, 2012)

Domestic Measures	In-use factor (%)
Cavity Wall Insulation	35
Internal Solid Wall Insulation (pre-1966 solid brick walls)	33
Internal Solid Wall Insulation (all other solid walls)	25
External Solid Wall Insulation (pre-1966 solid brick walls)	33
External Solid Wall Insulation (all other solid walls)	25
Loft insulation (including loft hatch, rafter insulation)	35
Flat roof insulation	15
Room in roof insulation	25
Floor insulation	15
Heating controls	50
Non condensing to condensing gas or oil boiler	25
Biomass boiler	25
Biomass room heater	25
Flue Gas heat recovery device	10
Hot water cylinder insulation	15
Double Glazing	15
Secondary glazing	15
High thermal performance external doors	15
Draught-proofing	15
Cylinder thermostat	10
New or replacement storage heaters	10
Replacement warm-air unit	10
Waste water heat recovery devices	10
Solar water heating	0
Photovoltaic panel	0
Ground source heat pump	10
Air source heat pump	25
Micro CHP	25
Building mounted wind turbine	0

The benefit of applying in-use factors is that the savings quoted to householders should be more realistic. However, it will also reduce the number of measures meeting the Golden Rule without extra subsidy (e.g. ECO or self-finance).

2.2 RdSAP update

The data was processed using the new version of RdSAP (v9.91)[8]. This new version of RdSAP has been enhanced to allow EPCs to become part of the Green Deal. This has a number of updates compared to the previous version of the software[9]:

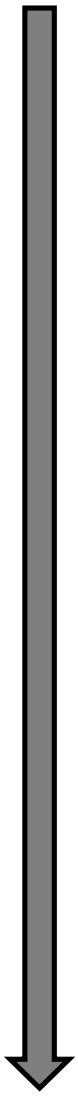
- EPCs show whether recommended measures meet the Golden Rule (using standardised costs, interest rates and lifetimes)
- More improvement measures are included (e.g. flat roof insulation, floor insulation and room-in-roof insulation may now be suggested)
- Measures are recommended in a specific order – and the savings predicted for measures assume that the preceding measures have been installed; see Section 5 for more details. The order of recommendations is replicated below, as it is important for those involved in traditional building retrofits to be aware of the recommendation process that EPCs will provide
- EPCs remain focused on the most cost-effective measures but now also mentions other, more expensive recommendations (e.g. heat pumps, biomass boilers) in a separate list to the main recommendations
- Location is factored into the assessment, using regional weather data to calculate costs and savings (previously, there were no regional variations)
- Additional data on walls shows whether they have hard-to-treat cavities and therefore require further investigation
- Additional data may be collected to make the assessment more accurate:
- Details of external walls (previously there were assumptions based on the property type)
- Details of heat recovery and micro-generation systems
- Proportion of draught-proofed windows and doors, and number of external doors (previously it was assumed that all double-glazed windows were draught-proofed and single-glazed windows were not)
- Wall thickness, the presence of a wall lining (e.g. lath and plaster or plasterboard) and additional wall insulation specifications can be entered (previously wall thickness was assumed, and dry lining was not recorded)
- Alternative walls for each part of the building (such as a wall between a room and unheated corridor) may be input, allowing partial wall insulation to be modelled
- Assessors will have the **option** to enter U-values of construction elements such as walls, windows and floors, where the U-value is known using documentary

[8]NES One on-line RdSAP EPC software. The revised version of RdSAP (v9.91) started being used in Scotland for EPCs from 1st October 2012.

[9]http://www.bre.co.uk/sap2009/page.jsp?id=2792 provides further details of RdSAP v9.91

evidence[10] (this is potentially significant, and is covered in more detail in the next Section).

The order of upgrade recommendations[11] is shown below.



1. Loft insulation
2. Flat roof insulation
3. Room-in-roof insulation
4. Cavity wall insulation
5. Internal or external solid wall insulation
6. Floor insulation
7. Cylinder jacket
8. Draught proofing
9. Low energy lighting
10. Cylinder thermostat
11. Heating controls (wet system)
12. Heating controls (warm air system)
13. Biomass boiler
14. Wood pellet stove and radiators
15. Biomass boiler (alternative)
16. Replacement condensing gas or oil boiler, same fuel
17. Condensing oil boiler (from warm air)
18. Condensing gas boiler (from gas fires)
19. Condensing gas boiler, fuel switch
20. Flue gas heat recovery in conjunction with new boiler
21. Replacement storage heaters
22. Replacement warm air unit
23. Solar water heating
24. Waste water heat recovery
25. Energy efficient glazing
26. Secondary glazing
27. Insulated doors

[10] 'This evidence shall be either: relevant building control approval … or a U-value calculation produced or verified by a suitably qualified person. Evidence of suitable qualification is through membership of a recognised U-value calculation competency scheme (BBA/TIMSA (UK)), OCDEA membership (England & Wales, Northern Ireland) or any other scheme formally agreed between Accreditation Schemes/Approved Organisations and Government.' (http://www.bre.co.uk/filelibrary/SAP/2009/RdSAP_Conventions.pdf)

11 Source: BRE (2012) Reduced Data SAP - amendments for 2012

2.3 Default vs calculated U-values

The discrepancy between default and calculated U-values is well documented. As the new version of RdSAP allows alternative U-values to be input, these were modelled for one of the property types (tenement flat) in order to assess the impact of Green Deal Assessors choosing to rely on the default figures rather than entering calculated U-values.

For the stone walls (600mm sandstone) the default U-value is 1.8, however Historic Scotland testing has shown this wall to have an *in situ* U-value of 1.25, meaning it performs better than the default U-value recognises (amending this in RdSAP reduces the predicted CO_2 emissions by 0.2 tonnes and running costs by £43). The impact of this is that insulation makes a lower saving than is predicted when using default U-values: applying the aerogel insulation (see Section 4), for example, shows cost and CO_2 savings of 8-9% when using default figures but this nearly halves (4-5%) when using calculated figures.

Similar discrepancies exist with single-glazed windows, where RdSAP assumes a U-value of 4.8 but Historic Scotland testing has shown an *in situ* U-value of 5.5. However, in this case the building fabric performs worse than assumed. Changeworks conducted a similar comparison exercise to that above, however the poorest U-value that can be entered in RdSAP is 5.1 – a further discrepancy in the software – so this exercise was more limited. Nonetheless this showed that using calculated U-values would lead to greater predicted savings than if using the default figures.

The impacts of this are clear: for some upgrade measures the savings predicted by a Green Deal Assessment will be under-estimates, and for other measures they will be over-estimates. This means that some measures could receive finance on the basis of savings that are hard to achieve in reality, while other measures could fail to meet the Golden Rule and be denied finance when in reality they may meet it.

2.3.1 Reliance on default U-values

Clearly using actual U-values, wherever possible, would seem to be the best option for Green Deal Assessors, to make the basis of the financial calculations as robust as possible. (The in use factors are included to address this potential misalignment, although how effectively they will do this is untested to date.)

However, this in itself brings complications in Scotland, as *in-situ* test research cannot currently be used as evidence for U-values. Instead, 'documentary evidence' must be proven for each specific building, either in the form of a) a 'relevant building control approval' or b)

a calculation 'produced or verified by a suitably qualified person'[12]. Being 'suitably qualified' means this person must be a member of various recognised schemes, and it is not yet clear how many assessors and other professionals in Scotland fall into this category.

Without a change to how calculated or *in situ* U-values can be used (for instance, allowing robust research such as that carried out by Historic Scotland to identify U-values that could be used for all equivalent building elements), default values will have to continue to be relied upon. (It should, however, be noted that in December 2012 DECC issued a tender invitation for *'Research to provide better estimates of solid wall insulation savings through improved understanding of heat losses'*, which it anticipates will inform updates to SAP, RdSAP and the Green Deal.)

2.4 Occupancy Assessments

As part of the Green Deal Assessment, Assessors will undertake an Occupancy Assessment[13]. Data is collected on the household's occupants (e.g. number of occupants, hours of heating, thermostat settings and so on), and that household's energy use is then compared against average or 'typical' household usage (which is used on the EPC to calculate savings). The Occupancy Assessment report states whether the household has high, average or low energy use, and whether the improvement measures recommended by the EPC are therefore likely to save them more or less energy than a typical householder. It is important to note that this is only used as an indication to the householder – it does not inform the Golden Rule calculation, and therefore the predicted savings are always those of a 'typical' household (with all the assumptions that go with that).

Thus, a household with fewer occupants and/or heating hours than those assumed by the Green Deal Assessment is likely to make lower savings and may therefore not meet the Golden Rule in practice (and vice versa for high energy users). Householders with a lower-than-average heating demand can still take out a Green Deal loan, however before doing so they will have to acknowledge in writing that they are aware, based on their energy use, that their Green Deal charge may not be fully offset by their energy savings[14].

The software for Occupancy Assessments was not available at the time of writing the report. However, to illustrate this point two different occupancy patterns have been modelled for

[12] http://www.bre.co.uk/sap2009/page.jsp?id=2792

[13] Green Deal Provider Guidance (DECC, 2012)

[14] The Green Deal and Energy Company Obligation: Government Response to the November 2011 Consultation (DECC, 2012)

the tenement flat using a different software programme[15] to illustrate the impact on energy use (EPCs are unable to account for differing occupancy patterns and assume a single, 'typical' pattern):

- The baseline annual energy bill is estimated at £1,089 on the EPC
- However, with a single occupant using 5 hours of heating per day this would reduce by 21% to £848
- By contrast, with five occupants using 16 hours of heating per day at 23^{o}C and using more hot water than average, the energy bill would rise by 25% to £1,359.

2.5 Future energy standards

To give the improvements modelled in this report context, Changeworks compared the performance of these properties in relation to current housing standards in the social rented sector – the private sector currently has no similar standards but is likely to in the future.

By 2015 social housing in Scotland must meet the Scottish Housing Quality Standard (SHQS); this includes minimum energy efficiency standards. Following 2015 this will be replaced by, the Energy Efficiency Standards for Social Housing (EESSH; currently in development). Under the EESSH, properties will have to meet energy efficiency (EE) and environmental impact (EI) ratings based on the type of property and fuel used within the home. In relation to the case study properties in this report, these ratings (expressed in RdSAP 2005) are:

- For a detached bungalow heated by electricity (the sandstone cottage and granite cottage): EI rating of 50 and EE rating of 55
- For a mid-floor flat heated by gas (the tenement flat): EI rating of 80 and EE rating of 80

Installing packages of upgrade measures in the three properties (see subsequent Sections for details) achieves the following ratings:

- Sandstone cottage: EI of 89 and EE of 41
- Granite cottage: EI of 90 and EE of 54
- Tenement flat: EI of 83 and EE of 82

These figures show that all three properties would achieve the EESSH standards except for the granite cottage's EE rating, which falls just below the threshold – although it should be noted that it is not yet possible to comment fully on the granite cottage as it is heated by biomass, for which a different rating will be set when the EES is finalised. (It should also be noted that detached properties such as this are not so representative of the Scottish social

[15] National Home Energy Rating (NHER) Plan Assessor v5.4.2

housing stock.) The EI rating of both cottages would far exceed the minimum requirement: this is due to the installation of biomass systems in both cases (which has a dramatic effect on the EI rating but a less good impact on the EE rating as RdSAP currently assumes a relatively low efficiency for biomass systems). While meeting the EESSH in most cases, however, the considerable capital costs must also be considered, as these are unlikely to replicable on a mass scale.

3. Property and upgrade details

3.1 Property types

Three different property types were assessed, to capture a range of elements that are likely to be subject to variation in traditional properties across Scotland (e.g. size, location, exposure, fuel options and so on). The three property types are an urban sandstone tenement flat in the central belt, a rural sandstone cottage in South-West Scotland and a granite cottage in North-East Scotland; brief details are below.

1. Sandstone cottage, South-West Scotland

This property is effectively detached although does adjoin disused workshops. It is a rural cottage building near Cumnock, comprising two storeys, and is situated off the gas network. Building elements and U-values are provided in the table below. It should be noted that the default U-values were used for the analysis in this report, as these are more likely to be used in formal Green Deal Assessments. The impact of relying on default U-values is covered elsewhere in the report.

Element	Description	U-value (W/m^2k)	RdSAP software U-value (W/m^2k)
Walls	Solid sandstone (600mm)	1.25 *	1.8
Floors	63% solid, 37% timber	0.73 (solid), 0.85 (timber)	Same
Windows	All sash single glazed	5.5 *	4.8
Loft	No insulation present	2.3	Same
Space & water heating	Coal fires (with back boiler and no radiators) and electric secondary heating. Hot water provided by back boiler.	(50% efficient)	Same
Lighting	**Low energy**	**(50%)**	
* denotes in-situ U-value; all other U-values are default			

2. Sandstone tenement flat, central Scotland

This property is an average-sized urban tenement flat, typical of town and cities across Scotland. A mid-floor flat was used, as these comprise the majority of flatted properties, and floor and roof improvement measures are covered by the other property types. Again, building elements and U-values are provided in the table below; default U-values were used for the subsequent analysis in this report for the same reasons as with the sandstone cottage.

Element	Description	In situ tested U-value (W/m^2k)	RdSAP software U-value (W/m^2k)
Walls	Solid sandstone (600mm)	1.25 *	**1.8**
Windows	All sash single glazed	5.5 *	**4.8**
Space & water heating	Mains gas pre-1998 wall mounted boiler with no heating controls. Hot water provided by boiler	(65% efficient)	
Lighting	Low energy	(50%)	

3. Granite cottage, North-East Scotland

This property is a single-storey detached cottage in rural Aberdeenshire. While its basic form is relatively simple, the cottage has been adapted through the addition of two solid brick extensions to the rear of the property. Building elements and U-values are provided in the table below; all U-values are the default values taken from RdSAP.

Element	Description	Default U-value (W/m^2k)
Walls	Solid granite	**2.3**
Floors	60% timber 40% solid	**0.63 (timber)** **0.96 (solid)**
Windows	Mostly single glazed	**4.8**
Loft	Partially insulated roof rooms (ceiling and joists) in original cottage. Unknown insulation on flat roof (assumed none) on the extension	**0.4 (main house, where insulated** **2.3 (flat roof)**
Space & water heating	Slim-line storage heating and electric panel heaters. Hot water provided by single immersion	**N/A**
Lighting	**Low energy**	**(75%)**

3.2 Upgrade measures and costs

The table on the following page provides details of all upgrade measures for each of the three properties. Costs are included for each property (where no cost is included, the measure in question was not installed).

The measures above are applicable for Green Deal funding. For some property elements (e.g. walls, windows, heating systems) several upgrade measures were included to allow comparison of different options.

In most cases actual costs were used (loft insulation being the sole exception). These mostly include preliminary, making good and redecoration costs, which can add a considerable amount to the total cost of a measure. There is a wide range of costs for insulation measures, even within the same property element – wall insulation options ranging from c.£2,000 to c.£15,000, for example. There are many reasons for these cost variations including property size, baseline performance, insulation specification, specialist measures for historic properties and so on.

The high total costs for such significant whole-property retrofits are also noteworthy: the sandstone cottage costs exceed £40,000, while the granite cottage costs exceed £50,000. These should be borne in mind when considering national retrofit cost projections, which tend to use significantly lower cost assumptions. It should also be noted that in the case of the granite cottage, the owner (an Aberdeenshire estate) was able to use their own labour and secure materials at trade prices, achieving lower costs than would otherwise be the case.

	individual single-glazed panes					
Secondary glazing	Slim whole-window units suitable for historic properties	2.0	£800/window + 10% for making good		£5,280	
Front door upgrade	Insulated added to existing front door	0.5	£50/m^2	£113	£208	
Front door replacement	New insulated door (existing frame retained)	0.5 *	£900 (cottage) £1,200 (flat)	£1,080	£1,440	
External door replacement	New insulated doors	1.8	£481/m^2			£2,076
Condensing boiler	From non-condensing to condensing boiler,+ controls upgrade		£4,000 + 10% for making good		£5,280	
Storage heating	From non-condensing mains gas boiler to electric storage heating		£300/heater + 10% for making good		£2,376	
Biomass boiler	Pellet boiler + radiators + controls (space and water heating) to replace coal + electric		£15,000	£18,000		
Biomass stove boiler	Stove boiler + radiators + controls (space and water heating) to replaceelectric		£13,383			£16,060

** Costs provided by Historic Scotland*
*** Costs provided by DWR Architecture and Alan Crichton*
**** Cost provided by surveyors in partnership with Changeworks*
*****This product was modelled in this location and not installed*

Measure	Details	U-value used	Unit cost excl. VAT	Total costs incl. VAT		
				Sandstone cottage *	Tenement flat *	Granite cottage **
Loft insulation	From 0mm to 250mm	0.16	£375	£450***		
Roof insulation	Wood fibre board & insulation quilt to flat roof and loft / roof rooms	0.13 (loft / roof rooms) 0.30 (flat roof)	£86 / m^2 (includes pre & post works)			£8,587
Wall insulation (whole house)	Bead insulation blown behind lath and plaster	0.60	£14/m^2 (+ 10% for renovation works)	£2,261		
Wall insulation (whole house)	Aerogel matt affixed behind steel mesh, plaster skim coat finish	0.60 (RdSAP for 50mm wall insulation)	£50/m^2 insulation £20/m^2 plasterwork (+ 10% for renovation works)	£11,475****	£3,982	
Wall insulation (whole house)	100mm wood fibre insulation board, plasterboard finish	0.35 (RdSAP for 100mm wall insulation)	£40/m^2(+ 10% for renovation works)		£2,276	
Wall insulation (whole house)	Wood fibre &insulation	0.25	£121/m^2 (includes pre & post works)			£15,028
Floor insulation (partial)	Wood fibre boards below floorboards (60% of exposed floor)	0.30	£49/m^2 (includes pre & post works)			£2,524
Floor insulation (partial)	Hemp batts below floorboards (37% of exposed floor)	0.38	£40/m^2	£562		
Floor insulation (partial)	Aerogel board on concrete floor (67% of exposed floor)	0.35	£50/m^2	£1,193		
Hot water tank ins	From 25mm to 160mm jacket, + pipework		£80	£96	£96	
Window draughtproofing	Windows dismantled,brushes fitted		£300/window	£2,880	£1,800	
Double glazing	Existing sashes retained, single glazing replaced with slim double-glazed units	2.0	£600/window + 10% for making good	£5,760	£3,960	
Double glazing	New timber double-glazed sashes	2.0	£800/window + 10% for making good		£5,280	
Double glazing	New timber double-glazed sashes	1.8	£687/m^2 (includes pre- & post works)			£10,800
Secondary glazing	Acrylic / polycarbonate panes fitted to existing	2.4	£60/m^2	£727	£1,093	

4. Upgrade impacts

This Section is divided into two subsections: the first summarises the impact of installing individual upgrade measures in each property; the second shows the impact of installing multiple measures as part of a package. The subsequent Green Deal and ECO analysis (see Sections 6 and 7) was carried out on the basis of packaged measures.

Detailed tables of the modelling results, showing impacts for each measure in each property, are available in Appendix A.

It is important to re-iterate that default U-values were used for this exercise, as these are likely to be used in most Green Deal Assessments. Section 3.3 shows the impact that using calculated U-values could have on predicted savings.

4.1 Individual measures

4.1.1 EPC ratings

Energy Performance Certificates (EPCs) provide both 'EE' and 'EI' ratings for a property. These refer to 'energy efficiency' (EE) and 'environmental impact' (EI). These ratings are significant, particularly as they could be linked to minimum housing energy efficiency standards in the future. However, it is important to be aware that the two ratings are not always closely linked, i.e. a property could be deemed efficient but still have a high environmental impact, and vice versa. Ratings are dependent not only on energy demand but also upon fuel types and tariffs, and it will therefore be easier for some properties to meet one rating than the other.

The following summaries show the impact that individual measures would have on these ratings for each property.

1. Sandstone cottage

It should first be noted that the pre-improvement condition of the sandstone cottage was very poor (effectively uninhabitable). This means that a) the baseline ratings are extremely low (significantly lower than most dwellings) and b) improvement measures could lead to greater jumps in performance ratings than would be the case with more efficient dwellings. The key findings are as follows:

- Wall insulation is of greatest benefit to the EE rating; loft insulation also leads to a marked increase.
- The EI rating is significantly improved by the biomass boiler; wall insulation also shows some benefit although this is relatively small.

- None of the other measures makes a significant impression on either rating; even where the rating is improved this does not always lead to a jump in banding (e.g. from a 'G' to an 'F').
- Despite improving the EI rating significantly, the biomass system leads to a drop in the EE rating. This is because RdSAP assumes a relatively low efficiency (65%) for a biomass system, and assumes a higher fuel cost (4.93p/kWh) than for coal (2.97p/kWh)[16]. In practice, most biomass systems are significantly more efficient and the local costs of biomass may be lower. The EE rating also does not take into account the financial benefits of the forthcoming domestic Renewable Heat Incentive.

2. Tenement flat

This property has relatively high baseline ratings, mainly due to the fact it is mid-floor and mid-terrace so the external wall area is small. Key findings are as follows:

- Upgrading the heating system to a condensing boiler has the best impact on the EE rating.
- Electric storage heaters also increase the EE rating, but they decrease the EI rating due to the more CO_2-intensive fuel (compared with gas).
- Of the fabric upgrades, double and secondary glazing has the biggest impact on both ratings – although it should be noted that RdSAP effectively treats both measures equally in most cases.

3. Granite cottage

The baseline performance of this property is relatively low, due to its relatively poor unimproved condition, high number of external walls and non-gas fuel type. Key findings are as follows:

- Roof insulation shows the greatest improvement in both EE and EI ratings.
- As with the sandstone cottage, the biomass improves the EI rating significantly (from a 'G' to a 'B'), but leads to a lower EE rating. It should be noted that the stated efficiency of the biomass system in question[17] is 81.6%.
- Other measures do not lead to any banding change, either for EE or EI.

[16] SAP 2009 manual, page 151 - http://www.bre.co.uk/filelibrary/SAP/2009/SAP-2009_9-90.pdf
[17] EdilkaminKlima Warm CS

4.1.2 Running costs

1. Sandstone cottage

By far the greatest saving for the sandstone cottage comes from wall insulation with an estimated £496 (21%) saving. Loft insulation and a biomass boiler also lead to significant savings. However, both the wall insulation and biomass boiler are among the most expensive measures to install (both potentially over £10,000), and loft insulation is one of the cheapest measures to install, so loft insulation is likely to represent better value for money.

2. Tenement flat

For the tenement flat, a new condensing boiler and controls would have the greatest impact, with a predicted annual saving of £287 (26%). Glazing measures would save 9-10% on fuel costs, whilst wall insulation would save 7-8% (a far lower impact than the sandstone cottage, due to the small area of external wall). For a traditional property with an old heating system, new storage heating could be significantly cheaper (c.£2,300) to install than a new condensing boiler, although this is unlikely to outweigh the considerably greater savings from a new gas boiler. The wall insulation options would cost c.£2,300-£4,000, and glazing improvements could cost c.£1,100-£5,200, so they are unlikely to represent such value for money as a heating upgrade.

3. Granite cottage

Roof insulation would generate significant annual savings of £539 (20%) for the granite cottage; wall insulation and double glazing also show relatively high savings of £306 and £166 respectively. The biomass system, however, is predicted to lead to an *increase* in fuel bills (by £71/year): this is likely to be a result of the software's default assumptions of 65% efficiency for a biomass system and 100% for electric storage heating (in fact, the biomass system installed in this property has an overall efficiency of 81.6%). Capital costs for all measures are significant, however, and the lowest-cost measures are also the ones that realise the least financial savings. Running costs for the biomass boiler are based on the software's default values for wood pellets. In practice this example runs on locally sourced logs which are considerably cheaper.

4.1.3 CO_2 emissions

1. Sandstone cottage

Unsurprisingly, the biomass boiler would achieve the greatest annual CO_2 reduction of nearly 70% (11.6 tonnes). Wall insulation shows a 22% reduction (3.8 tonnes) followed by loft insulation and double glazing at 8% and 5% respectively. RdSAP shows no CO_2 savings for any of the other measures.

2. Tenement flat

A new condensing boiler achieves by far the greatest CO_2 saving at 31% (1.7 tonnes). Glazing upgrades create annual savings of 11-13% and wall insulation saves 7-8%. Draught-proofing shows a saving of <5%, and there is no reduction recognised for door upgrades. Storage heating is estimated to **increase** CO_2 emissions by 1.2 tCO_2 (22%); due to the CO_2 intensity of electricity.

3. Granite cottage

Again the biomass system shows the greatest reduction in CO_2 emissions at 67% (12.7 tonnes), and roof insulation also shows a significant reduction at 24%(4.5 tonnes). Wall insulation is estimated to save 11%, while double glazing and floor insulation are estimated to save 9% and 5% respectively. The software showed no CO_2 savings for the door replacement. It should be noted that the modelling was undertaken based on RdSAP defaults specifying wood pellets with a emissions of 0.028 kg CO_2 per kWh. In practice, the cottage is fuelled with logs with emissions of 0.008 kg CO_2 per kWh.[18]

4.2 Packaged measures

A package of measures was modelled for each property (in the case of both cottages, this was based on actual measures installed). Within any package of measures, the impacts of each measure are cumulative and therefore vary from those presented in Section 5.1 above (individually-installed measures): installing a new boiler, for example, will generate lower savings in an insulated than an uninsulated house. It should also be noted that the savings shown for multiple measures on an EPC are also cumulative (i.e. they assume the preceding measures have been installed).

The order in which measures were modelled within the packages is the same in which Green Deal recommendations are presented on an EPC (see Section 3.2).

[18] http://www.bre.co.uk/filelibrary/SAP/2009/SAP-2009_9-90.pdf

EPC ratings

1. Sandstone cottage

Measure	EE		EI	
	Rating	Band	Rating	Band
Baseline	7	G	1	G
Loft insulation	14	G	1	G
Wall insulation (aerogel)	34	F	15	G
Floor ins (full)	36	F	17	G
Hot water tank ins (160mm jacket)	40	E	19	G
Biomass boiler	35	F	88	B
Double glazing	40	E	89	B
Front door upgrade (new insulated door)	41	E	89	B
Cumulative package results	**41**	**E**	**89**	**B**

The above measures are based on those that have actually been carried out on the property[19]. It should be noted that two of the measures (biomass boiler and door upgrade) were not recommended automatically on the baseline EPC generated: the latter omission suggests that RdSAP seems to recommend heating system changes within the same fuel type, and as the original fuel type was coal it did not suggest changing to a different fuel type. The EPC for this property does not therefore recommend any heating system improvement to the householder.

2. Tenement flat

Measure	EE		EI	
	Rating	Band	Rating	Band
Baseline	65	D	61	D
Internal wall insulation (Aerogel)	68	D	65	D
Hot water tank ins	70	C	67	D
Hot water tank thermostat	71	C	68	D
Condensing boiler / controls	79	C	80	C
Double glazing (timber sash)	82	B	83	B
Front door upgrade (new insulated door)	82	B	83	B
Cumulative package results	**82**	**B**	**83**	**B**

[19] See http://www.historic-scotland.gov.uk/refurb-case-study-8-garden-bothy-cumnock.pdf

With the exception of front door upgrade, all of the measures in the above package were recommendations on the baseline EPC generated. As the existing heating was a mains gas system, the software automatically recommended an upgrade mains gas boiler system.

3. Granite cottage

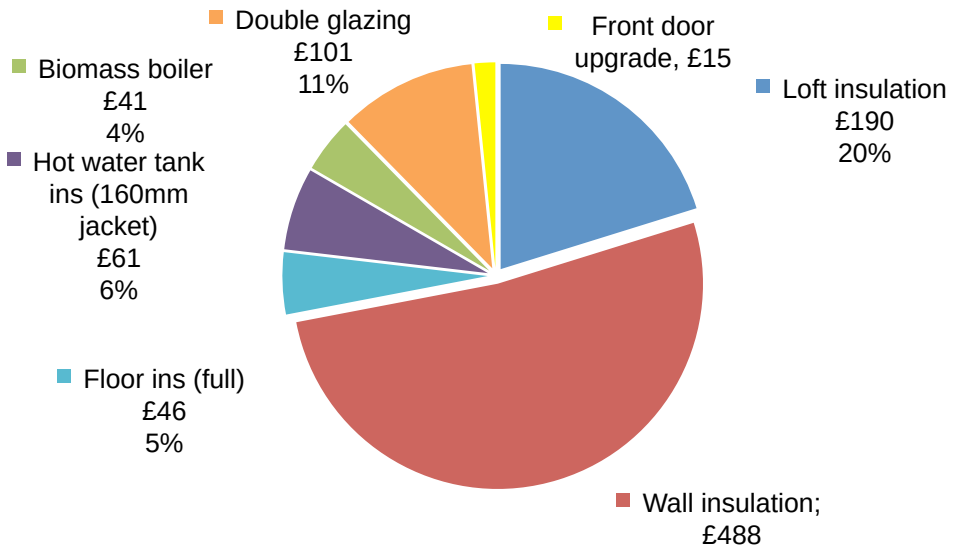
Measure	EE		EI	
	Rating	Band	Rating	Band
Baseline	21	F	8	G
Roof insulation	37	F	22	F
Wall insulation	51	E	34	F
Floor insulation (partial)	52	E	35	F
Biomass stove boiler system	46	E	89	B
Double glazing	54	E	90	B
Door replacement	54	E	90	B
Cumulative package results	**54**	**E**	**90**	**B**

As with the sandstone cottage, the above package of measures is based on actual upgrade measures in the property. Once again two of the measures (biomass boiler and door upgrade) were not recommended automatically on the baseline EPC generated, and the only heating improvement recommended was a storage heating upgrade.

4.2.1 Running costs

1. Sandstone cottage

Total savings for this property were calculated at £943/year, broken down as follows.



Over half of all savings come from the wall insulation, followed by c. 20% from loft insulation.

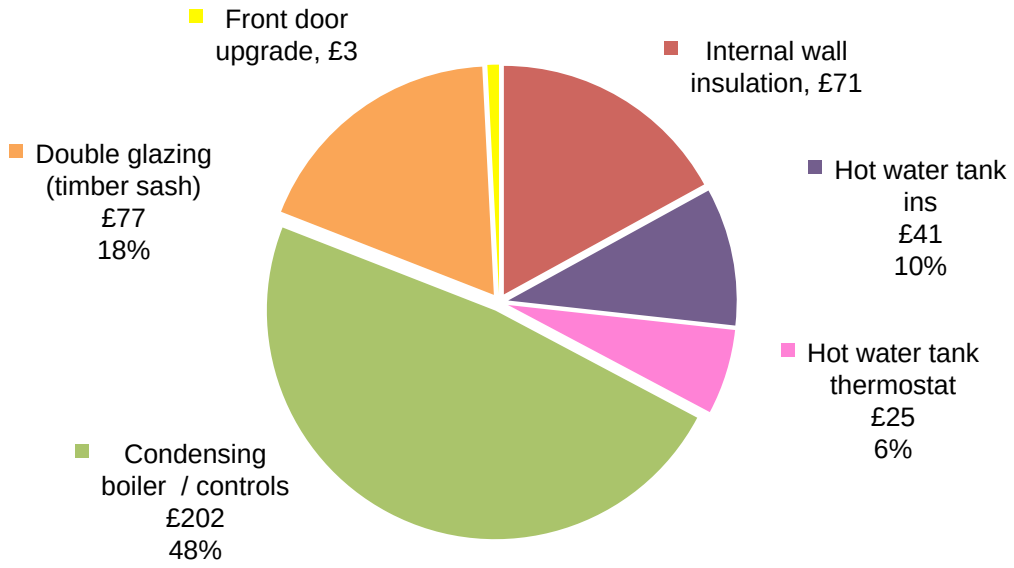
As modelled, the financial savings from the biomass system are negligible (in contrast with its CO_2 savings). However, this in part reflects the default efficiencies in RdSAP which are lower than the manufacturer-specified value for the system installed. In addition, for biomass stove boilers RdSAP defaults to wood pellets as the fuel type and assumes a cost of 4.93 p/kWh. In practice, the system installed uses logs which are costed by RdSAP at 3.42 p/kWh – a reduction of 30.6%[20]. For the modelled property, the owner was able to locally source logs for as low as 1.99 p/kWh[21].

[20] SAP costs March 2010 http://www.bre.co.uk/filelibrary/SAP/2009/SAP-2009_9-90.pdf

[21] Estimate provided by Glen Tanar Estate

2. Tenement flat

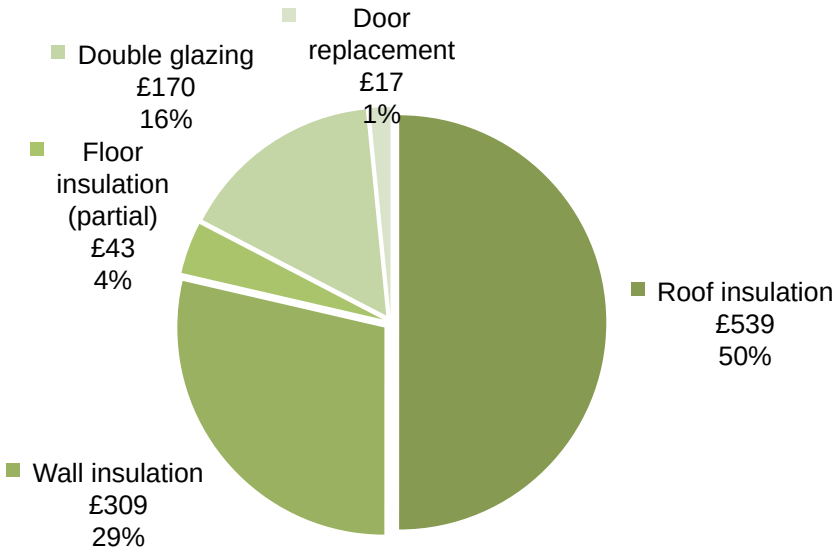
Total savings for this property are £419/year, broken down as follows.



The new condensing boiler accounts for c.50% of the savings. The actual savings for this measure (£202) contrast again with those predicted for the same measure when installed as an individual improvement (£287) – a good illustration of the difference between individual and cumulative impacts.

3. Granite cottage

Total savings are comparable with the sandstone cottage, at £840/year. Again the breakdown is shown below.



Unlike the sandstone cottage, however, while solid wall insulation still has a considerable impact for the granite cottage the greatest savings (over 50%) are generated by the insulating the roof. As modelled there are negative savings for the biomass stove boiler system (-£59) and so these are not represented in this chart. In reality, a higher than default value boiler and a lower than default value fuel source, mean that substantial reductions could be realised in practice.

4.2.2 CO_2 emissions

(Detailed results tables for this Section are provided in Appendix B.)

1. Sandstone cottage

Installing all measures in the sandstone cottage creates a 70% reduction in CO_2 emissions, savings 12 tonnes CO_2 per year. The biggest saving in this upgrade package comes from the biomass boiler (6 tonnes) – although its cumulative saving is much lower than when installed as a standalone measure (11.6 tonnes) due to the reduction in heating demand created by the insulation measures.

2. Tenement flat

The upgrade package for this property would lead to a 45% CO_2 reduction, saving 2.4 tonnes CO_2 per year. As with the sandstone cottage, the savings from the largest individual measure (in this case the condensing boiler) are reduced – by around a third – when it forms part of a package.

3. Granite cottage

The upgrade package for this property leads to the greatest CO_2 saving at 12.8 tonnes CO_2 per year, although the proportional saving of 67% is slightly lower than the sandstone cottage. Unsurprisingly, the measure with the biggest individual CO_2 saving (7.1 tonnes CO_2) is once again the biomass system. As previously discussed these savings could be slightly greater if the system uses logs rather than pellets.

4.3 Summary of packaged measures' impact

The impact of the upgrade packages on each property are summarised below.

Sandstone cottage:

- EE rating improves from 7 (G) to 41 (E)
- EI rating improves significantly from 1 (G) to 89 (B)
- Saves £943 and 12 tCO_2 (a 70% reduction) per year
- A Biomass boiler has biggest impact on CO_2 emissions*

Tenement flat:

- EE rating improves from 65 (D) to 82 (B)
- EI rating improves from 61 (D) to 83 (B)
- Saves £419 and 2.4 tCO_2 (a 45% reduction) per year
- A Condensing boiler makes the biggest CO_2 saving*

Granite cottage:

- EE rating improves from 21 (F) to 54 (E)
- EI rating improves from 8 (G) to 90 (B)
- Saves £840 and 12.8 tCO_2 (a 67% reduction) per year
- A Biomass boiler has biggest impact on CO_2 emissions*

*For heating improvements, which are modelled part of a package, the overall potential savings are reduced through better insulation, which lowers heat demand.

5. Green Deal analysis

In theory the Green Deal and ECO are designed to work together, i.e. ECO funding reduces the cost of the upgrade package to the point where there are no upfront costs to be met. However, they can also work independently of one another: for example, Green Deal borrowing is allowable up to the point where capital repayments + interest are less than the saving from a measure, but in some cases this may only cover part of the overall capital costs. ECO may also fully fund some measures without the need for a Green Deal loan, or the householder may simply pay for any upfront costs needed to meet the Golden Rule. DECC have confirmed the Green Deal can work alongside other incentives such as RHI, however the Golden Rule would be calculated before any RHI payment was applied.

This Section models the packages of measures to determine whether they would meet the Golden Rule and therefore qualify for Green Deal finance without additional support (i.e. ECO or self-funding by householders). Eligibility for ECO subsidy, and likely levels of support, are assessed in Section 7.

5.1 Methodology and assumptions

The following assumptions were made in the Green Deal calculations:

a) In line with the Green Deal Finance Company[22], payment interest rates of 7.67-7.96% (depending on the repayment period; see below) were used. It should be noted that these are based on a £5,000 loan sum (considerably lower than those modelled in this report). In reality, the interest rate will be determined by the market and will vary between providers.

b) The loan repayment period for each measure was based on its expected lifetime (from 10-25 years depending on the individual measure). In some cases loans may be taken out over a shorter period, in which case the total interest paid would be lower.

c) Savings from the measures are calculated cumulatively, on the assumption they are installed together as a package. (It should be noted that if fewer measures were included in the package the savings attributed to each measure may be higher – as will be seen, however, very few calculations are marginal in terms of meeting the Golden Rule and so this is unlikely to have a significant effect).

[22] http://www.thegreendealfinancecompany.com/

The calculation process used in this report is not as straightforward as in Technical Paper 16, due to recent refinements to the Green Deal process. A summary of the methodology is illustrated below, to facilitate reading in Fig. 1 below.

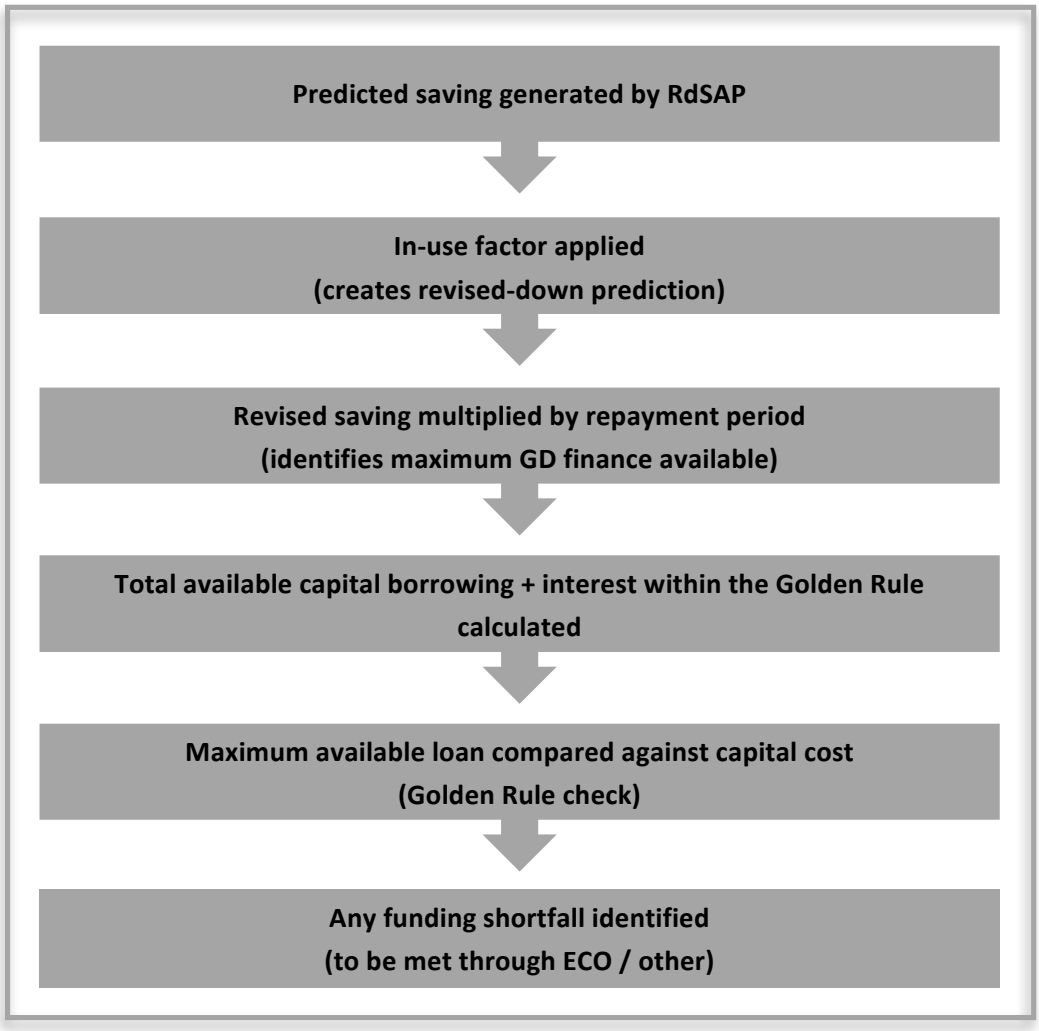


Fig. 1 Green Deal calculation process

5.2 Green Deal eligibility

1. Sandstone cottage

Measure	Loan period (years)	Cost (incl. VAT)	Maximum Green Deal borrowing	Total interest over loan period	Meets Golden Rule?	Funding shortfall
Loft insulation	25	£450	£2,092	£2,670	Yes	
Wall insulation (aerogel)	25	£11,475	£5,362	£6,844	No	-£6,113
Floor ins (full)	25	£1,755	£504	£643	No	-£1,251
Hot water tank ins	10	£96	£411	£201	Yes	
Biomass boiler	20	£18,000	£406	£404	No	-£17,594
Double glazing	20	£5,760	£1,013	£1,010	No	-£4,747
New insulated front door	20	£1,080	£153	£153	No	-£927
TOTAL		**£38,616**	**£9,942**	**£11,924**	**No**	**-£30,631**

As the table above shows, only loft and hot water tank insulation meet the Golden Rule without subsidy.

Given the low cost of these measures, it is unlikely that a Green Deal loan would be taken out to finance them; however, they may form part of a package, particularly as both measures actually would attract 'surplus' Green Deal finance, i.e. they would save more over their lifetime than they cost to install. This surplus would be counted in the Green Deal finance calculation, and used to contribute towards the cost of the other, more expensive measures.

Without subsidy to reduce the cost of the measures, the Green Deal loan will only partially cover the capital costs. For example, over £6,000 would need to be paid upfront for wall insulation and almost £1,300 for the floor insulation. (ECO funding could be available to reduce the cost of some packages, but not all; see Section 7).

The above table also highlights the total interest that would be paid for these measures through the Green Deal (based on interest rates detailed in Section 6.1). In this case the total interest would account for over 50% of the total loan repayments – a significant cost to the householder. Clearly, if a loan had a shorter term or a lower interest rate, the total interest payable would be less. A lower interest rate would allow more of the upfront costs of measures to be met within the Golden Rule.

2. Tenement flat

Measure	Loan period (years)	Cost (incl. VAT)	Maximum Green Deal borrowing	Total interest over loan period	Meets Golden Rule?	Funding shortfall
Wall insulation (aerogel)	25	£3,982	£783	£999	No	-£3,200
Hot water tank ins	10	£96	£274	£134	Yes	
Hot water tank thermostat	12	£96	£191	£111	Yes	
Condensing boiler / controls	12	£5,280	£1,529	£892	No	-£3,751
Double glazing (new sashes)	20	£5,280	£766	£764	No	-£4,514
New insulated front door	20	£1,440	£34	£34	No	-£1,406
TOTAL		**£16,174**	**£3,577**	**£2,933**	**No**	**-£12,870**

As shown above, only the hot water cylinder improvements (insulation and a thermostat) meet the Golden Rule without subsidy. Again, these are low-cost measures for which Green Deal finance is unlikely to be required. The other measures would receive relatively little funding through the Green Deal and would require considerable subsidy, although as with the sandstone cottage some of the qualifying measures create surplus Green Deal finance to contribute towards this.

3. Granite cottage

Measure	Loan period (years)	Cost (incl. VAT)	Maximum Green Deal borrowing	Total interest over loan period	Meets Golden Rule?	Funding shortfall
Roof insulation	25	£8,587	£5,922	£7,559	No	-£2,664
Wall insulation	25	£15,028	£3,388	£4,325	No	-£11,640
Floor insulation (partial)	25	£2,524	£476	£608	No	-£2,048
Biomass stove boiler	20	£16,060	£0	£0	No	-£16,647
Double glazing	20	£10,800	£1,706	£1,699	No	-£9,094
New insulated external doors	20	£2,076	£170	£170	No	-£1,906
TOTAL		**£55,075**	**£11,075**	**£13,775**	**No**	**-£43,999**

No measures in the granite cottage's package meet the Golden Rule, largely because of their high capital cost. The roof insulation receives significant funding through the Green Deal

(nearly £6,000), but its cost means it still requires considerable subsidy, as well as incurring a lot of interest (>£7,500). A similar situation can be seen for the solid wall insulation.

As RdSAP calculated negative savings for the biomass system, the Green Deal finance calculation also produces negative results. This could change if SAP were to use different figures for system efficiency and emission factors for the fuel. A better model could identify annual savings that could be used to support a Green Deal loan. This might meet some (but probably a limited proportion) of the installation costs as per the sandstone cottage example. Meanwhile, this situation should be substantially improved by the Renewable Heating Incentive (RHI) which is due to come into effect for domestic properties in summer 2013. Alongside a Green Deal loan the RHI might cover some or all of the annual repayments of a further loan needed to meet the upfront costs of the system.

5.3 Summary

The results show that the majority of the measures would not meet the Golden Rule, based on the costs provided by Historic Scotland – the only measures which do so are loft insulation in the sandstone cottage, and hot water tank insulation and thermostat in the sandstone cottage and tenement flat.

The majority of measures would therefore require significant reductions in capital costs or subsidy (ECO) in order to avoid householders having to pay some upfront costs. Total (approximate) subsidy levels required for the upgrade packages in each property are as follows:

- Sandstone cottage: £30,600
- Tenement flat: £12,900
- Granite cottage: £44,000

The results also show that, on the loan terms detailed in Section 6.1, interest charges account for over half the total repayment sum. This could be an important consideration for some householders: if, for example, a householder were able to secure a mortgage at today's typical lending rates (which are below Green Deal finance company offerings), annual repayments could be significantly cheaper. (Clearly, however, it should be noted that the two are not directly comparable, e.g. it is easier to access Green Deal finance, and over the medium to long term mortgage interest rates are likely to be variable, etc.)

6. ECO

Three streams of ECO are available: CERO, CSCO and HHCRO (see Section 2). As the CERO focuses on funding for hard-to-treat properties, this is the focus of this Section. Funding may be available through the other two streams for a wider range of measures, but in order to benefit from these subsidies households would need to be either a private low-income household on certain benefits[23], or situated in a low-income area or rural area[24].

Funding for the CERO stream of ECO is only available if the (domestic) property installs either solid wall insulation or non-standard cavity wall insulation as one of the upgrade measures. Other measures are eligible for funding alongside these measures as part of a package; the table below provides a full list of ECO-eligible measures[25].

Measure Type	Measure Name[1]	Eligibility by Obligation[2]		
		CERO	CSCO	HHCRO
	Internal Wall Insulation Systems, for: a solid brick wall built before - 1967 (England and Wales) - 1965 (Scotland)	√	√	√
	Internal Wall Insulation Systems, for: a solid brick wall built after - 1967 (England and Wales) - 1965 (Scotland)	√	√	√
	External Wall Insulation Systems, for: a solid brick wall built before - 1967 (England and Wales) - 1965 (Scotland)	√	√	√
	External Wall Insulation Systems, for: a solid brick wall built after - 1967 (England and Wales) - 1965 (Scotland)	√	√	√
	Internal non-brick solid wall insulation	√	√	√
	External non-brick solid wall insulation	√	√	√

[23] E.g. Child tax credit, working tax credit or state pension credit with a household income under £15,860, income-related employment and support allowance, income-based jobseekers allowance, income support.

[24] The bottom 15% areas of multiple deprivation ('data zones' in Scotland). 20% of this can be delivered in the adjoining areas and 15% must be delivered in rural settlements with a population under 10,000.

[25] http://www.ofgem.gov.uk/Sustainability/Environment/ECO/Info-for-suppliers/Documents1/Energy%20Companies%20Obligation%20ECO%20-%20List%20of%20Measures%20and%20Additional%20Information.pdf

Insulation	Cavity Wall Insulation	√	√	√
	Hard-to-treat Cavity Wall Insulation (CWI solution)	√	√	√
	Hard-to-treat Cavity Wall Insulation (SWI solution)	√	√	√
	Loft Insulation Ceiling : Virgin Level	√	√	√
	Loft Insulation Ceiling : Top-up	√	√	√
	Loft Insulation (rafter)	√	√	√
	Room in Roof Insulation	√	√	√
	Flat Roof Insulation	√	√	√
	Under Floor Insulation	√	√	√
	Hot Water Cylinder Insulation	√	√	
	Insulation to all primary pipework	√	√	√
	Draught Proofing	√	√	√
	Window Glazing	√	√	√
	Passageway Walk-through Doors	√	√	√
Heating	Qualifying boiler replacement			√
	Non-qualifying boiler installation			√
	Qualifying boiler Repair (1 year warranty)			√
	Qualifying boiler Repair (2 year warranty)			√
	Electric Storage Heaters			√
	Warm Air Units			√
	Heating Controls			√
	Flue Gas Heat Recovery Devices			√
	Heat Recovery Ventilation			√
	Radiator Panels			√
	District Heating Connections - Upgrades (Biomass boiler)	√	√	√
	District Heating Connections - New Connections (Biomass boiler)	√	√	√
	District Heating Connections - Upgrades (Gas/oil boiler)	√	√	√
	District Heating Connections - New Connections (Gas/oil boiler)	√	√	√
	District Heating Connections - Upgrades (CHP)	√	√	√
	District Heating Connections - New Connections (CHP)	√	√	√
	District Heating Connections - Heat Meters	√	√	√

Micro-Generation	Air Source Heat Pumps			√
	Ground Source Heat Pumps			√
	Biomass Boilers			√
	Micro Combined Heat and Power			√
	Photovoltaics			√
	Micro wind			√
	Micro hydro			√

Key	
Eligible measure	√
Eligible only as secondary measure	√

Notes
1. This list is non-exhaustive. Other measures may qualify, subject to review by us on a case-by-case basis
2. Measure eligibility will not change unless the legislation does. CERO: Carbon Emission Reduction Obligation; CSCO: Carbon Saving Community Obligation; HHCRO: Home Heating Cost Reduction Obligation
3. In-use factors (IUF) are provided in Schedule 3 of the Order, and are defined under 'relevant in-use factor' in Article 2. They are only applied to measures installed under CERO and CSCO. IUFs will not change unless the legislation does.
4. Lifetimes are standard, as referred to in Ofgem Guidance, chapter 8.17.
5. PAS - Publicly Available Specification 2030:2012 Edition 2

6.1 Methodology and assumptions

The level of ECO subsidy available for each of the eligible measures has been calculated[26] twice, based on two different costing scenarios (for reasons explained below):

1. £77 per tonne CO_2 saved;
2. £120 per tonne CO_2 saved.

£77 is the original figure cited by DECC[27], however this figure is subject to change and the actual rates householders receive are likely to differ. Indeed, recent ECO brokerage auctions[28] have been producing significantly higher costs, and £120 per tonne of CO_2 was

[26] Maximum ECO funding is calculated by multiplying the annual CO_2 savings by the lifetime of the measure by the ECO price.

[27] £77/tCO_2 is the figure cited in DECC's Final Stage Impact Assessment for the Green Deal and ECO for the CERO and CSCO.

[28] https://www.gov.uk/government/statistical-data-sets/eco-brokerage-results

reached for the first time in February (with March seeing a high of £125) – a significant jump from £77. Hence both figures have been used for modelling purposes, to allow comparison.

Clearly, a higher ECO price will enable more funding for some upgrade measures. However the implications of this are twofold, and these should both be considered:

1. Those householders whose properties are being upgraded will benefit;
2. Bill payers foot the cost of the ECO measures, so the higher the price of CO_2 the more householders will have to pay (through their bills) to subsidise this.

It should also be noted that energy companies may target 'cheaper' housing types/areas, where they can maximise their CO_2 savings for a lower cost per tonne.

Where ECO funding does not cover the whole cost of the measure, the remaining shortfall is shown; this would need to be covered from other sources.

6.2 ECO opportunities for the three properties

A fundamental barrier to access of ECO for these properties was observed during this research exercise: namely, solid wall insulation is only eligible for ECO funding if it achieves a U-value of 0.3 or less[29]. As shown in Section 5, only the wall insulation in the granite detached cottage achieves such a U-value (wood fibre +insulation, which achieves a U-value of 0.25). Thus, while ECO funding through the CERO stream would be applicable in the granite cottage**,** no ECO funding would be available for any upgrade measures in either the sandstone cottage or the tenement flat unless the end U-value of the solid walls could be improved. This is potentially significant for many traditional properties (see Section 7.2), particularly those wishing to focus on slim insulation materials where it is often harder to achieve very low U-values without paying a premium. However, in other Historic Scotland pilot refurbishments U-values of below 0.3 were achieved with a technically appropriate solution.

Window improvements are also subject to severe limitations under ECO, as follows[30]:

- Window upgrades will only be eligible for the CERO or CSCO streams of ECO where they achieve a U-value of 1.6 or better – i.e. where they exceed current Building Standards

[29] The Electricity and Gas (Energy Companies Obligation) Order 2012

[30] Energy Companies Obligation (ECO): Guidance for Suppliers, paragraphs 8.31-8.34 (Ofgem, 2013)

- If the original (i.e. pre-improvement) window has a U-value worse than 1.6, then this cannot be recognised for ECO purposes, and it will be assumed that 1.6 is the baseline

The reasoning behind these restrictions is not provided, however their implications are clear: ECO subsidy will effectively only be available through the HHCRO stream of ECO, i.e. for low-income householders. For all households falling outside this category, subsidy for any glazing improvement is extremely unlikely to be available. Once again this presents a significant problem for traditional properties, where single glazing is the norm and upgrade is expensive. Upgrade to a performance of 1.6 or better is likely to incur considerable cost and will rarely be specified (only one high-specification double glazing system installed as part of Changeworks' *Double Glazing In Listed Buildings* project[31] exceeded this U-value), and none or very little of the actual savings will be recognised by ECO calculations so very little subsidy will be available.

6.2.1 ECO availability in the granite cottage – Scenario 1 (£77/tonne)

Measure	ECO Availability	Maximum ECO available @ £77/tonne CO_2	Remaining shortfall (after accessing Green Deal + ECO)
Roof insulation	Yes	£14,553	+£11,889
Wall insulation	Yes	£5,871	-£5,769
Floor insulation (partial)	Yes	£825	-£1,223
Biomass stove boiler	No	£0	-£16,647
Double glazing (new sashes)	No	£0	-£9,094
New insulated external doors	Yes	£0	-£1,906
TOTAL		**£21,249**	**-£22,750**

As the solid wall insulation installed in the granite cottage meets the U-value criterion (see Section 7.1) it is eligible for ECO subsidy through the CERO stream. Other measures (roof insulation, floor insulation and new insulated external doors) are therefore also eligible – however it should be noted that, despite being eligible, the insulated door attracts no ECO funding as it shows no CO_2 savings in RdSAP. ECO is not applicable to the biomass system and double glazing based on modelled performance and savings. In any case support would only be available under the HHCRO stream targeting low income households.

The total cost of this upgrade package is c.£55,000, of which c.£11,000 was identified as being available through Green Deal finance without subsidy (see Section 6.2): this leaves a shortfall of c.£44,000. The above table shows that, at DECC's original assumed value per

[31] Double glazing in listed buildings: Project report (Changeworks, 2010)

tonne CO_2 (£77), ECO would cover nearly 50% of this shortfall, leaving c.£23,000 to be met by other means.

6.2.2 ECO availability in the granite cottage – Scenario 2 (£120/tonne)

Measure	ECO Availability	Maximum ECO available @ £120/tonne CO_2	Remaining shortfall (after accessing Green Deal + ECO)
Roof insulation	Yes	£22,680	+£20,016
Wall insulation	Yes	£9,150	-£2,490
Floor insulation (partial)	Yes	£1,285	-£762
Biomass stove boiler	No	£0	-£16,647
Double glazing (new sashes)	No	£0	-£9,094
New insulated external doors	Yes	£0	-£1,906
TOTAL		**£33,115**	**-£10,884**

Unsurprisingly, a higher ECO price (£120/tonne CO_2) makes a significant difference compared to £77.In this scenario ECO would subsidise c.£33,000 – this is around 75% of the £44,000 shortfall.

6.3 Comparison and summary

The higher the ECO price, the more subsidy will be available for harder-to-treat properties – but with a cost to the bill-payer.

For the granite cottage (the only property eligible for the CERO stream of ECO), 20% of capital costs may be met by Green Deal borrowing. Modelling two different ECO prices presented the following scenarios:

1. At £77/tonne CO_2), ECO could cover a further 39% of the capital costs – leaving over 40% of the costs to be met through other means;
2. At £120/tonne CO_2, ECO could cover a further 60%of the capital costs – leaving 20% of the costs to be met by other means.

Clearly, at £120/tonne CO_2 the subsidy is considerably bigger for the granite cottage than at £77/tonne CO_2. However, even with the higher price there remains a shortfall of nearly £11,000 which would have to be met by other means. To cover 100% of the £44,000 upgrade costs that would remain after accessing Green Deal finance, ECO levels would have to more than double from DECC's original estimate, to c.£160/tonne CO_2. (It should also be noted that the shortfall is significantly higher (c.75%) for the other properties as no ECO subsidy is available for the packages modelled.)

Alternatively, the measures in the package would have to change. The current package includes two costly upgrade measures that do not attract any ECO subsidy, i.e. the biomass system and the double glazing. If these measures were removed from the package, ECO would fully subsidise the shortfall and the total cost of the Green Deal package to the householder would reduce. This is not a 'solution' as such – the householder would be left with single-glazed windows and an old electric heating system – however it illustrates the importance that the make-up of a package has on its financial viability: ECO subsidy levels are highly sensitive to the contents of the upgrade package. The roof insulation provides a further example: its inclusion in the package is shown to be critical due to the level of Green Deal finance and ECO subsidy it attracts, as this more than covers the shortfall needed for the solid wall insulation (a required element of the package in order to access the CERO stream of ECO) and other measures.

Removing the biomass system from the granite cottage upgrade package may be a sensible action, as it attracts neither Green Deal nor ECO. If this were removed, the ECO shortfall would either be drastically reduced from £23,500 to <£7,000 (at £77/tonne CO_2), or fully covered (at a higher ECO price, c.£100/tonne CO_2). Indeed, it may be that biomass measures are better financed through other means, with the costs being recouped through the RHI over time.

Restricting funding for solid wall insulation to measures that achieve a U-value of 0.30 or less has significant implications. As illustrated above, only some types of wall insulation will be eligible and many will not; it is likely that the default insulation specifications used by RdSAP will not reach this U-value (even 100mm insulation only achieves a default U-value of 0.35, for example). Slimmer or technically compatible materials that are appropriate for historic or space-limited properties, but they are unlikely to be eligible through ECO as the measures are not included in the SAP list. For example, blown bead internal wall insulation is potentially of considerable interest to appropriate traditional properties due to its relative affordability and minimal disruption to householders, but as it is unlikely to reach the required U-value (unless there were an extremely large cavity) and is not on the list of eligible measures, it too is unlikely to qualify for subsidy. It may be a valuable exercise to run similar calculations using higher-specification insulation systems that would meet this U-value requirement, re-appraising them in terms of capital cost, feasibility (and possibly desirability) in traditional properties and financial opportunities through Green Deal and ECO.

Restricting the ECO available for window upgrades in traditional properties further limits the financial viability of many upgrade measures where alternative upfront funding cannot be found. The poor thermal performance of single glazing is not recognised by the ECO

calculations, and any upgrades are unlikely to reach the very demanding standards set so funding levels will be negligible.

Where funding for solid wall insulation can be attracted, this potentially brings in further funding for other measures in that package. As shown in the granite cottage example, this can significantly reduce the costs of installing measures. However, in this example there are still high upfront costs of upgrading the property, particularly the windows where no subsidy is available. It should be recognised that these are all substantial property upgrades with higher-than-average costs: however, in order to meet national and international CO_2 reduction targets these may well be the type of upgrades needed in traditional housing. While this modelling exercise does not take into account the financial benefits such as the RHI (and Feed-In Tariff for renewable electricity), the apparent limitations of CO_2 subsidy for insulation measures in traditional housing could present a significant barrier to uptake of improvements.

The above complications could to some degree be offset by changing the content of the upgrade packages. ECO subsidy levels are shown to be highly sensitive to the specific measures within the package. Inclusion of measures that show high savings could attract sufficient surplus money to offset the high costs of other measures in the package. This is unlikely to resolve the issues around glazing upgrades or biomass systems, however the latter are likely to receive financial support through the RHI in the future.

7. Conclusions

This report has modelled packages of energy efficiency measures in three traditional property types typical of both urban and rural Scotland, assessing their potential access to Green Deal and ECO finance (at different ECO prices). It must be reiterated that all the financial calculations within this report rest upon interpreting the Green Deal and ECO guidance but some aspects are likely to change as the programmes become better established. For instance, the costs of CO_2 will stabilise.

Whilst most of the modelled measures are eligible in principle to receive Green Deal finance, in very few cases do the predicted savings exceed the repayments (i.e. the majority fail to meet the Golden Rule) so would only be partially funded. Those measures that meet the Golden Rule as standalone measures have relatively low capital costs (e.g. loft insulation). Where households can afford the upfront costs for such measures this is likely to make more financial sense than using the Green Deal finance mechanism, due to the interest costs associated with the latter.

Many of the measures have high capital costs. In most cases these may be part financed through the Green Deal but would require substantial upfront subsidy from ECO and / or the homeowner. However, as ECO is only available for solid wall insulation where it achieves a U-value of 0.3 or less, two of the three properties would not be eligible for this ECO funding. Furthermore, as solid wall insulation is required to access the CERO stream of ECO – that specifically targets hard-to-treat properties – these two properties would also receive no ECO funding for any of the other measures in the upgrade package (unless they could access one of the other ECO streams). This means that most measures, and the packages as a whole, would require significant upfront capital in both the tenement and sandstone cottage. Whilst the Green Deal loan contribution may reduce this shortfall, it is important to consider that within these calculations the total interest payable is almost as high as the loan itself. In the granite cottage, despite the availability of ECO there is still a large upfront cost to be covered by other means.

In some cases householders may be able to source wall insulation materials which meet ECO's U-value requirements for similar or less cost. However, in principle these should meet with Historic Scotland's recommendations that such materials applied to solid stone walls should be air and water vapour permeable[32]. Some wall insulation materials are not, and recent research suggests there may be technical risks involved in applying such materials to

[32] Fabric improvements for energy efficiency in traditional buildings (Historic Scotland, 2012)

solid walls[33]. In addition, it must be considered that some properties (e.g. historic buildings) are likely to have space limitations and require slim wall insulation materials, which may find it harder to achieve the required U-value affordably.

Similar U-value restrictions apply for window improvements, which again restricts the ability of traditional properties to attract funding for what can be a considerable issue in terms of energy efficiency.

The results of this analysis indicate that whilst the Green Deal enables householders to access finance for energy efficiency measures, it will not always be practical:

- For cheaper measures, households may be better off to pay for the measure upfront to avoid paying high interest rates.
- For more expensive measures and/or those with lower financial savings, the Green Deal may help to contribute towards funding but is likely to mean that;
  a) Significant costs may be incurred by the householder.
  b) High amounts of interest are paid over the duration of the loan scheme.

The latter point may be even more of a problem for historic and traditional properties, where costs of retrofitting sensitively tend to be more expensive. Interest rates and loan periods will affect the financial viability of the Green Deal loans.

The above is drawn from calculations based upon the assumptions within RdSAP, as this is the tool behind Green Deal Assessments and savings calculations. However, it has been shown that these assumptions are not always accurate enough for the purposes of Green Deal or ECO assessments for certain property types. For example, default U-values are not always accurate and may misrepresent actual savings, both upwards and downwards depending on the improvement measure. In addition, the importance of user behaviour has been highlighted: the Golden Rule is only theoretical and in reality, the savings made will vary based on the number and behaviour of occupants. Whilst householders will be made aware of this through the Green Deal's Occupancy Assessment, there is no obligation for assessors or providers to factor the impacts of this into the loan calculations and it is therefore unlikely that they will do so.

It is important to note that the upgrade packages presented in this report are whole-property retrofits, some of which include renewable energy systems. Capital costs are therefore high – however, they also tend to generate high savings: for example, they would almost all be likely to meet the 2020 EESSH targets. While the capital costs involved in all

[33] Solid wall insulation in Scotland: Exploring barriers, solutions and new approaches (Changeworks, 2012)

three property retrofits are significantly higher than most Government forecasts, and economies of scale may be achieved in the future as mass retrofits are tackled and material costs reduce, it should be acknowledged that the cost of making significant CO_2 and running cost reductions in traditional properties is likely to be significant. Within the context of the current funding scenario, coupled with the lack of energy efficiency standards in privately owned housing, the level of uptake of measures and the impact on climate change policies must be questioned.

ECO subsidy levels were shown to be highly sensitive to the make-up of the improvement package. Measures generating high savings attract high levels of Green Deal and ECO that could help cover the costs of the more expensive measures. In the same manner measures that cost a lot but attract no or little Green Deal or ECO could jeopardise the financial viability of a Green Deal loan. Deciding on the right package of measures for a property will therefore have a significant impact on its viability for the householder – although it should be highlighted that the householder may not have a significant say in the package's make-up, as the calculations are conducted by the Green Deal Provider who is not obliged to share the ECO details with the householder.

From a utility company perspective, the relatively high costs of upgrading traditional properties may not be attractive, particularly in urban areas on the gas network. They may prioritise e.g. off-gas areas or easier-to-treat property types, where they can create CO_2 savings at a lower cost and therefore achieve greater value for money. It should also be noted that loft insulation (one of the measures generating the most 'surplus' Green Deal finance) will become increasingly difficult to apply as most lofts have now been fully or partially treated, and the savings from loft top-up (as opposed to installing full insulation in a virgin loft) are considerably less.

Based on the modelled examples, biomass boilers would attract negligible funding through Green Deal and ECO. This in part reflects their treatment in RdSAP in relation to default efficiencies that are lower than manufacturers specify and the use of a default fuel source (pellets), instead of lower cost alternatives such as logs. This is significant, because Green Deal assessments may not specify these types of improvements if the benefits are being underestimated. It would be beneficial if assessors had more flexibility in overriding these defaults to reflect actual specifications more accurately.

In summary, the level of ECO available is critical if households are to avoid having to pay up-front costs to access Green Deal finance. DECC's estimated levels of £77/tonne of CO_2 seem to fall significantly short of what is likely to be required for whole-house traditional property retrofits, if all building elements are to be addressed. At £120/tonne $CO_2$the situation is brighter, but for some properties this will still not cover all costs. Questions must be asked as

to whether energy companies will feel obliged to pay the higher CO_2 costs needed to reach these properties – if there are cheaper non-traditional properties available.

Appendix A: Full Modelling Results

EPC ratings for individual measures

Table A1: Sandstone cottage

Measure	EE		EI	
	Rating	Band	Rating	Band
Baseline	**7**	**G**	**1**	**G**
+ Loft insulation	14	G	1	G
+ Wall insulation (blown bead)	25	F	7	G
+ Wall insulation (aerogel)	25	F	7	G
+ Floor insulation (partial; timber)	8	G	1	G
+ Floor insulation (partial; solid)	8	G	1	G
+ Floor insulation (both the above combined)	8	G	1	G
+ Draught proofing	8	G	1	G
+ Double glazing (slim, in existing sashes)	10	G	1	G
+ Secondary glazing (acrylic panes)	10	G	1	G
+ Front door upgrade (insulation added)	8	G	1	G
+ Front door upgrade (new door)	8	G	1	G
+ Hot water tank ins (160mm jacket)	9	G	1	G
+ Biomass boiler	5	G	82	B

Table A2: Tenement flat

Measure	EE		EI	
	Rating	Band	Rating	Band
Baseline	**65**	**D**	**61**	**D**
+ Wall insulation (aerogel)	68	D	65	D
+ Wall insulation (100mm wood fibre board)	69	D	66	D
+ Draught proofing	66	D	62	D
+ Hot water tank insulation	67	D	63	D
+ Hot water tank thermostat	66	D	63	D
+ Double glazing (slim, in existing sashes)	70	C	67	D
+ Double glazing (new timber sashes)	70	C	67	D
+ Secondary glazing (acrylic panes)	69	C	66	D
+ Secondary glazing (slim, whole window)	70	C	67	D
+ Front door upgrade (insulation added)	65	D	61	D
+ Front door upgrade (new door)	65	D	61	D
+ Condensing boiler + controls	77	C	77	C
+ Storage heating system	72	C	53	E

Table A3: Granite cottage

Measure	EE		EI	
	Rating	Band	Rating	Band
Baseline	**21**	**F**	**8**	**G**
+ Roof insulation	37	F	22	F
+ Wall insulation	30	F	16	G
+ Floor insulation (partial)	22	F	8	G
+ Double glazing	25	F	11	G
+ Door replacement	21	F	8	G
+ Biomass stove boiler system	14	G	84	B

Financial savings for individual measures

Table A4: Sandstone cottage

Ref No	Measure	Measure costs	Annual financial savings	
			£	%
1	Loft insulation	£240	£190	8.2%
2	Wall insulation (whole house)	£2,261	£496	21.4%
3	Wall insulation (whole house)	£11,475	£496	21.4%
4	Floor insulation (partial - timber floor only)	£562	£20	0.9%
5	Floor insulation (partial - solid floor only)	£1,193	£28	1.2%
6	Floor insulation (full)	£1,755	£48	2.1%
7	Hot water tank ins	£96	£61	2.6%
8	Draughtproofing (whole house)	£2,880	£47	2.0%
9	Biomass boiler	£18,000	£170	7.3%
10	Double glazing (whole house)	£5,760	£115	4.9%
11	Secondary glazing	£727	£105	4.5%
12	Front door upgrade	£113	£17	0.7%
13	Front door replacement	£1,080	£17	0.7%

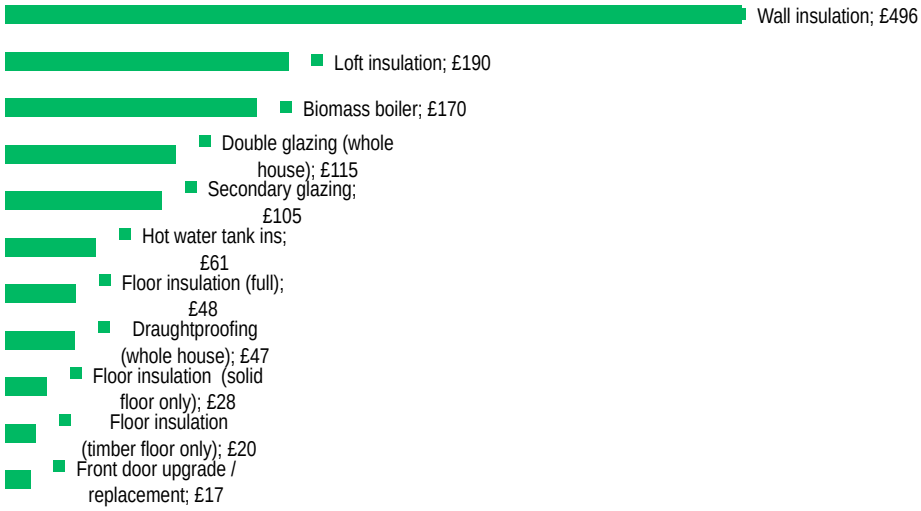


Table A5: Tenement flat

Ref No	Measure	Measure costs	Annual financial savings	
			£	%
1	Wall insulation	£3,982	£71	6.5%
2	Wall insulation	£2,276	£86	7.9%
3	Draughtproofing (whole house)	£1,800	£32	3.0%
4	Hot water tank ins	£96	£41	3.7%
5	Hot water tank thermostat	£96	£36	3.3%
6	Condensing boiler and controls	£5,280	£287	26.3%
7	Storage heating	£2,376	£145	13.3%
8	Double glazing	£3,960	£111	10.2%
9	Double glazing	£5,280	£111	10.2%
10	Secondary glazing	£1,093	£99	9.1%
11	Secondary glazing (Slim-line)	£5,280	£111	10.2%
12	Front door upgrade	£208	£5	0.5%
13	Front door replacement	£1,440	£5	0.5%

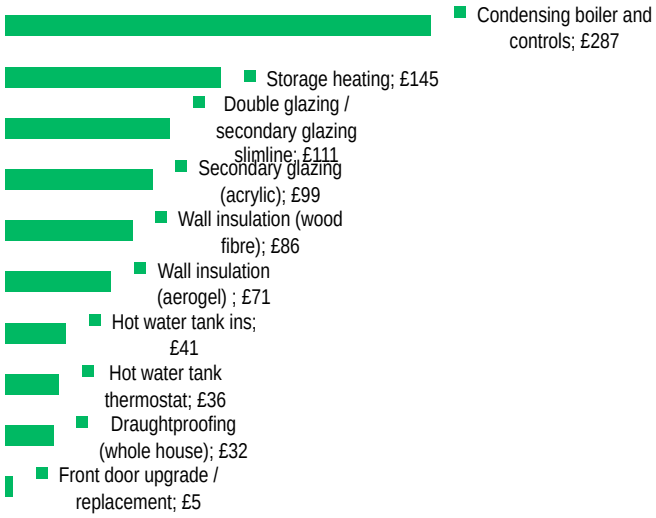
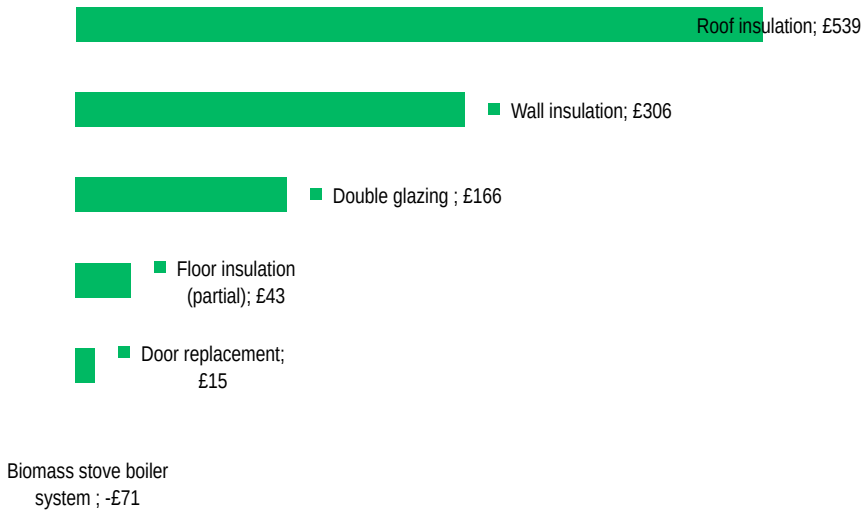


Table A6: Granite cottage

Ref No	Measure	Measure costs	Annual financial savings	
			£	%
1	Roof insulation	£8,587	£539	20.2%
2	Wall insulation	£15,028	£306	11.4%
3	Floor insulation (partial)	£2,524	£43	1.6%
4	Biomass stove boiler system	£16,060	-£71	-2.7%
5	Double glazing	£10,800	£166	6.2%
6	Door replacement	£2,076	£15	0.6%



CO_2 savings for individual measures

Table A7: Sandstone cottage

Ref No	Measure	CO_2 savings		
		Annual (tonnes)	%	Lifetime (tonnes)
1	Loft insulation	1.3	7.6%	55
2	Wall insulation (whole house)	3.8	22.1%	135
3	Wall insulation (whole house)	3.8	22.1%	135
4	Floor insulation (partial - timber floor only)	0.0	0.0%	0
5	Floor insulation (partial - solid floor only)	0.0	0.0%	0
6	Floor insulation (full)	0.0	0.0%	0
7	Hot water tank ins	0.0	0.0%	0
8	Draughtproofing (whole house)	0.0	0.0%	0
9	Biomass boiler	11.6	68.4%	233
10	Double glazing (whole house)	0.9	5.0%	17
11	Secondary glazing	0.9	5.0%	17
12	Front door upgrade	0.0	0.0%	0
13	Front door replacement	0.0	0.0%	0

Table A8: Tenement flat

Ref No	Measure	CO_2 savings		
		Annual (tonnes)	%	Lifetime (tonnes)
1	Wall insulation	0.4	6.9%	14
2	Wall insulation	0.5	8.3%	16
3	Draughtproofing (whole house)	0.2	3.1%	2
4	Hot water tank ins	0.3	4.7%	3
5	Hot water tank thermostat	0.2	3.3%	2
6	Condensing boiler and controls	1.7	30.6%	20
7	Storage heating	-1.2	-21.7%	-23
8	Double glazing	0.7	12.5%	14
9	Double glazing	0.7	12.5%	14
10	Secondary glazing	0.6	11.1%	12
11	Secondary glazing (Slim-line)	0.7	12.5%	14
12	Front door upgrade	0.0	0.0%	0
13	Front door replacement	0.0	0.0%	0

Table A9: Granite cottage

Ref No	Measure	CO_2 savings		
		Annual (tonnes)	%	Lifetime (tonnes)
1	Roof insulation	4.5	23.7%	189
2	Wall insulation	2.1	11.1%	76
3	Floor insulation (partial)	0.9	4.5%	11
4	Biomass stove boiler system	12.7	66.7%	141
5	Double glazing	1.7	8.9%	1
6	Door replacement	0.0	0.0%	0

Financial savings for cumulative measures

Table A10: Sandstone cottage

Ref No	Measure	Measure costs	Annual financial savings	
			£	%
1	Loft insulation	£240	£190	8.2%
3	Wall insulation (aerogel)	£11,475	£488	21.1%
6	Floor ins (full)	£1,755	£46	2.0%
7	Hot water tank ins (160mm jacket)	£96	£61	2.6%
9	Biomass boiler	£18,000	£41	1.7%
10	Double glazing	£5,760	£101	4.4%
13	Front door upgrade (new insulated door)	£1,080	£15	0.7%
TOTAL		**£38,406**	**£943**	**40.7%**

Table A11: Tenement flat

Ref No	Measure	Measure costs	Annual financial savings	
			£	%
1	Internal wall insulation (Aerogel)	£3,982	£71	6.5%
4	Hot water tank ins	£96	£41	3.7%
5	Hot water tank thermostat	£96	£25	2.3%
6	Condensing boiler / controls	£5,280	£202	18.5%
9	Double glazing (timber sash)	£5,280	£77	7.0%
13	Front door upgrade (new insulated door)	£1,440	£3	0.3%
TOTAL		**£16,174**	**£419**	**38.5%**

Table A12: Granite cottage

Ref No	Measure	Measure costs	Annual financial savings	
			£	%
1	Roof insulation	£8,587	£539	20.2%
2	Wall insulation	£15,028	£309	11.5%
3	Floor insulation (partial)	£2,524	£43	1.6%
4	Biomass stove boiler system	£16,060	-£59	-2.2%
5	Double glazing	£10,800	£170	6.4%
6	Door replacement	£2,076	£17	0.6%
TOTAL			**£55,074**	**£840**

CO_2 savings for cumulative measures

Table A13: Sandstone cottage

Ref No	Measure	CO_2 savings		
		Annual (tonnes)	%	Lifetime (tonnes)
1	Loft insulation	1.3	7.6%	55
3	Wall insulation (aerogel)	3.8	22.5%	138
6	Floor ins (full)	0.4	2.5%	18
7	Hot water tank ins (160mm jacket)	0.3	2.0%	3
9	Biomass boiler	6.0	35.3%	120
10	Double glazing	0.1	0.5%	2
13	Front door upgrade (new insulated door)	0.0	0.0%	0
TOTAL		**12.0**	**70.4%**	**336**

Table A14: Tenement flat

Ref No	Measure	CO_2 savings		
		Annual (tonnes)	%	Lifetime (tonnes)
1	Internal wall insulation (Aerogel)	0.4	6.9%	14
4	Hot water tank ins	0.3	4.7%	3
5	Hot water tank thermostat	0.2	3.3%	2
6	Condensing boiler / controls	1.1	20.8%	14
9	Double glazing (timber sash)	0.5	9.4%	10
13	Front door upgrade (new insulated door)	0.0	0.0%	0
TOTAL		**2.4**	**45.3%**	**42**

Table A15: Granite cottage

Ref No	Measure	CO_2 savings		
		Annual (tonnes)	%	Lifetime (tonnes)
1	Roof insulation	4.5	23.7%	189
2	Wall insulation	2.1	11.1%	76
3	Floor insulation (partial)	0.3	1.3%	11
4	Biomass stove boiler system	7.1	37.1%	141
5	Double glazing	0.1	0.4%	1
6	Door replacement	0.0	0.0%	0
TOTAL		**12.8**	**67.2%**	**374**

Appendix B: Green Deal and ECO information

Lifetime of measures installed through ECO

Table A20: Lifetime of measures

Measure	Assumed Lifetime
Loft Insulation	42 years
Cavity Wall Insulation	42 years
Solid Wall Insulation	36 years
Central Heating	12 years
Minor Measures	4 – 10 years

Source: DECC (2013) Energy Companies Obligation ECO – List of Measures and Additional Information

Table A21: RdSAP Default U-values for retrofitting external or internal wall insulation on solid wals covering all age bands pre-1975

Thickness (mm)	U-value (W/m2k)
50	0.6
100	0.35
150	0.25

Historic Scotland Technical Papers

Available at www.historic-scotland.gov.uk/technicalpapers

1 Thermal performance of traditional windows
2 In situ U-value measurements in traditional buildings – *Preliminary results*
3 Energy modelling analysis of a traditionally built Scottish tenement flat
4 Energy modelling in traditional Scottish Houses (EMITSH)
5 Energy modelling of a mid 19th century villa
6 Indoor air quality and energy efficiency in traditional buildings
7 Embodied energy in natural building stone in Scotland
8 Energy modelling of the Garden Bothy, Dumfries House
9 Slim-profile double glazing – *Thermal performance and embodied energy*
10 U-values and traditional buildings – *In situ measurements and their comparison to calculated values*
11 Scottish Renaissance interiors – *Facings and adhesives for size-tempera painted wood*
12 Indoor environmental quality in refurbishment
13 Embodied energy considerations for existing buildings
14 Keeping warm in a cooler house – *Creating thermal comfort with background heating and locally used supplementary warmth*
15 Assessing insulation retrofits with hygrothermal simulations – *Heat and moisture transfer in insulated solid stone walls*
16 Green Deal financial modelling of a traditional cottage and tenement flat – *a consideration of Green Deal Measures in older properties*
17 Green Deal, Energy Company Obligation and traditional buildings