Housing, Regeneration and Planning

The Scottish Government

Evidence on Tackling Hard to Treat Properties

social research

Evidence on Tackling Hard to Treat Properties

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Glossary

BERR – Department for Business, Enterprise and Regulatory Reform
CFL – Compact Fluorescent Light bulb
CHP – Combined Heat and Power
CHPA - Combined Heat and Power Association
CO_2 – Carbon Dioxide
CO_2e – Carbon Dioxide Equivalent
DP - Draught Proofing
EAS - Energy Action Scotland
EBP – Environmental Building Partnership
EHSNI – Environment and Heritage Service, Northern Ireland
EPS – Expanded Polystyrene
EPSRC – Engineering and Physical Sciences Research Council
EST – Energy Saving Trust
ESRU – Energy Systems Research Unit
GCH – Gas Central Heating
GHA – Glasgow Housing Association
HA - Housing Association
HCU - Heating Control Upgrade
HtT – Hard to Treat
JK – Jug Kettle
kWh – Kilowatt Hours
kWp – Kilowatt peak
LEEP – Lothian & Edinburgh Environmental Partnership
LI - Loft Insulation
MHVR – Mechanical Ventilation with Heat Recovery
NEA – National Energy Action
NHER – National Home Energy Rating (Service)
OO - Owner Occupied
PR - Privately Rented
PV – Photovoltaic
RGB – Replacement Gas Boiler
SAP – Standard Assessment Procedure
SWH – Solar Water Heating
TRV – Thermostatic Radiator Valve
VIP – Vacuum Insulation Panels

EXECUTIVE SUMMARY

Scottish Ministers re-established the Scottish Fuel Poverty Forum, chaired by the Rev Graham Blount, to develop proposals for the reform of fuel poverty programmes within existing budgets. In order to inform the Forum's discussions, a report on best practice in tackling Hard to Treat (HtT) properties was required, with a particular emphasis on tackling fuel poverty and carbon emissions.

The resulting report is set out below in 8 sections.

Section 1 introduces the issues that are driving the need to refurbish HtT homes.

Section 2 covers the background to HtT homes and describes their types.

Section 3 describes the seven different HtT buildings types that are covered in this report and outlines a range of options for treating each one of them. The types are:

- Solid wall properties
- Tenements
- High rise properties
- Flat roof homes
- Timber frame homes
- Mansard roof homes
- Park Homes

Section 4 describes a range of improvements applicable to most HtT properties with an overview of their relative costs and benefits where available. These include: insulation; windows and glazing; internal shutters; draughtproofing; heating systems and controls; lighting and appliances; smart meters; Combined Heat and Power and renewable energy systems.

Section 5 summarises some new research involving innovative interventions that may be introduced in future markets including advanced surface treatments, non-technological solutions and management solutions.

Section 6 outlines refurbishment recommendations for all seven of the HtT house types that include not only physical interventions but also highlight the need for management and methodological issues to be taken into account. These recommendations are outlined in the charts at the end of this executive summary.

Section 7 concludes by drawing out key recommendations from the body of the text. Because of the speed with which energy prices are rising pushing more people into fuel poverty the authors of this report suggested that Scottish councils and the Scottish Government have an opportunity to act together to facilitate the informing and funding of refurbishment schemes of HtT housing in which many of those in fuel poverty are living.

A review of the available funding sources to eliminate the double funding of certain refurbishment interventions while others are excluded under programmes such as those providing CERT and WARM DEAL funding is questioned and action to promote the extension of funding provision to cover a wider range of actions would provide real benefits.

Tenements and high rise blocks are in need of urgent attention

A review of the cost effectiveness of actual completed refurbishment schemes for two house types in particular would provide useful data for decision makers across the board. These are the tenements and the high rise blocks. Packages of cost efficient interventions such as draft stripping, insulation and secondary glazing in tenements have significantly reduced energy use in them and improved comfort for their occupants. Such schemes need to be rolled out rapidly to impact of rising numbers falling into fuel poverty and a better data base on costs and impacts on which decisions on investment could be based would be valuable.

A comprehensive database on high rise blocks and the refurbishment costs and impacts in particular would benefit not only larger housing organisations but the many smaller councils that do have high rise blocks but cannot afford the research on which to base judicious choices on the improvement of their tower blocks.

The development of a range of new tools such as EDEM for use in evaluating the cost benefits of refurbishment choices are welcomed and further work on complementing such predictive tools with post occupancy evaluations of the completed schemes would also provide valuable information on which future policies and actions could be based.

In 2008 the number of Scottish households in fuel poverty in Scotland has reached 543,000, of the total of around 2.3 million homes. These households contain 1 million of the 5 million population of Scotland. Thus around 20% of the Scottish population are currently in fuel poverty. Councils and housing organizations around Scotland are doing a stirling job in trying to improve stock to keep an many as possible from falling into fuel poverty as they can, but this is an extremely expensive task. The Glasgow Housing Association alone has an annual turnover of around £225 million (GHA Annual Report) indicating the scale of cash flow through the sector. By working together, and learning from each other, across the region on the issue of HtT housing refurbishment there is the potential to reduce units costs across the board while at the same time building local capacity in the building trades and energy sectors for the benefit of all.

In 2008 the number of Scottish households in fuel poverty in Scotland has reached 543,000, of the total of around 2.3 million homes

SUMMARY OF RECOMMENDATIONS FOR HARD TO TREAT PROPERTIES

Property Type	Primary Recommendation(s)	Secondary Recommendation(s)
Solid Wall	• Aim to develop a cost efficient set of interventions that are appropriate to the individual requirements of the solid wall house type	• Eliminate cold bridging • Eliminate infiltration • Experiment with new insulation types • Reduce energy use through options applicable to all / most HtT properties
Tenement	• Aim to have all blocks covered by factoring agreements that include carbon factoring, use these to ensure all blocks are brought up to recommended energy efficiency standards • Introduce a new scheme to promote and subside secondary glazing and draughtproofing • Amend Tenements Scotland Act to mandate for carbon factoring	• Use factoring schemes to offer energy audits for individual flats and use these to promote improvements such as heating system upgrades, low energy lights, energy efficient appliances and behavioural changes • Consider promoting and subsiding the construction of draught lobbys and the installation of under-floor insulation • Consider designing and trialling micro-CHP schemes specifically for groups of tenements
High Rise	• Develop a reliable and replicable process for evaluating the cost efficiency of high rise investments • Externally insulate • Consider lift and water energy • Use Combined Heat and Power systems • Include management issues in the solutions	• Consider trialling CHP and building energy services to other local buildings • Combine with other Authorities to find ways of reducing over-cladding costs • Life cycle cost all decisions
Timber Frame pre-1982	• Target to promote the uptake of external and internal cladding suitable for timber frame walls	• Reduce energy use through options applicable to all / most HtT properties
Flat Roof	• Target to promote the installation of warm deck flat roofs on all suitable properties	• Where installing a warm deck is not possible promote the installation of internal cladding on ceilings

Property Type	Primary Recommendation(s)	Secondary Recommendation(s)
Mansard Roof	• Target to promote the upgrading by adding blown fibre insulation behind the tiles on the lower section (note that this needs to be carried out in dry weather) • Treat upper sections as for normal sloping roofs where access allows	• Promote the installation of internal cladding on the walls and ceilings of rooms contained within the mansard
Park Homes and Residential Mobile Homes	• Target to promote internal wall, ceiling and floor insulation, external cladding / render, and the sealing of leaks around doors and windows • Legislate to ensure all landlords of rented homes bring insulation up to recommended levels • British Standard 3632:1995 could be revised to improve minimum energy efficiency standards	• Installing double glazing will benefit some homes, but has a long payback period • For homes with flat roofs adding an insulated sloping roof may be an option, but payback periods suggest offering subsidies is not cost-effective • Promote solar thermal and micro-renewables, particularly to homes not on mains gas / electricity supplies
All Hard to Treat	• Target all HtT properties with information on secondary glazing and draughtproofing • For properties with gas central heating promote the replacement of old boilers with newer combi / condensing models, encourage annual servicing and installation of improved controls (TRVs, thermostats programmable timers) • For properties without a mains gas supply promote the upgrading of heating systems to the latest, most energy efficient designs • Target all properties with information on the savings that can be made from using low energy light bulbs and replacing old appliances with 'A-rated' and above • Consider trialling a scheme to subsidise the above, particularly secondary glazing and draughtproofing, and prioritise older properties and households on low incomes	• Consider pushing ahead with a programme to install smart meters in all Scottish homes • Promote community CHP schemes • Encourage the uptake of micro-CHP and renewables, and consider revising planning and conservation legislation where feasible

1 INTRODUCTION

Scottish Ministers re-established the Scottish Fuel Poverty Forum, chaired by the Reverend Graham Blount, to develop proposals for the reform of fuel poverty programmes within existing budgets. In order to inform the Forum's discussions, a paper on national and international best practice in tackling hard to treat (HtT) properties has been prepared below, with a view to informing the Fuel Poverty Forum on the subject.

Hard to treat high rise block in an urban centre

The aim of this report is to produce a detailed, short, and easy-to-read summary of evidence on best practice in tackling hard to treat properties to address fuel poverty and/or carbon emissions.
In this report an overview of the different type of hard to treat homes in Scotland is given with an outline of their physical characteristics and methods currently used to address the hard to treat problems, which are particularly severe in Scotland.
Evidence from the 2002 House Condition Survey showed that an estimated 286,000 households (13%) were fuel poor. Of these, 24% (69,000) are in extreme fuel poverty (i.e. would have to spend more than 20% of their income on fuel to maintain the standard heating regime). Most of the extremely fuel poor are single person households.

The Health and Wellbeing Secretary Nicola Sturgeon also recently announced the publication of the Scottish Government's Review of Fuel Poverty. The review highlights that the latest 2008 figures show that the 2002 figure has almost doubled to a figure of 543,000 Scottish households, in which live the nearly one million people, being classed as fuel poor.

The rise of fuel poverty in Scotland is linked to soaring energy prices and is predicted to worsen following large rises in the price of gas and electricity in July 2008. Communities Minister Stewart Maxwell stated in the Scotsman on the 31st July that Scots will struggle to cope with a record 35% price rise levied by British Gas parent company Centrica. A 9% rise in electricity prices was announced at the same time. The "fuel poverty" bracket is defined by the Government as those who spend more than 10% of their income on energy bills. In January 2008 tariffs had already been raised by an average of 15 per cent and the combined effect of both price rises was predicted to take average combined bills for gas and electricity to £1,317, up by more than £400 since the start of 2008.

The UK has had the cheapest gas in Europe since 2000, and the cost of electricity has been below average. But in 2004, Britain became a net importer of gas, despite the presence of North Sea gas. The opening of pipelines connecting the UK to Europe's gas markets has had the effect of increasing UK prices to the European level. Further problems have been caused by delays in building new storage facilities. The UK can store only 13 days of gas, compared with 99 days in Germany and 122 in France.

Fuel security has become a real issue for Scotland, and particularly those in very poor housing and the "only answer", according to Phil Bentley, the Managing Director of British Gas at the time of the July price rises, was for customers to become more energy efficient.

Money has been made available to fund higher levels of refurbishments and Ministers have secured an extra £225 million from energy companies over three years to be targeted at poorer households, while the winter fuel payment will rise this year from £200 to £250 (and from £300 to £400 for over 80s). However the use of these funds is not without problems as outlined in our conclusions.

What is set out below is a review of the different types of hard to treat homes in Scotland and how they are currently being improved. From this study of the problem it is clear that there are a wide variety of different approaches being followed in relation to different building types and the authors of this report would like to suggest that a follow on from this review might take the form of further research to quantify impacts on the total housing stock of different levels of improvement to the different house types.

2 BACKGROUND

2.1 Definition of Hard to Treat Properties

For the purposes of this report Hard to Treat (HtT) properties are defined as having one or more of the following characteristics:

- Solid walls
- High-rise (all flats and maisonettes in a multi-storey tower with 5 or more levels and all tenements)
- Timber frame houses constructed prior to 1982
- Mansard / flat roofs
- Park homes (mobile homes on licensed sites, e.g. caravan parks) and residential mobile homes (mobile homes on other sites)

All these characteristics pose non-trivial problems for reducing energy consumption. These may be technical (e.g. difficulties with installing insulation), economic (e.g. unfavourable cost / benefit results for improvement options), social (e.g. getting 'buy-in' from all residents in a tenement block), or any combination of these factors.

Note: Many historic homes could be classified as hard to treat due to the conservation legislation that governs them. However, for the purposes of this report only those that fall under the above definition are covered. Where common planning restrictions may prevent the improvements covered being made this has been noted, however these can be highly variable between localities. Therefore it must be stressed that consent **must always** be sought if there is **any** doubt over whether or not restrictions apply.

2.2 Hard to Treat Properties in the Scottish Housing Stock

For 2003/04 the total number of residential properties in Scotland stood at 2,269,000 (excluding park homes / residential mobile homes). Construction, demolition and renovation rates are low (4%, 0.01% and 2% respectively) so the figures will have changed little since then.

The numbers of Scottish properties falling into each of the HtT categories are as follows:

- 25% have solid walls
- 23% are tenement flats and 3% are high rise flats
- 5% are timber framed (including post-1982 properties)[1]
- 4% have flat roofs and 1% have Mansard roofs
- The number of park and residential mobile homes in Scotland has been estimated to be an absolute minimum of 4,121 units.[2]

[1] The Scottish House Condition Survey does not make this distinction

[2] Figure excludes tents, Gypsy caravans and similar structures (which were included in the 2001 Census) as these would require individual attention. The most recent data suggests that approximately 34% of park and mobile homes are

Table 1: Scottish Housing Stock 2005/2006 with weighted percentages/

Type of dwelling	Frequency	Percent
Detached	493,342	21.3
Semi-detached	486,430	21.0
Terrace	537,969	23.2
Tenement	487,810	21.1
4-in-a-block	210,700	9.1
Tower/slab	71,998	3.1
Flat from converted house	26,405	1.1
Total	**2,314,654**	**100.0**

Source: The SHCS team

3 OPTIONS FOR TREATING HARD TO TREAT PROPERTIES

This section discusses the options for treating the various hard to treat properties that can be found in the Scottish housing stock. Particular attention has been paid to solid wall properties and tenements as these constitute the majority of hard to treat properties and so any schemes targeting these dwellings will have the greatest potential to yield significant reductions in fuel bills and CO_2 emissions.

3.1 Solid Wall Properties

Approximately 25% of Scottish homes are solid wall with a further 5% being of timber frame construction, which are effectively solid wall as the ventilated cavity cannot be in-filled. The ability of the Scottish domestic sector to create enough CO_2 emissions reductions to meet stated government targets is dependant to a significant extent on being able to reduce heat loss from solid wall dwellings in Scotland. To illustrate the extent of the problem, the total CO_2 emissions attributable to a domestic property was disaggregated by building element and end use (Figure 1). For a detached Victorian property with a floor area 144m^2 with characteristic family occupancy it was found that the contribution of heat loss through the solid wall to the total CO_2 emissions of the dwelling is approximately 27% (Peacock et al., 2007).

3.1.1 Solid Wall Insulation Measures

Current Solutions

External wall insulation can be applied using in effect an external cladding system. This approach has a number of possible benefits that are likely to include; elimination of thermal

privately rented - be they on licensed sites, tied to employment, or provided for seasonal workers (compared to 18% in England and Wales).

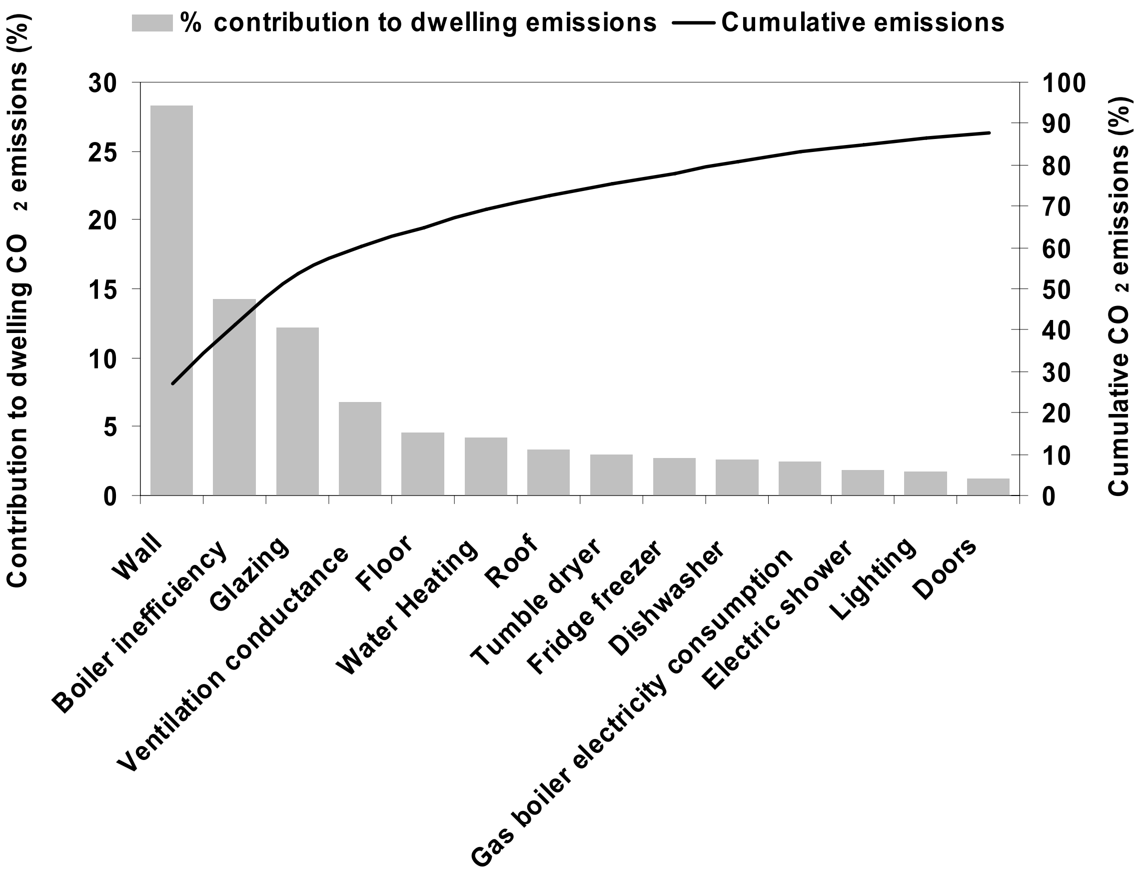

Figure 1: Figure showing the amount of CO2 emissions that are saved by different technologies and building interventions in a Victorian detached dwelling of 144m2 floor area. Insulation of the external wall is by far the most effective means of reducing emissions and the black line of cumulative emission reductions shows that if all the measures are applied then getting on for 90% of emissions from the house can be saved.

bridging, minimal disruption to occupants, room sizes are not reduced, opportunity for greater thicknesses of insulation than with internal insulation and importantly potential improvement to building appearance. Whilst acknowledging that there are many dwellings where the modification of the external appearance would not currently be deemed palatable by the planning authorities, there are many more where the result would be acceptable.

There are a number of steps needed to apply either internal or external insulation to an existing property that need careful handling to be successful. Insulation may be mineral fibre, expanded polystyrene, or a number of closed cell foams or vacuum insulation panels. Wet renders are secured to the insulation by first attaching metal of fibre mesh to act as a key. A number of factors need to be considered during the application. Insulation should be returned into the window reveals and head and this may limit the thickness in these areas. This problem is overcome if windows are replaced at the same time. Eaves overhangs, weather drips on sills and other features may also limit the thickness of insulant that can be applied. Flues for existing heating devices will need to be extended and rainwater services will need to be removed and refitted or replaced.

Internal insulation can be applied in conservation areas where the outer appearance of the building must remain unchanged but this may require the decanting of the occupants during building work and the subsequent redecoration of properties. Insulation is usually applied in the form of composite insulated plasterboard incorporating either polyurethane, extruded or expanded polystyrene or mineral wool. Vacuum insulation panels have also been applied in the German market but care needs to be taken to ensure their application takes into account subsequent penetrations that may be made into wall surfaces to accommodate internal decorations, shelving and storage. The board can be directly bonded to the internal wall surface. Alternatively, walls can be battened out and insulation fitted between the framework to produce a surface that can be plastered over. Care needs to be taken though to ensure that insulated boards are adequately sealed to prevent warm air movement which in turn may lead to interstitial condensation.

3.1.2 Case Study: Technological Intervention to a Detached Victorian Property

The problem of treating solid wall properties is, of course, not all about the treatment of the wall. Other measures can also contribute to cumulative reductions in energy consumption and CO_2 emissions. To explore the extent to which this is the case, we continue with the example of the Victorian detached dwelling in Edinburgh (see Figure 1). This had baseline annual thermal and electrical demand of 28,600 and 5,400kWh respectively resulting in 8.1TCO_2 emission per annum. The results indicated are from work done at Heriot-Watt University on a range of technological interventions that can be applied to existing buildings (domestic and non-domestic) to reduce their CO_2 emissions by 50% by 2030 (the TARBASE Project).

Results from work at Heriot-Watt University show that technological interventions can reduce the CO_2 emissions of existing buildings by 50% by 2030

Improvements that can be made to the dwelling that do not involve modification of the external wall include: loft insulation was increased to 250mm, all infiltration measures were applied, a ventilation heat recovery systems was installed, lighting upgraded to low energy light bulbs only, refrigeration appliances contained vacuum insulation panels, a range of other appliance improvements were applied, glazing improved to a u-value of 1.4, solar water heating panels installed, new boiler installed and finally allowance taken for the warming climate. A reduction in CO_2 emissions of just over 42% could be achieved.

It should be noted here that a U-Value is a measure of air-to-heat transmission (loss or gain) due to the thermal conductance of the walls floors and ceilings of buildings and the difference in indoor and outdoor temperatures. As the U-value decreases, so does the amount of heat that is transferred through the envelope. The U-value is a measure of the overall energy efficiency of the building envelope. It tells you the rate at which heat flows through the entire wall, window or door, floor or roof. The lower the U-value, the more energy-efficient the building element is. U-Values of walls that are lower than 0.20 in Scotland are very good although the U-values of windows are much higher at between 1.2 for triple glazing and 5.4 for single glazing.

External wall insulation is extremely effective is achieving high levels of emissions reductions. If 40% of the external wall area was treated with 100mm of expanded polystyrene (EPS) on timber battens in conjunction with all the other measures indicated in Figure 2, the emissions savings would leap to 52%. If the maximum external wall area was treated (80% of total external wall area) then this figure would rise to 62%. To place this in some context, approximately 22m^2 (2.9kWp) of PV would be required in conjunction with the measures outlined in Figure 2 to produce equivalent CO_2 savings.

Of course, the relevance of the external wall to the emissions saved by implementing an intervention set as indicated in Figure 2 is predicated on the dwelling. For instance, a terraced dwelling of floor area 60m2 would see its CO_2 emission cut by approximately 50%. This would rise to 58% and 66% if external wall insulation were applied at levels of 40% and 80% respectively (Massini et al., n.d.).

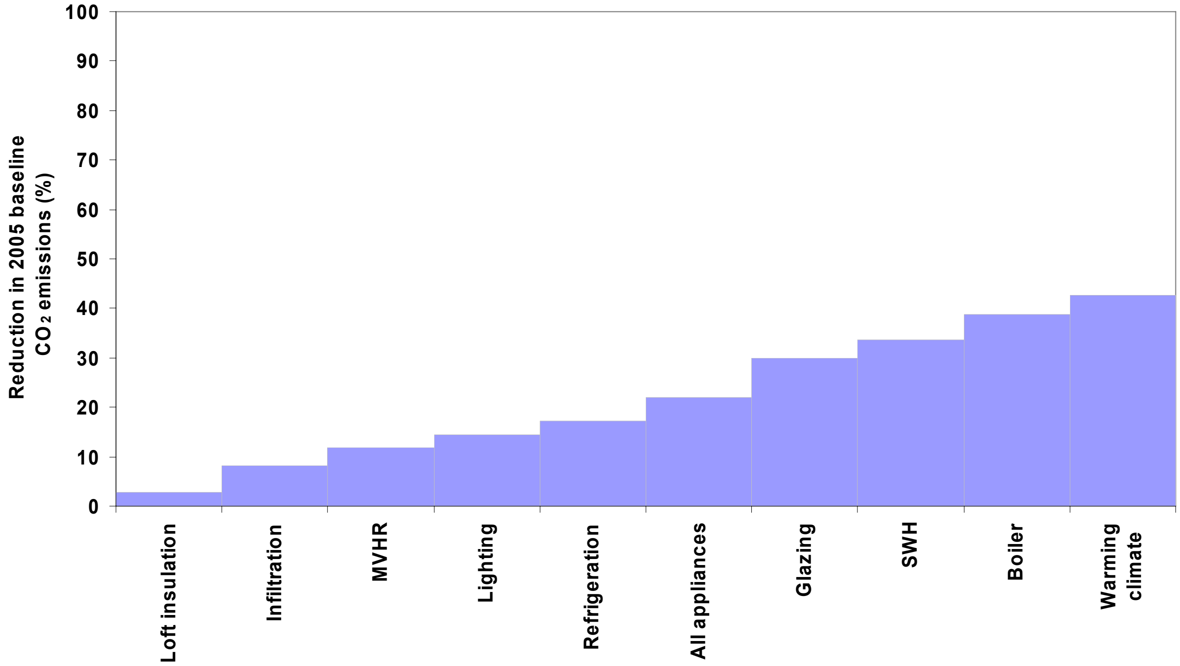

Figure 2: A range of Interventions for a Victorian detached dwelling of floor area 144m^2 that excludes modification of external wall showing where the most savings can be made in the home

Costs of intervention sets

The complete range or set of interventions modelled in this project including application of external wall insulation to 40% of the available wall area would cost approximately £25.8k for the Victorian detached dwelling with a floor area of 144m^2 assuming no learning rate for the technologies i.e. at current market prices. This would rise to £31.9k if external insulation were to be applied to 80% of the available wall area. Both these interventions sets would have a negative net present value in 25 years and would have a simple payback in excess of 60 years using 2008 utility prices. It was assumed that the interventions themselves would not add to the equity contained in the dwelling – only limited evidence exists to suggest that they would positively add to the selling price of a dwelling and the authors were aware of no evidence of their effect during a period of falling house prices. A debate regarding the use of either simple payback or whole life cycle cost metrics to describe the suitability or applicability of these intervention sets in domestic dwelling is long over due. Similarly the method by which these intervention sets might be sold to householders has been largely ignored but is critical to improving the perceived and real 'affordability' of measures that will lead to emission savings of the scale demanded by current climate science. Many of the technologies identified in these intervention sets are relatively mature. As a consequence, successive IPCC documents have identified the domestic sector as having the greatest potential for achieving substantial CO_2 emission reductions. However, a vehicle for accelerating their uptake has yet to be developed. These issues are extremely critical but lie outside the remit of the current document.

3.2 Tenements

Tenements make up almost one quarter of Scottish housing stock and their abundance represents the key difference between Scottish housing and that of the rest of the UK stock. They are an incredibly popular form of housing, as the combination of traditional design and solid build quality makes many tenement flats attractive and comfortable living spaces. The solid walls provide high thermal mass to help keep them cooler in summer and warmer in winter; the use of porous building materials (lime, etc) makes them 'breathable' and so less prone to condensation; and the layouts limit the wall areas exposed to the external environment. All of these factors make tenements potentially very energy efficient, even compared with modern building designs, but their age also means many are falling into states of disrepair that can seriously compromise energy performance and living conditions (Changeworks, 2008). They are also notoriously hard to treat properties as they suffer from all three aspects of the HtT definition:

Tenement blocks in Edinburgh

Technical:

- Solid walls provide excellent thermal mass but mean any insulation must be applied internally unless local regulations permit external modification.
- Being high rise (over three floors) makes accessing some building elements difficult without incurring considerable expense.
- Lack of maintenance can lead to drafts and leaks that may be difficult to locate and access for treatment.
- High ceilings & large rooms in older tenements have higher heating demands.
- Large windows, single glazing and sash windows are common and frequently protected by law. Where windows are not protected loss of traditional appearance and the cost of big areas of glazing makes replacing them unattractive to many residents.
- Many have top-floor roofspace flats that pose problems like those of Mansard roofs.
- Many are governed by the strict planning laws that protect historic buildings.

Economic:

- Cost / benefit analyses for some measures (e.g. loft insulation) are difficult to attribute to individual flats as savings will differ between, and often across each floor.
- Many tenements are mixed-use (having businesses on one or more lower floors).
- The often high cost of energy efficiency interventions mean that residents cannot afford if they have low incomes and are already fuel poor.

Social:

- The combination of multiple occupancy and shared ownership of the roof and communal circulation spaces means any major renovations invariably require gaining the agreement of all residents.
- Even when agreements are reached the cost of renovation work may be prohibitive to some residents of a block, and the often unequal distribution of the benefits invariably requires negotiating different levels of financial contribution.
- Many tenements are mixed-tenure; therefore reaching any agreement often requires consulting a mix of owner-occupiers, public and private sector landlords, and the tenants of rented flats.

The following sections cover how each of these aspects of the problem relate to treating tenements to improve energy efficiency.

3.2.1 Technical solutions for improving the energy efficiency of tenements

Energy efficiency improvements for tenements can be divided into those that can be applied within individual flats and those that apply to the block as a whole, the latter being notoriously difficult to implement due to the problems outlined above.

One of the most detailed practical study of interventions to tenements was a pilot project on three blocks in Edinburgh (LEEP, 2004). The three blocks comprised one block of 12 and two blocks of 8 flats, covering a total of 22 flats (as not all residents agreed to participate) and included a mix if sizes (1-3 bedrooms), household types and tenures that are representative of typical tenement communities.

The blocks were assessed pre and post intervention using the National Homes Energy Rating (NHER) methodology, which other research has found to be more appropriate for application to tenements than some other common methodologies (Baker, 2007) and Standard Assessment Procedure (SAP) ratings were also produced before and after.

Whole block improvements

Tenement stair showing wiring and loft access

A 2002 study by the ESRU at Strathclyde University that formed the basis for the LEEP work investigated the heating energy savings from three measures applicable at the whole block level: loft insulation; creation of a draught lobby[3] and draught proofing of external stair doors; and 'solar slate' heat recovery (Clarke et al., 2005). The average savings from each are given in Table 2. All three measures varying in their effectiveness for reducing heating energy demand on different floors, most notably loft insulation on the top floor. Creating a draught lobby entails installing a new door beyond the main stair door and so may be unpopular with residents without another means of accessing back greens, and has no effect on heat losses from 'main door' flats (ground floor flats with front doors that open directly onto the street). Solar slates consist of photovoltaic (PV) cells with fans underneath that blow warm air back into stairwells. They have been used effectively in 'four in a block' flats but the results of the ESRU study found them to be of limited value and they were not recommended for the LEEP pilot project.

Table 2: Heating energy savings from whole block improvements to tenements

Measure	Savings			
	Ground floor		Mid floor	Top floor
	Main door	In stair		
Loft insulation	0%	0%	*3.5%	20%
Creation of draught lobby in main entrance and draught proofing of external stair doors	0%	*6.4%	*7.5%	*5%
Solar slate heat recovery	0%	1%	*1.1%	*1%

*Average saving – individual flats varied between buildings
Sources: Clarke et al., 2005; reproduced from LEEP, 2004

[3] Note that creation of draught lobbies involves internal alterations that may require consent but evidence suggests this is generally non-prohibitive (see City of Edinburgh Council, 2004).

Making whole block improvements to tenements is problematic for a variety of other non-technical reasons that are explained in sections above, yet these problems can and need to be overcome in order to produce significant reductions in emissions from Scotland's housing stock.

Improvements to Individual Tenement Flats

The most common and effective improvements to tenement flats are those that reduce energy demand from heating

Significant reductions in tenement flat energy demand and CO_2 emissions can be made through improvements to individual flats alone. Given the difficulties that may be encountered with treating whole blocks there are clear benefits from proceeding with improvements to individual flats when schemes to target whole blocks stall. A caveat to this is that as the benefits of loft insulation mainly apply to top floor flats there is clear value in pursuing top floor households alone where residents further down prove uncooperative, especially where 100% grants are available for the work (e.g. from EST Scotland).

The most common and effective improvements to tenement flats are those that reduce energy demand from heating: installing or upgrading gas central heating; replacing gas boilers (combi / condensing models where building restrictions permit); upgrading heating system controls[4]; and draught proofing. Where flats are not connected to the mains gas supply installing the most energy efficient models of storage heaters is generally the best option, although alternatives such as wood burning stoves may be favoured by some residents where fuel storage space is available and local regulations permit them.

Further savings can be made from increasing the efficiencies of lighting and appliances. Low energy compact fluorescent light bulbs (CFLs) are a simple and cheap (often free) way of reducing electricity use, and the EST also reports that using jug kettles can save 0.11t CO_2 per year and even more sophisticated 'eco-kettles' are now on the market.

Replacing appliances, particularly major energy consumers such as refrigerators and washing machines, and with more energy efficient 'A'-rated and above models will further reduce electricity consumption. This is covered in more detail in section 4.

The LEEP study was able to quantify the financial and CO_2 emissions savings of these improvements for individual flats. Total and average savings per block are given in Table 3, and a full breakdown of the savings and improvements made to the individual flats is given in Appendix A.

The study was successful in saving the individual households an average of £164 per year and 1.9t CO_2 per year (including savings from loft insulation to top floor flats only) totalling savings of £3770 per year and 42.6t CO_2 per year.

If these same results could be achieved in every Scottish tenement total savings by residents could amount to over £82.6m and just under 1mt CO_2 per year. This would equate to reducing approximately 1.6% of Scotland's total annual CO_2 emissions and approximately 13.6% of CO_2 emissions from the residential sector.[5]

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[4] There is evidence that residents with greater control over their heating systems do use them more optimally - see Baker 2007 & 2008.

[5] Based on figures for 2003 from UK Government, 2006. Savings are for *total* emissions rather than *net* emissions. Assumes sample was adequately representative of tenements in Scottish housing stock – see LEEP, 2004.

Table 3: Example Savings from Improvements to Individual Tenement Flats taken from a LEEP study showing how the range of interventions outlined in Appendix A led to an average range of savings for the individual households of between £186 - £162 a year per home at 2004 prices with significant CO2 emission reductions

Block	Total Savings (£/yr)	Total Savings (tCO2/yr)
Total Block A	1489	11.6
Average Block A	186	1.5
Total Block B	1204	18.4
Average Block B	172	2.6
Total Block C	1204	18.1
Average Block C	172	2.6
Overall Total	**3370**	**42.6**
Overall Average	**164**	**1.9**

Note: Savings include those from loft insulation attributed to top floor flats only.
Source: LEEP, 2004.

When the whole block improvements (draught lobbies and loft insulation savings to lower floors) were added these average savings rose to £196 and 2.2t CO_2 per flat per year, with individual savings ranging from £13 to £775 and 0.1t to 7.1t CO_2 per year. Again, if these same results could be achieved in every Scottish tenement total savings by residents could amount to over £99m and just over 1.1mt CO_2 per year. This would equate to reducing approximately 1.7% of Scotland's total annual CO_2 emissions and approximately 15.1% of CO_2 emissions from the residential sector.[6]

3.2.2 Economic solutions for improving the energy efficiency of tenements

Developing schemes that make improving energy efficiency economically viable for the poorest households should be an essential part of Scotland's housing emissions reduction strategy. The problem of fuel poverty is particularly pertinent for those on low incomes living in tenement flats as these can be both more difficult and more expensive to treat than other common forms of housing. This is a particular problem in Scotland as due to the climate Scottish households can spend 68% more on fuel bills than equivalent households in the south of England.

Installing cavity wall and loft insulation are two of the most effective means of reducing domestic heating bills. A variety of grants are available for them but the only real benefits of these grants for residents of solid wall tenements are for those in top floor flats – although this is also an argument for targeting loft insulation grants at top floor households and ensuring they stipulate that permission for the go ahead is only needed from these residents.

Another economic barrier to improvement is the shift in tenure mix from 37.5% ownership by local authorities and housing associations in 1993 to 25.5% in 2005 with 74.5% being in the owner-occupied and privately rented today (62.5% in 1993). This has resulted in many residents who took the opportunity to buy their council flats now being seen as *'asset rich but cash poor'* - i.e. owning homes but unable to adequately maintain them (EAS, 2008).

It is beyond the scope of this report to comment on the wider policy changes that are necessary to tackle fuel poverty as a whole, however in light of the reforms and increased

[6] Based on figures for 2003 from UK Government, 2006. Savings are for *total* emissions rather than *net* emissions. Assumes sample was adequately representative of tenements in Scottish housing stock – see LEEP, 2004. The LEEP study also concluded that a 32.6% reduction in CO_2 emissions can be made from improving home energy efficiency, however as it was not possible to confirm how this figure was reached it is assumed to be based on a wider set of measures.

flexibility for making interventions brought in with the Tenements (Scotland) Bill there are clear opportunities for trialling new schemes targeted specifically at residents of tenements who are in, or at risk of falling into, fuel poverty (see Dewar, 2004). These should be used to establish both the effectiveness of improvements not generally covered under existing schemes (e.g. secondary glazing, floor insulation, subsidies for replacing old energy-hungry appliances, and other improvements that can be made to individual flats) and the level at which they become attractive to households on low incomes. They should also be used to test the usefulness of the new legislation in making whole block improvements where some residents are unwilling or unable to pay their share of any costs.

3.2.3 Social solutions for improving the energy efficiency of tenements

Tenement blocks can be highly mixed communities comprising different types of household, different tenures, and often sharing the block with businesses, yet all share responsibilities for the upkeep of the building. This frequently means that even essential repairs are difficult to negotiate, fund and implement. Some tenements are 'factored' whereby a third party, e.g. a council body or housing association, takes an annual fee for maintaining the tenement stair (also known as the close) and other shared elements of the block. However, factoring is much more common in some parts of Scotland than others, for example it is commonplace in Glasgow and a relative rarity in Edinburgh. Factoring is also much less common in older tenements, meaning that many of those most in need of treatment are amongst the hardest to treat. Residents of non-factored blocks are often reluctant to sign up to a factoring agreement because these inevitably result in increased annual repair bills as the maintenance agreements go further than mere patching up, however this is likely to offset more costly future repairs. As each block appoints an individual to act as the contact for the factoring organisation it becomes much easier to negotiate maintenance and gain access to make repairs (LEEP, 2004).

Factoring can also help overcome the problem of absentee landlords. Many of the UK's privately-rented homes would benefit from improved energy efficiency measures, but as in most cases the responsibility for paying fuel bills lies with the tenants and so the landlord or letting agency has no financial incentive to manage the property beyond basic maintenance. A poorly maintained flat may also lead to impacts on other elements of the building and cause problems for other residents. Factoring gives both the tenants and other residents a third party to consult on repairs to shared elements and if necessary may be able to intervene on behalf of private tenants in poorly maintained or particularly inefficient flats. This should also be helpful for keeping residents on good terms with each other.

'Carbon factoring' is an extension of traditional factoring that extends the agreement to include energy efficiency improvements, and can also include interventions to individual flats and the installation of renewable energy technologies. The LEEP pilot study found that carbon factoring was only viable when offered as an addition to a proposed or existing factoring agreement, however support for both traditional and carbon factoring was relatively low. Only 38% of respondents to a market research exercise were interested in carbon factoring, and only 21% willing to pay for the service. There was also a great degree of scepticism regarding the willingness of neighbours to sign up. When asked about joining the Edinburgh Stair Partnership (which offers both services) only 5% were already members or about to join, only 15% expressing an interest in doing so, and most doubting their neighbours would do so (LEEP, 2004).

The 2004 Tenements (Scotland) Act has made it considerably easier for residents of a tenement block to enter into a factoring agreement through removing many of the uncertainties and anomalies relating to the maintenance and management of tenement blocks. Whereas historically all tenement residents needed to agree to enter a factoring scheme (referred to as a Tenement Management Scheme, or TMS) the new legislation means that only a majority or residents need to agree for the remained to be required to join the scheme and contribute payments. This should significantly improve the potential for carbon factoring as part of those schemes, especially where offered at no or minimal additional cost. In addition now that under the Act consent for maintenance of shared elements of the building is only needed from the majority it should increase the uptake of improvements for which 100% grants are available and for low cost measures where the majority agree to cover costs without all residents contributing.

3.3 High Rise Properties

High-rise buildings, for the purpose of this study, include all flats and maisonettes in a multi-storey tower with 5 or more levels but here excluding tenements. Some 64,000 high rise dwellings exist in Scotland being around 3% of the stock. Built largely in the 1960s and 1970s, high rise buildings pose a number of unique problems when improving their energy performance. Because of their form, housing a large number of families in one block interventions more difficult to make and manage in practice.

High rise buildings pose a number of unique problems when improving their energy performance

The following considerations relating to their refurbishment are discussed below:

- Technical solutions
- Economic solutions
- Social solutions

3.3.1 Technical solutions for improving energy efficiency of high rise blocks

Envelope improvements

Walls

Overcladding using some form of external insulation with either a rendered finish or rain screen cladding is a popular solution for tower blocks, particularly when the external cladding is in poor condition. This copes well with thermal bridges at intermediate floors, balconies and access walkways. Balconies and walkways can be fully enclosed to create buffer zones. If external wall insulation is not considered then enclosing the balconies etc. will also reduce the effect of the thermal bridges associated with them.

High rise blocks in poor condition

If external walls are in good condition cavity wall insulation can be used at heights up to 25 meters in some circumstances, but may leave problems with thermal bridging at intermediate floors.

Individual flats could be treated with internal insulation, but that would present problems dealing with thermal bridges.

Glazing

Window areas are often very generous in high rise, leading to high heat loss and discomfort in colder months and overheating in summer. Consideration could be given to reducing window sizes in such cases. Spandrel panels below windows are frequently very poorly insulated and should be treated separately if necessary. Many windows in tower blocks were originally delivered as an integral part of a wall panel and were made of metal and were bonded into the concrete panels so creating further cold bridging of the structure. Simply by replacing the windows in tower blocks major improvements in the thermal and acoustic performance of the envelope are achieved. In addition in some refurbishments open walkways have been glazed in to provide weatherproof passive solar corridors that again have major impacts on the thermal performance of the blocks.

Table 4: Improvements in the U-values of the refurbished envelope of a concrete frame and in-fill panel high rise block in Birmingham

Table II Energy-efficiency improvements

Element	Before refurbishment	After refurbishment
External walls	Concrete infill panels 0.90-1.10W/m^{2}K	Twin-block "skin" has been built up around the tower added *U*-value 0.48-0.60W/m^{2}K
Internal panels	Of pre-cast or cast-in-situ concrete *U*-value 0.82W/m^{2}K	50mm rock wool added *U*-value 0.32W/m^{2}K
Roof	Pre-cast concrete, with an insulating agent bonded to their underside	Thermal insulation added *U*-value 0.40W/m^{2}K
Windows	Single glazed steel windows *U*-value 5.4W/m^{2}K	Maintenance-free UPVC double glazed units providing a *U*-value of 2.9W/m^{2}K and up to 32db sound reduction

Source: Ghasson, 2003 (Costs not available from this study)

Floors
Thermal bridging at the edges of intermediate floors is the most common issue with this type of construction. If external insulation is not used then dealing with the thermal bridge is very difficult. External insulation could be used locally (i.e. only on the edge of the floor slabs), but that would be highly visible externally.

Solid floors can be insulated using an insulation / chipboard composite to create a floating floor above the existing, although the finish floor level will be raised and may necessitate other work such as shortening of doors and installing thresholds. An insulation/chipboard composite floor can be produced in a range of thicknesses, and this approach can be taken using only 5mm of latex foam beneath the chipboard 'floating floor'. Such a thin layer of insulation will not save large amounts of energy but may be sufficient to prevent condensation. If the floor is solid and bridges the cavity or extends to create a balcony there may be a significant thermal bridge depending on the type of insulation installed. The effects of the thermal bridge can be minimised by the creation of a 'floating floor' as described above, coupled with insulating the underside of the floor for ~0.5 meter adjacent to the external wall.

Roof
Flat roofs in high rise can be dealt with in two ways - either warm deck insulation can be applied or a pitched roof can be added. Flat roof technology may be quicker and cheaper, and may be the preferred solution if the building is not being fully scaffolded for other reasons. The drawback is that there is a long term maintenance commitment associated with it. Pitched roofs are longer lasting between maintenance cycles and have the advantage that they can make the building look more attractive and extra useable space can be created - they are, however, more expensive.

Ventilation
Precast concrete buildings with solid floors can be inherently very airtight unless they are fitted with poorly fitting windows. Existing single glazed units should be draught stripped, and any replacement double glazed units should incorporate effective draught strips and trickle ventilation. Humidistat controlled extract fans, preferably with heat recovery, should be fitted to kitchens and bathrooms (EST 2008i).

Energy supply improvements

Heating
Gas heating in individual flats is not condoned by many social housing landlords because of the potential consequences of a gas explosion. However, if gas is already present it would be the most economical choice. A centralised boiler plant is feasible, running from either gas or oil, if

there is a suitable location within the block. Alternatively district heating or Combined Heat and Power (CHP) plant can be used, either dedicated to the building or by connecting into a local scheme. But if the pipes running to individual flats are not already in place they can be difficult and/or disruptive to install. Where distribution pipes are already in place, smaller communal boilers with effective controls can be connected to it, taking advantage of lower heat loads resulting from insulation upgrades. Consideration also needs to be given to the mechanism by which tenants are charged for the energy they use. If centralised provision is not practical then a well-controlled off-peak storage system is probably best. Where centralized provision has been achieved it has been with considerable success as the following case study demonstrates.

3.3.2 Case Study: Aberdeen City Council

Aberdeen City Council has led the way in developing a strategic approach to the use of CHP district heating for the upgrading of its existing high rise properties and has established an independent not-for-profit company to develop and manage these CHP schemes. Aberdeen City Council has progressively upgraded the energy efficiency in their housing stock over the years through improvements in heating systems, building fabric and levels of insulation. These energy efficiency improvements have helped to meet the council's key objectives of affordability, sustainability, safety and carbon dioxide (CO_2) emissions reduction. Out of its total housing stock the properties that proved most problematic to improve in terms of energy efficiency were the council's multi-storey blocks of flats. The options for such buildings were more limited as many could not benefit from cavity wall insulation and, on safety grounds, the council was unwilling to install individual gas heating systems in blocks of five or more storeys.

Consequently the council were finding it difficult to identify a more energy efficient approach than simply replacing the existing heating with a modern form of mains electric heating. Therefore, progress in the provision and upgrading of central heating systems to the council's fifty nine 10 – 18 storey blocks of flats (totalling 4,505 dwellings) was progressively falling behind the energy efficiency improvements achieved in the low–rise dwellings. The council set in place a clear methodology for baselining the energy consumed in its tower blocks, using external consultants, and then went on to choose not to improve the building envelopes of the towers but to install CHP in its Stokethill blocks with 288 flats in four towers, as shown on Table 5.

Table 5: Appraisal of option table on which the choices at Stockethill were made. This table shows the significant increase in costs of over-cladding the blocks and that the main CO2 savings were achieved with the CHP schemes. The council chose to refurbish more blocks with CHP than fewer with CHP and over-cladding as well.

Options	Average NHER	% reduction of NHER	Total capital (£)	25 year whole life cost	Estimated running cost/week/ flat (£)	% reduction in estimated running costs	Total CO_2 emissions (tonnes/ annum)	% reduction in CO_2 emissions
Existing heating systems	3.3	N/A	N/A	N/A	5.23	N/A	1597	N/A
Upgrading electrical unit (no cladding)	3.3	0	780,00	2,680,000	5.23	0	1581	1
Upgrading electrical unit (cladding applied)	4.5	25	1,570,000	3,317,745	4.47	14.5	1282	20
Centralised boiler plant (no cladding)	6.5	49	935,000	2,275,589	4.15	20.5	1007	37
Centralised boiler plant (cladding applied)	7.5	56	1,630,000	2,932,540	3.93	25	837	48
CHP scheme (no cladding)	6.0	44	1,530,000	1,896,956	3.20	39	936	42
CHP scheme (cladding applied)	6.9	52	2,250,000	2,658,854	2.75	47.5	794	50

Source: EST, 2008j

This scheme was followed by further schemes at Hazlehead and at Seaton at a cost of £1.6million and £3.38million respectively to the Arms Length Energy Services Company (ESCO) set up by Aberdeen City Council to develop and manage these schemes. It is planned that the installed CHP schemes will now be rolled out to supply local sports facilities, a primary school and other blocks locally. It is planned that the Seaton plant will be switched to biomass for the baseload supply using gas only to meet the peaks with gas back-up generators.

Lift improvements
Lift running costs in the 56 Edinburgh high rise block are currently in the region of £250,000 a year. The current favourable tariffs for electricity purchase are about to be re-negotiated and will certainly rise in large steps. There are 116 lifts in these blocks so averaging around £2155 a year to run each. The key factor in many of the blocks is that where vandalism is rife the lift costs soar and where there is no vandalism the costs are moderate so the social management of the blocks and the estates is vital in keeping energy costs down.

Water pumping system improvements
Water for each flat is typically pumped from the ground floor to holding tanks on the roof of the block. The arrangement often results in poorer flow rates in the top flats than in the lower flats where the water head is higher. The refurbishment of the pumping systems can be expensive but does result in better water flow quality and lower energy use for pumping. It is not often taken into account but a systematic programme of installing water efficient toilets, taps and shower heads as well as water and energy efficient appliances would have a significant impact on water, and in turn energy, use in blocks. Also systematic water metering of flats would also reduce energy use as occupants become liable for their own consumption.

3.3.3 Economic solutions for improving the energy efficiency of high rise buildings

Each individual Local Authority and its related housing organisations will have established their own method of evaluating the cost effectiveness of a range of strategies for the refurbishment of its high rise stock based often on the consultants expertise they have employed and also on the nature of their own council choice of retaining, selling or alternatively managing their own stock through the medium of a hands-off organisation. We saw above in Aberdeen that CHP was invested in as the most cost efficient delivery method for carbon savings. Lessons learnt and issues raised in the Aberdeen Case Study included:

- The need to approach the process strategically.
- Whole life costing is the best way to establish the real cost and best value.
- External specialist assistance is essential.
- Due to the development workload it is advisable to delegate an individual to champion the project and keep it moving.
- An arm’s length company arrangement enables acceleration of refurbishment plans.

3.3.4 Case Study: South Ayrshire Council

Source: Making choices on 8000 dwellings (Source Paul Touhy, ESRU).

For the South Ayrshire housing stock, ESRU (Energy Systems Research Unit) at Strathclyde University systematically presented energy and carbon costed benefits of different refurbishment options to the council and Table 6 below shows what these were for a 30 flat 6 floor development.

Table 6: Table of energy and CO2 savings for range of refurbishment options at a 30 Flat, 6 floor development in Deer Road. The block has 30 flats, 6 floors, 5 flats per floor in a 1977 to 1981 cavity wall property. The table shows the CO2 benefits of improving the insulation to advanced standards and the effectiveness of CHP systems (Source: Paul Touhy, ESRU, Strathclyde University).

(Emissions are for Heating, Hot water, Lights and Appliances) Individual improvement measures applied to DEEP ROAD	Emissions $kgCO_2$ /year	Rating G to A (0 to 100)	CO2 % saving	Percentage CO2 saving (%) [SAP] 10% 20% 30% 40% 50% 60% 70% 80%
base case (wall, roof and window std upgrades, elec heating)	3391	D (57)	0	
Fabric Improved to 2002 B.Reg (wall 0.35, glz 1.85, 100%cfl)	2778	D (66)	18%	
Fabric Improved to advanced stds (wall 0.1, glz 0.7, 100%cfl)	2011	C (76)	41%	
Supply measures applied to building with fabric upgraded to 2002 standards:				
2002 + gas condensing combi	1685	B (81)	50%	
2002 + gas community heating	1758	B (80)	48%	
2002 + gshp community heating	1515	B (83)	55%	
2002 + biomass	817	A (93)	76%	
2002 + gas community chp	756	A (94)	78%	
2002 + 60m2PV, 60m2SHW, gas combi	1438	B (84)	58%	
Supply measures applied to building with fabric upgraded to advanced standards:				
Advanced + gas combi	1299	B (86)	62%	

The similar carbon saving from improved fabric and the use of community heating demonstrate why Aberdeen chose to go down the CHP route. In their own local market the cost of a single over-clad block would pay for 2 to 3 CHP systems for towers. For councils that do not have the experience of Aberdeen it would be difficult to be so clear about the decisions to be made. What is clear however is that to do more than one scheme of a type in a place is to start to lower the unit cost of provision and to start to begin a market transformation in that field. This has happened in Aberdeen with CHP and in Glasgow and Edinburgh with over-cladding, so issues of the stimulation of local markets are also key.

The issue of decision making tools is also key, particularly for large complex buildings like high rise blocks. Over time a wide range of studies and approaches have been developed to evaluate the cost and energy benefits of a wide range of solutions. The resulting actions demonstrate that there is not a single set of solutions adopted. For high rise housing Aberdeen has gone down the route of developing CHP and Edinburgh and Glasgow have chosen instead to over-clad their tower blocks.

In order to develop a more standard approach the ESRU Unit of Strathclyde have developed a new tool for stock appraisal for refurbishment that may provide such an approach and it is suggested that stakeholders in this market may like to take a look at the website for this new tool called EDEM, with the web address in the references below.

What is important in any decision is that the evidence on which choices are made is clearly and correctly presented to decision makers, and that there is a thorough understanding of the related social and economic implications of the decisions made, for instance on fuel poverty and on the development of local skills and trades in region.

3.3.5 Social solutions for improving energy efficiency in high rise blocks

The improvement of the thermal comfort, security and energy performance of the blocks impacts in turn on a number of the core problems affecting and affected by fuel poverty including issues of health, mortality, allergens, mould and asthma. For and excellent range of papers on the subject see Rudge and Nicol (2000).

Local authorities originally built the social housing tower blocks in the UK. Recent stock transfer agreements mean that a number are now owned or managed by housing associations, and arms length management companies may well increase in the next few years. High-rise residents pay rent to their local authority or housing association. The majority of tower blocks in the UK cater for social housing needs and this has been seen in the past to be associated with a social stigma associated in many places, with living in such blocks being considered not appropriate for the upwardly mobility that our culture promotes.   With the up-grading of many ex-council blocks and the increase in the number of new inner city flat in fashionable blocks being bought by the upwardly mobile younger home owner this is changing leading to a virtuous circle and improvement in the local environment in and around the blocks, in turn reducing energy costs e.g. in lifts as outlined above.

The quality of the management of the housing estate is important to the level of energy consumed in the blocks. There are a number of key social issues related to tower blocks. These derive from a large number of housing units being lumped together using common access routes.

For instance in Edinburgh where there are some 56 housing tower blocks, of which 14 were earmarked for demolition there has been a substantial improvement in their lift and corridor lighting provision and related costs as a result of refurbishment. Many blocks now have full concierge systems in place that have radically improved behaviour in the communal areas of the blocks. Full concierge systems involve the use of extensive CCTV coverage, both internally and externally, with 24 hour or day and night shift surveillance provision, door entry systems and good levels of maintenance of common areas and their lighting. In a number of blocks servicing costs for the lifts have fallen dramatically as a result of these measures, but at a cost. The installation costs of the CCTV systems comes at around £15,000 a block and the running costs of the surveillance are met by the council and by the owner-occupier tenants on a pro-rata basis.

It should be noted that Edinburgh is one of the few councils in the UK where tenants voted against stock transfer. This will have major impacts on the level of finance available to the city council in the longer term to fund such high levels of resident provision. The refurbishment budgets of all Scottish Councils are dependent on Carbon Energy Reduction Target funding (CERT). Between 2008 and 2011 the six largest energy suppliers will be required to spend in the region of £2.8 billion on carbon reduction measures including the refurbishment of social housing (EST, 2008h).

The impacts of the management of violence within blocks has often had a profound effect on the lifting of the quality of the local environment with residents decorating communal spaces in a behavioural cycle that results in reduced energy and financial costs for the maintenance of the common areas.

The quality of the management of where different tenants live in a block can also have a considerable influence on the quality of life the block. In particular management of nuisance neighbours is important and the ways in which flats are allocated to difficult tenants. The rise in the profile of local neighbourhood management structures and resident tenant organisations has been important because decisions in how flats are allocated and managed can be better made on the basis of a thorough knowledge of what actually goes on in the blocks themselves.

The location of a family in a block may also make a difference. There are locations in the blocks that are thermally more stable than other, such as in the horizontal and vertical centre of the blocks themselves where flats are less exposed to the elements. Corner and top floor flats have less good internal environments being more exposed to the external climate. In some cases the most vulnerable people, particularly the elderly and single parents with young children may benefit if they are located in the centre of blocks.

3.4 Timber Frame Properties pre-1982

No accurate information was available on the number of pre-1982 timber frame properties in Scotland as the Scottish House Condition Survey does not make this distinction. There are approximately 94,000 timber frame properties in Scotland, the majority of which are in the highlands and islands. Poorly performing timber frame homes can be treated in essentially the same manner as solid wall properties – i.e. in terms of reducing heat loss through walls external or internal cladding is the most effective solution (see section 3.1). As with many older buildings timber frame walls are 'breathable' and therefore the important consideration is to provide gaps in the cladding (usually near the top of the wall) to allow some air to flow through and moisture to escape.

3.5 Properties with Flat Roofs

Properties with flat roofs are rare amongst Scottish housing stock, and many flat roofs only cover part of a property. They are most commonly found on high-rise flats, where the benefits of improving insulation apply almost entirely to the top floor, as is the case for tenements (see Table 2). Where they do exist on other properties they can be responsible for significant amounts of heat loss, which is reflected in the financial and CO_2 savings from upgrading insulation to meet the latest Building Regulations.

Flat roofs are rare, but where they exist they can be responsible for significant amounts of heat loss

Table 7: Cost and CO2 Savings from Insulating Flat Roofs, for a typical house of the type

	Annual Savings (£/yr)	**CO2 Saving (CO2/yr)**
Rigid insulation to give U value of 0.25 W/m^2K	£65 - £260	265kg - 640kg

Assumes whole property is flat-roofed.
Source: EST, 2008g.

Three main options exist for treating flat roofs, these are as follows:

Warm deck flat roof
The insulation is installed on a deck above the joists and covered by the waterproof membrane. This option should be considered as part of any major maintenance to a flat roof (e.g. when replacing the waterproof membrane) and is applicable in almost all cases where there are no restrictions on adding thickness to the roof and the supports are capable of carrying the extra weight. Warm decks can also be constructed over the existing waterproof membrane of an un-insulated roof, (including adding a new waterproof membrane).

Inverted flat roof
The insulation is placed above the waterproof membrane and retained in place by heavy ballast (e.g. gravel) or paving slabs. This is a simpler option than constructing a warm deck and does not require a new waterproof membrane, however there is a risk of water seeing through the ballast material and cooling the insulation to the point that condensation forms on the inner surface. British Standard 5250 covers inverted flat roofs.

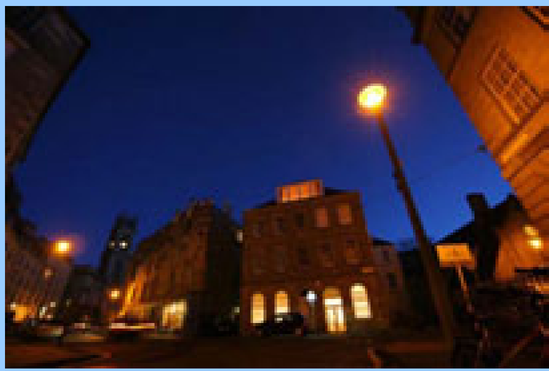
Cold deck flat roof
These are constructed by placing insulation between the joists that support the deck and membrane, and a ventilated void is required between the insulation and the deck that supports the waterproof membrane. Cold deck flat roofs are generally not recommended, in particular for heated buildings, and the Scottish Building Standards specifically advise against their use. Where adding additional layers to a flat roof is not possible, or is undesirable, an alternative is to apply internal insulation to the ceiling of the property.

Where feasible the warm deck option is preferable as the most effective in terms of improving insulation levels and should be considered as part of any maintenance to flat roofed properties (EST 2008g and Green Building Forum, 2007).

3.6 Properties with Mansard Roofs

The term "mansard" comes from the French architect François Mansart (1598-1666) of the Beaux Arts School of Architecture in Paris. Mansard roofs are formed of two sections: a gently sloping upper section and a steep sloping lower section, often with openings for dormer windows.

Traditional mansard roofs are extremely rare in Scottish housing and it is difficult to make recommendations to reduce energy losses from them beyond improving insulation. The most appropriate option for treating these roofs is to treat the upper section as per a normal sloping roof, and apply blown fibre to the lower section by removing the tiles during a period of dry weather. The Energy Savings Trust reports that Carrick Housing achieved this for a group of six properties in Cornwall at a cost of between £500 and £700 for the lower section and between £175 and £215 for those requiring insulation in the upper section. The roofs are subject to on-going monitoring for any settling of the fibre within the cavity (EST, 2006). An additional or alternative option is to strip away wallpaper and install an approved internal cladding material on the walls and ceilings within the mansard, which can improve the insulative properties of the roof by around 1/3 (MGC, 2007).



Although not strictly a mansard roof the incorporation of this penthouse flat into a traditional building shows how the space for loft insulation has been restricted

3.7 Park Homes and Residential Mobile Homes

Residents of mobile homes, evidenced from a range of related websites, are often quoted as being generally happy with their accommodation, for example because it allows them to live in picturesque locations. However they have also been found to be very concerned about the cost of heating them and their vulnerability to bad weather. It is unsurprising as residents of mobile homes are particularly vulnerable to falling into fuel poverty. As socio-demographic trends suggest the demand for park homes is growing, particularly amongst the elderly and vulnerable members of society, the problems with these homes need to be addressed as part of future housing policies.

Park and mobile homes have been found to have very low levels of energy efficiency and to be responsible for significantly more CO_2 emissions than other similar size homes. Few are connected to the mains gas supply and most rely on LPG, or in some cases coal. Cost of electricity and gas is also higher for these residents, due to both the higher price of LPG and because site owners are charged commercial rates for mains utilities, which is then passed on to residents. Furthermore, the residents of homes with mains connections are invariably unable to change their supplier.

Residents of mobile homes are particularly vulnerable to falling into fuel poverty

Perhaps surprisingly for those used to living in permanent structures over half (57%) of Scottish park and mobile homes are equipped with central heating, although this is still much lower than for all Scottish home types (93%). However, there is some distinction to be made between park homes and mobile homes, with the latter being much more likely to have serious problems with heating (which can then lead to problems such as frozen pipes). Residents of park homes have been found to be improving their properties by fitting cladding, insulation, double glazing, and even insulated pitched roofs. Although data is insufficient to establish this for certain, research into other property types suggests that tenure (owner-occupiers and long-term tenants) is a key influence on whether or not residents are prepared to make these investments (Bevan, 2007).

As park and mobile homes are not covered under the Building Regulations it is difficult to legislate for minimal standards of warmth, and therefore it is recommended that as these are semi-permanent structures future revisions of the licensing laws consider extending the remit of the regulations. Due to their lightweight structures it is difficult to apply conventional options to improving their energy efficiency, however the charity National Energy Action (NEA) recommend the external insulative cladding Paraclad™ which has been shown to significantly reduce heat loss, as well as being made from recycled material (NEA, 2007).

Park Home in South West England

3.7.1 Insulation Options for Park Homes

Although the diversity of mobile homes means quantitative data on savings from installing insulation is scarce there has been some work on park homes that demonstrates the energy, financial and CO_2 savings from various insulation options.

As of 1995 the thermal efficiency of park homes is covered by the (subsequently revised) British Standard for Park Homes BS 3632:2005. Table 8 shows how these compare to the Building Regulations Part L (see section 3.1.2 for an explanation of U-values).

Table 8: Comparison of U-values for park homes and other domestic properties showing how much poorer the wall, roof and floor performance is in BS 3632 relating to Park Homes than in the current Building Regulations

Elements	BS 3632	Building Regulations Part L
Walls	0.5	0.35
Floor	0.5	0.35
Roof	0.3	0.25
Windows	0.2	0.2 (uPVC) 0.22 (metal)

A study conducted by the Centre for Sustainable Energy and South Gloucestershire Council (Preston & Jones, 2004) measured and modelled the savings from insulating a group of park homes with Sempatap™ internal cladding. The study found that heat losses through insulated walls reduced by between 10 and 21%, with further improvements possible through installation of external cladding and insulated pitched roofs. Savings were higher for pre-1996 homes and financial savings were much higher for those homes not connected to a mains gas supply (see Table 9). Payback periods were acceptable - up to 20 years for pre-1996 homes and ~8 years for those with flat roofs or inaccessible loft spaces, but longer for homes built after 1995 and to better standards of construction. However the same study also found that the cladding was not suitable for DIY installation by all residents and the additional cost of paying for professional installation resulted in the decision not to pursue a wider implementation scheme.

Table 9: Examples of Yearly Savings from Insulating Park Homes

Installed Areas	Pre-1996?	kWh/yr Saving	£/yr Saving	CO_2/yr Saving (tonnes)
All Walls and Floor	N	361	£14	0.1
Majority Walls and Floor	N	417	£18	0.1
Floor only	Y	250	£5*	0.1
Floor only	Y	250	£5*	0.1
Lounge Walls and Floor	Y	350	£7*	0.1
Ceiling	Y	1,194	£23*	0.3
All Walls and Floor	Y	1,750	£74	0.5
Ceiling and Walls	Y	1,972	£80	0.5
Majority Ceiling, Walls and Floor	Y	2,111	£86	0.5
Total Savings		**8,656**	**£311**	**2.3**
Average Savings		**962**	**£35**	**0.3**

*Properties were connected to mains gas
Source: Preston & Jones, 2004

4 IMPROVEMENTS APPLICABLE TO MOST OR ALL HARD TO TREAT PROPERTIES

4.1 Insulation

Installing or improving the insulation of a property is an incredibly cost effective option for saving money on fuel bills and reducing CO_2 emissions. Table 10 summaries the costs and benefits of common insulation options, most of which are applicable to most HtT properties (windows and glazing are covered separately in section 4.2). The figures are approximate and based on a gas centrally heated semi-detached house, so costs and savings for HtT homes may be higher - e.g. if installation includes maintenance of the building fabric.

Adding external wall insulation is generally not feasible for high-rise properties and not permitted under planning and conservation legislation, however it is suitable for many park homes and homes with exposed single-brick walls.

Adding internal wall insulation is perhaps the most cost effective measure to improve energy efficiency and can be applied to many HtT properties. Internal insulation comes in two basic forms: a lining or fill fitted between the batons holding the plasterboard or added as an additional layer in itself; and solid boards or a dry liner that are attached onto the existing wall. The former requires significant building work and is generally unlikely to be attractive during major refurbishment whilst the latter generally does not require expert installation and can be added during general redecoration. However care needs to be taken to ensure that the properties of the insulation and the wall are compatible as a permeable wall insulated with an impermeable liner will produce damp problems and damage the wall.

Simple measures such as filling gaps and insulating pipes and water tanks can produce smaller but appreciable reductions in fuel bills

As adding internal insulation may require the remove of internal fixtures special care needs to be taken with historic buildings. In some cases it should be permissible to use a thin insulative lining to replace the existing wall lining, whereas in others it may be more useful to consider a wider refurbishment including the replacement of plasterboard. The relevant bodies will need to be consulted in all cases.

Loft and floor insulation have lower impacts but are easier and less intrusive to install than internal wall insulation, and floor insulation may be particularly attractive to residents of tenements where the traditional wooden floorboards remain exposed. Table 10 also shows that simple measures such as filling gaps and insulating pipes and water tanks can produce smaller but appreciable reductions in fuel bills.

Table 10: Insulation Options for Hard to Treat Properties

Measure	Installed Cost	Installed Payback	DIY Cost	DIY Payback	Annual Savings (£/yr)	CO2 Saving (CO_2/yr)
External Wall Insulation	£4,500	12 years	Generally N/A	Generally N/A	£380	2.6t
Internal Wall Insulation	No data	No data	*From £42/m^2	No data, but short	**£130 - £360	***2.4t
Loft Insulation (0-270mm)	£500	3 years	From £250	From 2 years	£155	1t
Loft Insulation (50-270mm)	£500	11 years	£180	4 years	£45	350kg
Floor Insulation	No data	No data	£90	From 2 years	£40	250kg
Filling gaps between Floor and Skirting Board	N/A	N/A	£20	1 year	£20	130kg
Draughtproofing	£200	8 years	£90	4 years	£25	150kg
Hot Water Tank Jacket	N/A	N/A	£12	6 months	£30	195kg
Primary Pipe Insulation	N/A	N/A	£10	1 year	£10	65kg

All figures are approximate and based on a gas centrally heated semi-detached house.
*Figure is for boarding, flexible liners are cheaper
**Depending on insulation type and area covered
*** Depending on insulation type and area covered
Source: EST, 2008b

Mixed-use tenement block showing a mix of windows and glazing, Edinburgh

Windows and Glazing

Replacing or making improvements to windows and glazing is a popular option for many householders, but doing so is particularly problematic for hard to treat homes in Scotland as many are listed, in conservation areas, or subject to other local planning restrictions.

As with other building elements the first priority should be to ensure that all windows are maintained to a good standard as many hard to treat properties that have fallen into disrepair will originally have been much more energy efficient - particularly historic buildings and newer buildings designed to more modern standards. For properties governed by a listed status and/or in conservation areas there may be considerable costs involved for replacing all or part of a window (grants may be available to subsidise these) but where this is recommended it is essential to reduce higher costs at a later date and to maximise the benefits of any additional measures.

This report is not intended to provide a complete coverage of improvements to historic properties but as improving windows and glazing is a particular problem for a large number of Scottish properties that fall into both categories efforts have been made to cover both aspects here. It should of course be re-iterated that whenever there is any doubt as to whether or not consent is required the relevant bodies should be consulted as early as possible.

The information in this section also applies to buildings with windows in shared elements (e.g. in stairwells and roofs) although the individual savings will obviously be significantly lower.

4.2.1 Replacement with Modern Double or Triple Glazing

Replacing old windows with modern uPVC double glazing can reduce heat losses through windows by half, save around £110 a year on fuel bills, and around 720kg CO_2 a year (EST, 2008c), it is both a popular and effective measure although relatively expensive and with payback periods that can be in excess of 20 years. These calculations do not take into account the embodied energy implications of the energy used in manufacturing the windows. Triple glazing is still uncommon as the relatively minor improvements in energy efficiency over double glazing come at the cost of a 20%-40% higher price (British Gas, 2008).

Table 11: Costs and Benefits of Installing Double Glazing

	Installed Cost	Installed Payback	Annual Savings (£/yr)	CO2 Saving (CO2/yr)
Double Glazing	£3,000	20+ years	£90-£110	720kg

Source: EST, 2008c

Although only around 10% of a dwelling's heat losses are through its windows the popularity of this option is obvious given that a loose-fitting frame with glass that feels cold to touch can be a very visible and audible reminder of heating losses, and adding extra layers of glazing can make an appreciable impact on the volume of external sounds entering the home.

Many hard to treat buildings are subject to strict legislation that prevents installation of uPVC windows but they are generally permissible for non-listed houses outside of conservation areas and can also benefit some older park homes.

4.2.2 Secondary Glazing

Secondary glazing should be considered as part of any plan to improve the energy efficiency of a property where replacement with double glazing is not allowed

Installing secondary glazing is a cheaper option for reducing heat loss and sound ingress through windows, and provides an alternative to double glazing for the many HtT properties where this is not an option due to planning and conservation restrictions. A wide variety of types exist and not all are suitable for all properties. They vary from adding a second internal window to adding layers on the back of existing glazing inside the original frame. The former is a more effective solution, particularly for blocking sound, but is more expensive, may intrude into the room and may be subject to conservation restrictions. The latter can be less intrusive, and can be custom-designed to meet conservation guidelines, but keeping at least a 150mm gap between the primary and secondary glazing is recommended for there to be an appreciable impact on sound.

Selecting the most appropriate form of secondary glazing is essential and householders should seek advice from the installers or an energy efficiency advice service as well as checking whether or not consent is needed. In general the system should be chosen to be as invisible as possible from the outside: any bars on the internal window should match those on the original;

ideally the method of opening should match that of the existing window; and the glazing and any coatings that may be applied to it should be chosen to avoid the problem of 'double reflection'. The chosen system should not prevent the easy opening of the existing window, both for safety reasons in the event of needing to use the window for escape in an emergency, and so as not to restrict ventilation. In addition, some systems are designed to be removed during the summer and so the panes require safe storage to avoid potentially serious and costly accidents. As an alternative many householders opt for perspex inner secondary glazing frames as these are cheaper, lighter and easier to remove and replace.

Table 12: Costs and Benefits of Installing Secondary Glazing

	Installed Cost	**Installed Payback**	**Annual Savings (£/yr)**	**CO2 Saving (CO2/yr)**
Secondary Glazing	£1,200 - £2,000	20+ years	£20 - £70	85kg - 195kg

Source: EST, 2008d

Despite these caveats, the cost and the long payback period installing secondary glazing is an option for almost all HtT properties and should be considered as part of any plan to improve the energy efficiency of a property where replacement with double glazing is not allowed. Case studies have also found it to be very popular, which may relate to it being both a visible and audible improvement as well as reducing heat losses and energy bills. It is generally not covered by grant schemes and so voluntary take up is most likely to be by owner-occupiers as a long-term investment, although some grants are available for its installation in historic properties (EST 2008d, Changeworks, 2008 and Historic Scotland, 2007).

4.2.3 Reinstating or Adding Internal Shutters

The costs and benefits of adding or reinstating internal shutters are difficult to calculate because they are highly dependent on the individual circumstances of both the property and the occupants. There are unlikely to be problems with their installation in historic properties where the design fits with the character of the building, and where there is evidence that they were part of the original design their reinstatement is encouraged by conservation bodies (in which case grants may be available). Costs vary depending on whether shutters already exist in the building, if they can be sourced from a recovery service, or if they are custom made.

Energy savings are difficult to calculate as the diversity of designs means there is no approximate rule of thumb, and their effectiveness is also dependent on occupant behaviour. They are most effective in buildings not occupied during the day as they need to be closed to reduce heat losses in winter and heat gains in summer, but they are also useful if only used as an additional layer of insulation at night. However, they may be incompatible with curtains (which have a similar effect) and so choosing whether or not to install them should be based on their aesthetics as well as their practicalities (English Heritage, 2000, EHSNI, 2006 and Changeworks, 2008).

4.2.4 Draughtproofing

The costs and savings for draughtproofing windows are included in the figures given in Table 10 but are mentioned separately here as some comments apply specifically to windows in older and historic HtT properties. Draughtproofing is a cheap and cost effective measure that is recommended for all HtT buildings and can have the additional benefit of eliminating rattling in loose-fitting windows. A wide range of options exist, some of which are more visible, costly and difficult to install than others, which should mean that even residents of listed buildings will have several to choose from. Care should be taken to choose an option that does not block

Draughtproofing is a cheap and cost effective measure that is recommended for all HtT buildings

access to the opening mechanism for the window or risk jamming it shut, but this mainly applies to sash windows and plenty of material is available to help householders find the best solution (Changeworks 2008 and 2008c).

4.3 Heating Systems and Controls

Space and water heating accounts for nearly two thirds of the energy consumption of an average home, so ensuring all heating systems are regularly maintained is essential for energy efficiency

Space and water heating accounts for nearly two thirds of the energy consumption of an average home, so ensuring all heating systems are regularly maintained is essential for energy efficiency. Poor maintenance of heating systems can lead to knock-on problems with other building elements, e.g. damage from the build up of moisture. The replacement of boilers every 10 years should be seen as maintenance rather than improvement and there is a wealth of information available to help householders make the most effective choices[7]. Grants are currently available under Scotland's Warm Deal scheme and individual utility companies can often subsidise costs.

There are no barriers to preventing the upgrading of heating systems in HtT properties and few limitations to the choices for historic buildings. The main factor that will dictate the choice of system is whether or not the property has a mains gas supply. Some households use LPG, paraffin or wood-burning stoves but the LPG and paraffin stoves can produce moisture problems and wood burners, although more sustainable, require storage space for fuel and are permitted in all local authorities. Therefore energy efficient conventional systems, where necessary selected with professional advice, are recommended for HtT properties

For homes with radiators further gains can be made by simple additional improvements. An aluminium foil sheet can be added behind the radiators to reflect heat back into the roof and small shelves can be added to help direct heat into the room space (this may not be permissible for historic properties).

Improving the level of control householders have over their heating can also produce notable reductions in energy consumption, and there is some evidence that occupants with more control do heat their homes more optimally. For gas fuelled systems the highest levels of control can be achieved when all of the following are installed: an electronic (ideally fully programmable) timer; a room thermostat; thermostatic radiator valves (TRVs); and a thermostat on the hot water tank (or on the boiler in the case of combi boilers). All these can be retro-fitted to most gas heating systems and will have very little or no impact on historic properties. If the system is so old that fitting additional controls is problematic it is likely to be worth investing in a complete replacement.

Electric heating systems are generally more difficult to control, more expensive to run and produce higher emissions (unless that electricity is generated from renewables) so gas central heating is recommended where possible (Changeworks, 2008 & Baker, 2007).

4.4 Lighting and Appliances

Replacing light bulbs and appliances with energy efficient versions is a measure that can and should be taken by all households and so is not covered in detail here. Financial and CO_2 savings for lighting and some common improvements are given in Table 13. A small number of HtT and historic homes will have fittings that are unsuitable for energy efficient light bulbs but

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[7] See http://www.sedbuk.com for information on boiler efficiencies.

otherwise there are no notable problems with or restrictions on their use. However older or poorly maintained fittings, switches and sockets may be evidence of hidden wiring problems that should be investigated as part of any maintenance or renovation.

Table 13: Savings from Common Energy Efficiency Upgrades for Lighting and Appliances

Appliance	EU Energy Rating	Potential Savings (£ per year)	Potential Savings (kgCO2 / yr)
Fridge freezer	A+ or A++	£34	142kg
Upright / Chest Freezer	A+ or A++	£20	85kg
Refrigerator	A+ or A++	£12	48kg
Washing Machine	A	£10	45kg
Dishwasher	A	£20	90kg
Integrated Digital TV		£6	24kg
Energy Efficient Light Bulbs*		£45 (£600 over lifetime)	11kg (2.4t over lifetime)

All figures are approximate and based on a gas centrally heated semi-detached house.
*Based on replacing all light bulbs.
Sources: EST 2008e & 2008f.

4.5 Smart Meters

Smart meters are one of the latest tools available to help reduce household energy consumption and research has shown that they can save households between 3% and 15% on their fuel bills. As current prices are around £40-£50 even a 5% saving (equivalent to approximately £35) means that most meters can pay back their cost in about a year. As well as making households more aware of their energy use they also provide accurate data to energy companies. This reduces the need for estimate-based billing and can be used to identify high-energy consuming households and target them for energy efficiency schemes, as well as cutting operational costs. Making this data available to the Government and to researchers (with the appropriate safeguards) would provide valuable evidence for research and policy-making.

The UK Government is already committed to the installation of smart meters in all large business premises and is reviewing the case for domestic properties. Given the benefits of smart metering to households, energy suppliers, researchers and the Government it seems likely that this review will reach positive conclusions and therefore the Scottish Government may find that pushing ahead with promoting smart metering is an attractive option for reducing CO_2 emissions from the housing stock (EnergyWatch, 2005 and BERR, 2008).

4.6 CHP and Renewable Energy

Although it is not within the scope of this report to provide a detailed discussion of supply-side options for reducing emissions from properties in Scotland it is worth noting that they will have a role to play in Scotland's domestic energy future. Micro-CHP schemes may be useful for dense groups of properties such as tenements and high-rise flats, and community CHP schemes are already up and running in some councils (e.g. Leicester – see CHPA, 2007).

Community CHP plants can be based at council premises, and therefore help reduce the emissions from both the council and the community it serves.

Installing solar thermal and micro-generation systems such as photovoltaics and micro-wind turbines is problematic for many Scottish properties due to planning and conservation legislation, however in light of the long-term benefits of meeting energy demand and reducing emissions future revisions of any housing legislation should consider removing some of the barriers to stimulate the market and reduce the amount of disincentives for those householders considering investing in them.

5 SUMMARY OF NEW RESEARCH INTO OPTIONS FOR IMPROVING HARD TO TREAT PROPERTIES

A comprehensive review of research that may result in emission savings in hard to treat homes is beyond the scope of this document. However, a couple of areas are highlighted here that may yield benefits within the next 5 years.

5.1 Innovative Advanced Surface Treatments

The principal impetus for the research that is being conducted on thermal barriers for the built environment is in identifying treatments which are thinner then current insulation solutions. For instance, fundamental research investigating the feasibility and potential for development of dynamic response surfaces and nanoparticle surface treatments as a means for controlling both the insulation performance and dynamic thermal behaviour of building elements is on-going (EPSRC, 2008). The challenge of creating high-performance insulation with a low thickness (~ $\leq$25mm) may be addressed via advanced technologies such as vacuum insulation panels (VIPs) or Aerogel. However, heat transfer through the wall is significantly reduced and could result in buildings that are unable to respond to warming climates. An alternative approach that avoids these pitfalls is to develop thin nanocomposite absorbent layers that can be applied, for example, to internal VIP surfaces. The layer may consist of bound select particle-size distributions of engineered desiccants coupled with micro-encapsulated phase change materials. The layer behaviour can thus be climate matched to allow it to be more responsive to changes in the indoor environment (Hawkes, 2007).

5.2 Non-wall Technological Research

Ventilation systems have and are being developed that permit the ventilation air in dwellings to be pre-warmed via passive means. These include systems where ventilation air is pre-warmed using solar factors and those that are pre-warmed using the thermal boundary layer of the dwelling (EPSRC, 2008, & EBP, 2008).

Significant efforts are being made to reduce the grid emission factor attributable to network electricity. These include the resurrection of the nuclear power programme, the mass deployment of wind generation, development of tidal and wave devices and research into carbon capture and storage from fossil fuel fired thermal generation plants. Whilst the success of these initiatives is not guaranteed, it is interesting to consider the impact they would have on the CO_2 emission attributable to hard to treat dwellings. If a grid emission factor of 0.28kgCO_2/kWh were to be achieved for network electricity (it is currently approximately 0.52kgCO_2/kWh), then savings amounting to approximately 11-16% depending on the dwelling type and occupancy characteristics.

On the supply side, micro-CHP systems are being developed with high electrical efficiency based on engine and fuel cell technology. These will yield substantial savings in their own right but only if their reliability can be proven. For instance, solid oxide fuel cell based systems would save approximately 10-12% in dwellings (prior to the installation of the intervention set indicated in Figure 2) (Hawkes et al., 2007).

5.3 Measuring, Modelling, Mapping and Managing Energy Consumption by Scottish Households

Academic and commercial research has produced a range of methods for measuring and modelling domestic energy consumption, however our changing lifestyles mean that these methods will always require revision to maintain accurate measurements and predictions of consumption. Two important examples of such changes are as follows:

Many households now use their bedrooms for much more than just sleeping in. Increasing uptake of new technology means more and more bedrooms are being used for entertainment and as home offices, particularly in shared households and families where adult children have yet to leave home. This change in usage means that many bedrooms are now being heated to higher levels and longer periods than is generally assumed in existing models.

Similarly the recent increase in the number of households with residents who regularly work from home is adding to the energy consumption of the UK's housing stock.

Understanding more about the way households use energy is the key to help reducing it, just as identifying hard to treat properties is essential for targeting those properties most in need of improvement. Clearly any means of capturing data to improve the evidence for both of these will have cumulative benefits.

Research has shown that this data can be captured at relatively little cost and produce useful and usable results if households are willing to cooperate (Baker, 2007). Support from the Government and local authorities, engaging energy suppliers, using smart meters and drawing on expertise from academia and the private sector should be of great value to any such projects.

Further work is also needed to establish the most effective ways of influencing households to improve their properties and adopt energy efficient behaviours in order to manage Scotland's transition to a low carbon economy. In the immediate future this will also need to cover how to increase the uptake of options such as solar water heating and of micro-generation technologies. The good news is that Scotland is home to many experts in these fields. So, as is the case with renewable energy, meeting the challenges of climate change and coping with rising fuel prices may only need to rely on making the best use of what Scotland already has.

6 RECOMMENDATIONS FOR HARD TO TREAT PROPERTIES

6.1 Solid Wall Properties

Treatment of solid walls will require some form of thermal barrier being placed at the wall surface either internally or externally. The thicknesses required of conventional insulation make it problematic for internal insulation as it would result in significant loss of internal space. Research is on-going to identify materials that could provide equivalent performance in much thinner applications.

The deployment of external wall insulation will of course change the appearance of the dwelling but in many instances this can be beneficial. The application of solid wall insulations is non-trivial and will require significant preparatory and finishing work.

It is possible to identify alternative technological intervention sets that do not require treatment to the external wall. These are likely to produce savings of approximately 30-50% depending on the dwelling in question. Clearly, this is not sufficient for solid wall dwellings to contribute their full quotient of savings required to meet national targets. The shortfall would have to be met from increased savings in other dwelling types or from other sectors.

These intervention sets require greater than 10 individual interventions and the complexity of delivering this scale of change is significant. The success of an *intervention set* approach will be predicated to some degree on the management of the number of transactions expected of a householder. The intervention sets are expensive and so the economic case can be made for their adoption must be clearly articulated. Alternative ways of stimulating their uptake therefore have to be explored. These should include:

- Making homes more comfortable and healthy places to be in, with knock-on benefits to the community at large, etc
- Reducing the number households in fuel poverty in order to meet Government targets
- Safeguarding households at risk from fuel poverty against future energy price rises

Justification for this expenditure may also be viewed as a marketing exercise where answers to the question *"How do we ensure people prioritise expenditure on lowering the energy costs of their housing?"* need to be sought.

Answers to the question *"How do we ensure people prioritise expenditure on lowering the energy costs of their housing?"* **need to be sought**

6.2 Tenements

Tenements pose some of the most complex problems for reducing the energy consumption of Scottish homes, however their preponderance in Scotland's housing stock and the range of cost efficient savings that can be made from treating them mean that there they are a strategically important cohort for consideration when policies and schemes for refurbishment of hard to treat stock are developed.

Tenement occupants are increasingly being required to enter into factoring agreements for general maintenance, and where these exist it should be easy to extend them to include carbon factoring. The numbers of tenements signed up to these agreements has a degree of regional variation and therefore councils with low proportions of factored tenements, e.g. Edinburgh, should be encouraged to develop and promote factoring services with carbon factoring as standard. Even where carbon factoring exists it is likely to cover only shared elements of the building and so could be extended to include offering energy audits for individual flats. Carbon factoring and individual audits could be used to provide residents with simple information on the costs and benefits of improving the energy efficiency of both shared spaces and flats, and simplify the process of appointing contractors for the work. Where certain improvements afford more savings to some floors and less to other factoring is a useful option for impartially attributing costs to residents. Howeve, as effective improvements such as loft insulation are already covered by 100% grants under the Warm Deal scheme this may not even be an issue.

Tenement undergoing renovation, Glasgow

The 2004 Tenements (Scotland) Act should be a useful lever for improving the energy efficiency of tenement blocks, as it removes the need to gain agreement from all residents for any work to be carried out. As the Act also makes provision for extending management / factoring schemes to all tenements the Scottish Government now has all the necessary measures in place to begin an aggressive scheme to ensure that this objective is met as soon as possible. A future amendment of the Act could be used to ensure carbon factoring is added to all existing agreements and included as standard in all new ones. Carbon factoring could then be used as a mechanism to ensure that all Scottish tenements are brought up to the recommended energy efficiency standards and that all households are offered energy audits.

The problem of reducing heat losses through windows and glazing needs particular attention due to the conservation regulations that apply to many tenements and because double or secondary glazing is generally not covered by grant schemes. Although double glazing is costly and not suitable for all tenements there is a clear case for a new scheme to promote appropriate forms of secondary glazing, and case studies have shown that this is likely to be very popular with residents.

In the longer term the density of tenements makes them ideal candidates for local micro-CHP projects as well as for installing solar thermal panels and micro-generation technologies such as photovoltaics and micro-wind turbines. However, it should be stressed that the greatest immediate gains can be made from energy efficiency and changing household behaviours.

Carbon factoring could then be used as a mechanism to ensure that all Scottish tenements are brought up to the recommended energy efficiency standards

6.3 High Rise Properties

Although high rise properties account for only 3% of the total building stock they are the most expensive and difficult to refurbish for technical and non-technical reasons. In the stock of any authority with a number of high rise blocks some will be considered to be in too bad a condition to keep and many are already being demolished in larger cities. Refurbishment is not always the best option.

The solutions to the improvement of these blocks have to date in Scotland fallen into two camps. In Edinburgh and Glasgow, the practice of over-cladding the blocks is favoured. This involves the improvement to the walls, roofs, glazing and floors of the block with system improvement for the heating and energy supplies.

In Aberdeen the city council has chosen, through the auspices of an arms length housing company, to develop a number of CHP plants to supply cost-effective heat and power to the blocks. In doing so they have built up and refined an expertise that has led to cost reductions and knock on benefits in the local market place.

The larger high rise housing blocks are of such a scale they can effectively be used to develop and consolidate skills and expertise and build market transformation in the larger region.

The importance of controlling energy use in tower lifts and in water pumping systems should not be overlooked when planning refurbishments.

In order to decide on where best to invest in such schemes better tools are needed to help decision makers to evaluate alternatives. EDEN is a new tool that is being developed by ESRU at Strathclyde University that may prove a key development for decision makers.

High rise block, Glasgow

The importance of the social aspect of the improvement of the high rise environment has proved crucial in controlling energy use in public spaces and lifts and nowhere is the link between management and energy use clearer than in high rise housing. Plans for refurbishment should contain detailed sections on the social management and spatial planning of residents within the blocks.

6.4 Timber Frame Properties pre-1982

Older timber frame walls can effectively be treated as for solid wall properties, and so external or internal cladding is recommended as the most effective solution for reducing energy consumption and emissions. When fitting this insulation advice should be sought as to the most appropriate material and how to ensure that the wall is ventilated to prevent the build up of moisture.

6.5 Flat Roof Properties

Although only a small percentage of properties have flat roofs, those that do can incur significant heat losses through them. Wherever possible, these should be treated by adding insulation in the form of a warm deck flat roof. Where this is not possible, adding a cold deck flat roof or internal insulation applied to the ceiling should be considered.

6.6 Properties with Mansard Roofs

The most effective treatment option for mansard roofs is to apply blown fibre behind the tiles of the lower section of the roof. As this requires the removal of the tiles, it must be carried out during a period of dry weather, and therefore any new schemes to target mansard-roofed properties for this improvement need to bear in mind that Scottish weather will be a limiting factor. The upper sections of mansard roofs can be insulated in a similar manner to normal sloping roofs (assuming there is sufficient access to fit insulation) and internal wall and ceiling cladding is also applicable.

6.7 Park Homes and Residential Mobile Homes

Legislation is needed to mandate all landlords of park and mobile homes to fit approved insulation to their properties, with emphasis on mobile homes and park homes constructed pre-1996. The Scottish Government's Warm Deal grants schemes could be extended to cover improvements to these homes (as is the case for disabled access grants). Further gains can be made from insulating pipes, ensuring seals around windows and doors are maintained to high standards, installing energy efficient appliances, and in some cases more significant interventions such as double glazing and roof modifications.

Park Home in South West England

The improvements in efficiency resulting from the 1995 British Standard demonstrate that one of the most effective methods to reduce emissions from park homes is to legislate for them to be constructed with high minimum levels of thermal efficiency, thereby reducing or eliminating the need for later interventions. The 2005 revision of the Standard has improved the minimum thermal efficiency requirements but given the relatively inexpensive measures available to reduce heat losses through walls and floors it would seem reasonable for these to be tightened further. However as park homes are invariably manufactured in England and Wales this would require support from Westminster.

Going beyond energy efficiency, the energy demand and location (often off-grid and exposed) of many park and mobile homes makes them ideal candidates for using renewable micro-generation systems such as solar photovoltaics and micro-wind.

6.8 Improvements Applicable to All or Most Hard to Treat Properties

The benefits of maintaining and improving windows and glazing go beyond reducing a property's energy demand and so many homeowners who have the means to do so need little encouragement to make repairs and upgrades. However the two most effective measures (double and secondary glazing) are relatively expensive and the legacy of the changes in tenure of many Scottish homes and the current financial climate indicate that many households will be deterred from making those investments. Yet grants for repair and upgrading of windows and glazing are invariably only available for historic properties.

Double glazing is not an option for many Scottish homes categorised as HtT and therefore investing money in schemes to promote further uptake would seem to be of limited value. Yet the evidence gathered for this report suggests that this would not be the case with secondary glazing, which case studies have found to be very popular amongst householders. Furthermore, as secondary glazing comes in a wide variety of forms, not all of which are appropriate for all properties, trialling a combined information campaign and grant scheme could have real and measurable benefits both in terms of reducing residential emissions and improving comfort levels in HtT homes. The results of such a trial would also help close a knowledge gap by producing evidence to inform better guidance on the effectiveness and technical feasibility of the different options.

Draughtproofing is a much cheaper measure, although technical issues apply to many older windows, and some grants are available through the Scottish Government's Warm Deal scheme. Installing or reinstating internal shutters may be an effective option for some properties but the evidence suggests that where this is of real value it is already supported by grants for historic properties.

A potentially very effective option would be to combine the trial suggested for secondary glazing with additional information and allowances for repairs and draughtproofing to produce an all-in-one offering that should appeal to residents and landlords of a large proportion of HtT properties.

All properties with gas central heating systems would benefit from replacing boilers with modern and efficient condensing models and those with electric heating would benefit from upgrading to the latest, most energy efficient models. All households should be encouraged to have their heating systems serviced annually. Maximising the level of control households have over their heating has been shown to enable more optimal use of energy, although this is easier for gas central heating systems than electric ones. Grants are already available for most of these and the expansion of these schemes should be encouraged.

Replacing traditional tungsten light bulbs with low energy light bulbs is a cheap way of making savings on electricity, and many energy suppliers and energy efficiency centres offer these at low or no cost. Upgrading appliances to A-rated and above models (or more energy efficient ones where they are not currently covered by energy labelling) will also reduce consumption, but as this is an expensive option for households on low incomes it is worth considering offering subsidies to the poorest households.

The Scottish Government may wish to consider leading the way with a trial programme for installing smart meters

Smart meters look set to be recommended a the forthcoming UK Government review and so the Scottish Government may wish to consider leading the way with a trial programme, perhaps in partnership with energy suppliers and Scottish universities.

Micro and community CHP also offer means of reducing emissions from the Scottish housing stock, as well as from council premises, and therefore should be considered as part of any long-term planning strategy.

Solar thermal and micro-generation systems are becoming attractive to some householders, although planning and conservation legislation can be barriers to their uptake. In light of the drive to reduce emissions from Scotland's housing those responsible future revisions of any such legislation may wish to consider where it can be relaxed to support the uptake of these technologies.

Finally it should be emphasised that all the savings noted in this report can be increased further if householders can be encouraged to make simples changes to their behaviour. In the long term this means a cultural shift so that actions such as reducing unnecessary heating use, switching off lights when leaving a room, and switching off appliances rather than leaving them on standby become *unconscious* behaviours. Our homes need to become buildings that we live *with*, rather than just buildings that we live *in*.

Our homes need to become buildings that we live *with*, rather than just buildings that we live *in*.

7 CONCLUSIONS

Scottish councils and the Scottish Government have an opportunity to work together to facilitate the refurbishment of all types of Hard to Treat Housing in which many of those in fuel poverty are living

Evidence from the 2002 House Condition Survey showed that an estimated 286,000 households (13%) were fuel poor. Of these, 24% (69,000) are in extreme fuel poverty (i.e. would have to spend more than 20% of their income on fuel to maintain the standard heating regime). Most of the extremely fuel poor are single person households.

By 2008 this figure has risen to 543,000 households, of the total of around 2.3 million homes, containing 1 million of the 5 million population of Scotland. Thus around 20% of the Scottish population are currently in fuel poverty. Councils and housing organizations around Scotland are doing a stirling job in trying to improve stock to keep an many as possible from falling into fuel poverty as they can, but this is an extremely expensive task.

The practical recommendations of this report are summarised in the chart that follows the Executive Summary. Because of the speed with which energy prices are rising and at which people are falling into fuel poverty Scottish councils and the Scottish Government have an opportunity to act together to facilitate the funding of the refurbishment schemes, particularly in all types of Hard to Treat Housing where many of those in fuel poverty are living.

An important finding of this report concerns the building Standards relating to park homes. The improvements in efficiency resulting from the 1995 British Standard demonstrate that one of the most effective methods to reduce emissions from park homes is to legislate for them to be constructed with high minimum levels of thermal efficiency, thereby reducing or eliminating the need for later interventions. Therefore revision of this Standard should be a priority.

A review of the available funding sources and overlaps for such refurbishment projects may well yield very cost efficient method of enabling this facilitation. The elimination of the double funding of projects, where the same actions can be funded from two or more different sources of money (for instance the CERT monies and the Warm Deal funding) while other technologies that would provide significant improvements cannot be funded at all, would be welcomed. A consultation with active councils would reinforce the need for this review to take place immediately to enable councils and housing associations to optimize the benefits that accrue to the fuel poor from the available funds.

A review of the cost effectiveness of actual completed refurbishment schemes for two house types in particular would provide useful data for decision makers across the board. These are the tenements and high rise blocks. Packages of cost efficient interventions such as draft stripping, insulation and secondary glazing in tenements have significantly reduced energy use in them and improved comfort for their occupants. Such schemes need to be rolled out rapidly to impact of rising numbers falling into fuel poverty and a better data base on costs and impacts on which decisions on investment could be based would be valuable.

High rise buildings are the most costly to improve, with refurbishment budgets ranging typically from £500,000 to £2 million a block. We have found a wide range of approaches being applied to their refurbishment. Because of their high numbers in Scottish towns and cities we recommend that a report solely done on this building type is prepared for the Scottish government with an attribute analysis of the actual measures, costs and benefits of every refurbished tower to date in Scotland with a detailed analysis of the results to inform policy on the future funding of refurbishments. A comprehensive database on high rise blocks and the refurbishment costs and impacts, on the scale of the study done for the Netherlands Government (TNO Bouw, 2004), would benefit not only that larger housing organisations but the many smaller councils that do have high rise blocks but cannot afford the research on which to base judicious choices on the improvement of their tower blocks.

The development of a range of new tools such as EDEM for use in evaluating the cost benefits of refurbishment choices are welcomed and further work on complementing such predictive tools with post occupancy evaluations of the completed schemes would also provide valuable information on which future policies and actions could be based.

8 ABOUT THE AUTHORS

Prof. Sue Roaf

Award winning teacher, architect, researcher and author Susan Roaf is Professor of Architectural Engineering at Heriot Watt University in Edinburgh, Visiting Professor at the Open University and Arizona State University, and an Oxford City Councillor. She lectures to a wide range of specialist and general audiences on related subjects and is the founder of the Westminster and Scotland Carbon Accounting Groups, which bring together policy-makers and carbon accounting professionals to share and develop knowledge and experience in this fast-moving field. During her time as lecturer, then Professor of Sustainable Architecture at Oxford Brookes University she developed a national and international reputation for work on thermal comfort, photovoltaics, passive building design, ecohousing, and the education of architects. She co-chaired the 2006 2nd International Solar Cities Congress in Oxford, and co-chairs the biannual Windsor Conference on Thermal Comfort the TIA Conferences on Architectural Education, including the 2008 Oxford Conference. She has served on a range of national and international committees, think tanks and working groups with architects, planners and engineers. She is a member of the EPSRC College, Fellow of the Royal Society of Arts and Fellow of the Schumacher Society.

She is currently engaged in research, in the fields of thermal comfort, low carbon building design and the adaptation of buildings and cities for climate change. She is author of a number of books on benchmarks for sustainable buildings, adapting buildings for climate change, low carbon architecture and ecohouse design.

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He is a member of the Environment and Sustainability Group within Compass, an invited member of the UK Displays and Lighting Knowledge Transfer Network sub-committee for Systems, Professional Users, Regulations, Standards and Safety, and a founder member of the Scottish Carbon Accounting Group. Along with Sue Roaf and many others he is a co-author of the Berne Manifesto on Climate Change and its Impact on Cities, which was produced at the British Council's Youth Scientists Summit in 2005.

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His other areas of research interest include the integration of micro-combined-heat-and-power (micro-CHP) systems, with ongoing investigation of the potential for micro-CHP systems to provide ancillary services that will aid the management of the UK electrical network. The robustness of these methodologies to changes in the fuel mix of network electrical generation expected over the next two decades is being explored.

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WARM DEAL. This scheme give a grant of £500 for houses where occupants are on certain income-related benefits, or are aged 60 or over, you may be eligible for a grant of up to £500 to have your home insulated under the Scottish Government's Warm Deal. If you are aged 60 or over and do not receive income-related benefits, you can get a smaller grant of up to £125.The package includes: Cavity wall insulation ; Loft insulation ; Hot and cold tank and pipe insulation ; Draughtproofing ; Advice on energy efficiency is given. For a review of the strengths and weaknesses of the scheme see: http://www.scottish.parliament.uk/s3/committees/lgc/inquiries/fuelpoverty/SolasSubmission.pdf

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Appendix A Case Study: Interventions to Three Tenement Blocks

How to interpret this table
This table has been taken from LEEP, 2004, and has been included to illustrate how the benefits of different energy efficiency improvements can vary between tenement blocks and individual flats. The acronyms are defined as follows:

Tenure: HA = Housing Association; OO = Owner Occupied; PR = Privately Rented
Measures: GCH = Gas Central Heating; RGB = Replacement Gas Boiler; HCU = Heating Control Upgrade; DP = Draught Proofing; CFLS = Compact Fluorescent Light bulbs; JK = Jug Kettle; LI = Loft Insulation
Measures in italics were recommended but not installed.

Flat	Tenure	Measures	Total Savings (£/yr)	Total Savings (tCO_2/yr)
A1	HA	GCH, CFLS, DP, *JK*	140	1.1
A3	OO	GCH, CFLS, DP, JK	536	1.7
A5	PR	DP, CFLS, JK	17	0.2
A8	HA	GCH, CFLS, DP, JK	116	0.9
A9	PR	GCH, CFLS, JK	210	4.5
A10	HA	GCH, CFLS, DP, JK, LI	250	1.5
A11	PR	LI	30	0.4
A12	PR	GCH, CFLS, *DP*, JK, LI	190	1.3
Total Block A			**1489**	**11.6**
Average Block A			**186**	**1.5**
B2	OO	CFLS, DP, JK	36	0.4
B3	OO	GCH, CFLS, *DP*, JK	420	4.9
B4	OO	RGB, CFLS, *DP*, JK	100	1.4
B5	OO	*RGB*, CFLS, *DP*, JK	12	0.3
B6	OO	RGB, CFLS, DP, JK	46	1.2
B7	PR	*RGB*, CFLS, *DP*, JK, LI	350	4.7
B8	OO	RGB, CFLS, *DP*, JK, LI	240	5.2
Total Block B			**1204**	**18.4**
Average Block B			**172**	**2.6**
C1	OO	CFLS, JK	19	0.1
C2	OO	CFLS, JK	20	0.1
C3	OO	CFLS, DP, JK	26	0.8
C4	OO	*HCU*, CFLS, *DP*, JK	18	0.1
C5	OO	CFLS, JK	18	0.6
C6	OO	RGB, CFLS, DP, JK	116	1.3
C7	OO	GCH, CFLS, *DP*, JK, LI	620	5.7
C8	OO	CFLS, DP, JK, LI	240	4.2
Total Block C			**1204**	**18.1**
Average Block C			**172**	**2.6**
Overall Total			**3370**	**42.6**
Overall Average			**164**	**1.9**

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