Report to the Energy Savings Trust

# REFURBISH OR REPLACE?

## CONTEXT REPORT

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**Executive Summary**


It is not obvious when to demolish housing and build something new on the site or when to refurbish and upgrade existing housing. This is a fundamental policy question for the Energy Savings Trust, who contracted CAR to do a scoping study and unravel pertinent issues. CAR did desk-based research, indicative modelling of energy consumption in three common building types, and ran an expert workshop.

The modelling destroyed once and for all the myth that it is better to rebuild than refurbish older housing to improve energy efficiency. In fact, energy efficiency and comfort are almost always insufficient as motives to replace housing. Moreover, energy efficiency is a second-order issue in the decision to refurbish or rebuild. Cost, comfort and health are much more significant.

Energy efficiency refurbishment is an order of magnitude cheaper than replacing a building (around a tenth of the cost of rebuilding in terms of energy savings/pound). It is also much more effective to focus effort on improving inefficient dwellings, and draw up performance evenly across the whole building stock

The EST's current policy stance is that the UK should increase the annual replacement of dwellings from 15 000 to 50 000. In CAR's view this target is only viable if the 50 000 homes to be replaced have very poor energy performance and there are reasons apart from just energy efficiency that motivate replacement.

We also believe this target to be unsustainable in the long term. We propose a new target, framed as a proportion of inefficient homes (say, with SAP ratings below 30) to be rebuilt each year.

CAR prepared three possible approaches for producing guidance in this area. At a workshop, experts we invited expressed real enthusiasm for the first, a self-assessment matrix that would help local authorities and social landlords to define their strategy. They also supported the second idea: generic upgrade tables showing costs and benefits of different options. However, they felt that the third, cost-benefit analysis based on net present value, was less useful and should not be included in any guidance.

CAR suggests a staged programme of future work in this area, including:

1. baseline research to establish how many UK dwellings require comprehensive refurbishment, a robust set of housing types, accurate costs and embodied energy in new build and refurb projects, and an estimate of what energy efficiency improvements are feasible
2. consultation with local authorities and registered social landlords to establish what guidance they need, and in what form
3. designing and testing a decision-support tool for LAs and RSLs

4. drafting guidance material for LAs and RSLs that includes the support tool and generic upgrade scenarios to represent all common building types.

## Refurbishing or replacing social housing

**Introduction**

The Energy Savings Trust contracted Cambridge Architectural Research to do a scoping study examining refurbishment in residential buildings. In particular, the EST wanted to explore the question of when it makes more sense to demolish housing and build something new on the site than to refurbish and upgrade a existing housing.

The EST needed this work for two reasons:

1. to inform its own policy stance on the point at which refurbishing homes is not longer viable
2. to define what guidance material is needed by local authorities and other social landlords, which EST can then commission as a future project.

The current annual replacement rate for housing in Great Britain is 0.06%, or 15 000 houses per year. The EST currently proposes raising this to 50 000 p.a. to achieve savings in $CO_2$, housing improvements and regeneration (EST, 2002[1]).

CAR conducted desk-based research, did energy modelling of refurbishment options on different house types, and ran a workshop to canvass expert opinion on these issues.

**Broad issues**

This section prioritises the practical issues decision-makers consider in strategic planning for improving energy efficiency in housing.

Our main finding is that the decision to replace or refurbish homes is likely to revolve around 'first order issues'. These include a) the technical constraints of the proposed refurbishment, which will determine the cost, and b) tenants' views and opinions, which will, at least in part, be influenced by comfort and health issues.

The relative energy efficiency that can be achieved by new build compared to refurbishment is seen as part of a bundle of second order issues. In order of priority these also include the appearance or architectural merit of the existing dwelling; the social character of the existing neighbourhood; the physical environment, the remaining functional life of the dwelling; how efficiently the existing dwellings use land and planning constraints and regional planning policy.

[1] EST (2002) Putting climate change at the heart of energy policy, EST submission to the Energy White Paper, EST, London.

Of these, the remaining functional life of the dwelling may be irrelevant since refurbishment can infinitely extend the life of most dwelling types.

Other issues were considered to be unimportant. Surprisingly perhaps, embodied energy was not seen as being a significant factor in the decision making process. (This opinion may need revisiting in any future research.) Nor were disruption, time of on-site work or temporary stock loss seen as being significant issues.

The results are based on a workshop exercise in which 12 experts were given a list of 16 issues. They were asked to identify any issues they thought were missing. Four issues were added. The experts then voted on whether they thought each of the 20 issues would form part of the decision making.

CAR ordered or prioritised the issues as follows. The numbers refer to the number of people, out of 12, voting for an issue. The experts agreed on first and second order issues in subsequent discussions.

*First order issues*

| | | | |
|---|---|---|---|
| cost, compared to new build | 11 | technological constraints | 9 |
| views/opinions of tenants | 9 | health and comfort of residents | 9 |

*Second order issues*

| | | | |
|---|---|---|---|
| energy efficiency | 8 | social impact on neighbourhood | 7 |
| appearance/ architectural merit | 7 | environment around home | 6 |
| remaining functional life | 6 | planning constraints/regional policy | 5 |
| efficient use of land | 6 | | |

These results need to be read with some caution because the number of experts consulted is relatively small. Any future research should seek to test these findings on a larger number of housing professionals, and particularly local authority decision makers, whom CAR invited to the workshop but were unable to attend.

# Energy Modelling

In discussion with the EST, CAR characterised three common types of dwelling found all across the UK:

Type 1: Solid wall 1920's local authority semi-detached house

Type 2: Cavity wall 1950's local authority terraced house

Type 3: 1970s maisonette in local authority 4-storey slab block.

We used these types to assess the effectiveness of different refurbishment measures aimed at improving energy efficiency. Following the Housing Energy Efficiency Best Practice Programme and EST's conventions (HEEBPp & EST, 2003[2]), we distinguished between low, medium, and high cost measures to refurbish dwellings (see table below).

*Grouped refurbishment measures included in modelling*

| | **Simple payback** | **Measures** |
|---|---|---|
| **Low cost bundle** | <5 years | solid walls - no insulation, cavity wall 50mm cavity fill, 150mm roof insulation, new boiler and controls |
| **Medium cost bundle** | 5-10 years | solid wall insulation, extra roof insulation, draught stripping |
| **High cost bundle** | >10 years | low-e double glazing, insulated doors and floor insulation |

For comparison, we also modelled a terrace house, a semi, and a 4-storey maisonette built to meet current building regulations (i.e. with modern levels of insulation, double glazing, and a condensing boiler). These dwellings' performance fell somewhere between the medium and high cost refurbishment bundles applied to existing homes.

**Energy modelling results**

The results of our modelling (below) show how much delivered energy is used in each dwelling for space heating, how much it costs, and how much $CO_2$ it would generate. The model starts with a 'base case' of no energy efficiency improvements at all. There are very few houses with no insulation whatsoever, but this is still a useful benchmark for comparison.

[2] Housing Energy Efficiency Best Practice programme and EST (2003) Domestic energy efficiency primer (GPG171), HEEBPp, London.

Lighting, appliances, and water heating were not included in the modelling, for two linked reasons:

1. they are highly variable even in identical dwellings, and energy consumption depends how lighting, appliances, and water are used
2. building fabric is a much less important determinant of light, appliances, and water heating energy than for space heating.

For information, average household hot water costs £138 p.a. but varies widely. The best gas-fired system could cost as little as £60 while an inefficient on peak electric heated system could cost as much as £450 p.a.

The modelling is intended to be indicative only, because actual $CO_2$ and costs will vary according to floor area, layout, glazed areas and orientation of actual dwellings.

**1920s Semi**

| Conservation package | Delivered energy kWh | Energy cost £ | $CO_2$ tonnes |
|---|---|---|---|
| Base case | 29,980 | 374.75 | 5.7 |
| Low | 18,541 | 231.76 | 3.52 |
| Medium | 8449 | 105.62 | 1.6 |
| Medium + | 4505 | 56.26 | 0.86 |
| Current building reg's | 4076 | 50.96 | 0.77 |
| High | 2882 | 36.00 | 0.55 |

**1950s Terrace**

| Conservation package | Delivered energy kWh | Energy cost £ | $CO_2$ tonnes |
|---|---|---|---|
| Base case | 18,183 | 227.30 | 3.64 |
| Low | 7909 | 98.90 | 1.58 |
| Medium | 6783 | 84.78 | 1.36 |
| Medium + | 5828 | 54.22 | 0.87 |
| Current building reg's | 5099 | 63.74 | 0.97 |
| High | 3180 | 39.85 | 0.64 |

**1970s maisonette in four storey block**

| Conservation package | Delivered energy kWh | Energy cost £ | $CO_2$ tonnes |
|---|---|---|---|
| Base case | 16,536 | 206.7 | 3.31 |
| Low | 11,182 | 139.77 | 2.24 |
| Medium | 5789 | 72.37 | 1.16 |
| Medium + | 3248 | 40.59 | 0.65 |
| Current building reg's | 4103 | 51.29 | 0.78 |
| High | 1908 | 23.85 | 0.38 |

CAR presented these results during the workshop. The experts were supportive of the model, and agreed with the assumptions underpinning it (described in the appendix to this document).

It is important to note that not all the energy savings indicated in this modelling would actually be achieved. Part of the savings (up to around 30%) would be absorbed as comfort improvements by residents.

The overwhelming conclusion from this modelling is that, for all common building types,

- **it is possible, on paper, to refurbish an existing building to give practically any desired thermal performance**.

For the three house types we modelled, using tried-and-tested refurbishment methods, you can cut energy use and $CO_2$ emissions for heating to between a fifth and a tenth of their energy use when built. You can also take these house types beyond current building regulations – saving between a third and half of the space heating energy requirements of a modern house. The cost of these refurbishment measures is only moderate, and only a fraction of the cost of demolishing and rebuilding (see next sections).

## Cost Comparisons

**1. Refurbishment and energy savings**

CAR used cost data published by the HEEBPp and EST (2003[3]) to investigate the cost of different energy refurbishments for housing. We advise that the figures be treated cautiously, and they need to be updated and verified as part of follow-up research.

We divided energy efficiency investments into three:

1. low cost – measures costing less than 5 times annual fuel savings
2. medium cost – measures costing 5-10 times annual fuel savings, and
3. high cost – measures costing more than 10 times annual fuel savings.

CAR bundled together specific measures of each type to see what effect they have on $CO_2$ emissions and energy costs from the three defined building types. All costs include professional installation (not DIY), and replacement costs (e.g. for a new, condensing boiler) are the extra cost on top of normal boiler if you were to replace it anyway.

All tables show energy use and costs from space heating using gas.

| 1920's semi | Base case | Low-cost refurb | Medium-cost refurb (extra cost) | High-cost refurb (extra cost) |
|---|---|---|---|---|
| **Cost** | - | £545-£700+ | £495-£650+ | £4735 |
| **Annual $CO_2$ emissions (tonnes)** | 5.7 | 3.52 | 1.6 | 0.55 |
| **Annual energy cost** | £374.75 | £231.76 | £105.62 | £36.00 |

| 1950's terrace | Base case | Low-cost refurb | Medium-cost refurb | High-cost refurb |
|---|---|---|---|---|
| **Cost** | - | £470-£590 | £890-£1130 | £4235 |
| **Annual $CO_2$ emissions (tonnes)** | 3.64 | 1.58 | 1.36 | 0.64 |
| **Annual energy cost** | £227.3 | £98.90 | £84.78 | £39.85 |

[3] Housing Energy Efficiency Best Practice programme and EST (2003) Domestic energy efficiency primer (GPG171), HEEBPp, London.

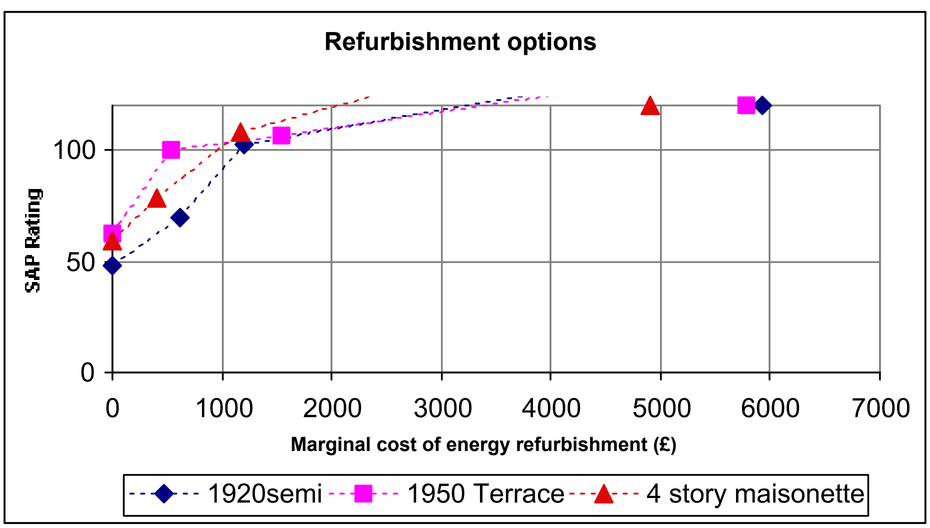
| 1970s maisonette | Base case | Low-cost refurb | Medium-cost refurb | High-cost refurb |
|---|---|---|---|---|
| **Cost** | - | £350-£465 | £650-£880 | £3735 |
| **Annual $CO_2$ emissions (tonnes)** | 3.31 | 2.24 | 1.16 | 0.38 |
| **Annual energy cost** | £206.70 | £139.77 | £72.37 | £23.85 |

There was strong support at the expert workshop for tables like these to be produced as tools for decision-makers in local authorities and social landlords. However, the experts felt that the tables should be more detailed – allowing decision makers to identify more precisely where their buildings are now, and showing precisely what steps they could take to raise performance. In addition, tables (or graphs) are required for all common UK house types.

Some experts thought that the information may be clearer, and easier to use, if you could show what effect a given expenditure would have on SAP rating for buildings with different levels of current energy-efficiency.

Just for illustration, CAR has attempted to translate the energy costs from the tables above into graphs showing energy investments against SAP rating, below. If EST supports this idea, we could refine it for future guidance material.

*Indicative graph showing the effect of energy refurbishment investment on SAP rating (Note: these values are not accurate)*




Both the tables and graph show clearly that the marginal effect of investments on energy use declines as housing efficiency increases. It costs approximately £200-£400 to save one tonne of $CO_2$/y from a base case of no energy improvements, rising to approximately £4000-£8000 for a building that already has medium-cost improvements.

This means that **it is much more effective to focus effort on low-cost improvements to inefficient dwellings, drawing up performance evenly across the whole building stock**, than to make a small number of homes extremely energy-efficient. This strategy brings additional benefits in relation to broader policy objectives (for central and local government) of equity and equality.

Conversely, the scope for improving performance of better-performing dwellings (which already have insulation and heating systems close to current building regulations) is much less. Investments at this end of the housing stock represent much lower value-for-money.

**2. Refurbishment and new build**

CAR also presented indicative values for the cost of demolishing housing and replacing it with new buildings at the workshop, shown below. We assumed a cost of £50/$m^2$ for demolishing (above and below ground costs), and £700/$m^2$ for a standard two-storey house (based on Spain, 2001[4]). We also assumed a cost to build beyond the 2001 building regulations, with upgraded insulation and infiltration controls, of £6000. These assumptions went unchallenged by experts at the workshop, but need validation and updating in future research.

We ran the new build and new low-energy house types through our energy model, leading to the $CO_2$ and energy cost figures in the table.

| New build | Mid-terrace family house to current building reg's | Mid-terrace low-energy house |
|---|---|---|
| **Build cost (inc. demolition)** | £69 000 | £75 000 |
| **Annual $CO_2$ emissions (tonnes)** | 0.97 | 0.64 |
| **Annual energy cost** | £54.22 | £39.85 |

Assuming that the HEEBPp/EST cost data is correct, these figures indicate that it is an order of magnitude more expensive to replace housing than to do an energy refurbishment – in the region of 10 times more. If detailing and build quality are up to standard, it is possible to get the same energy performance from a refurbished existing building as from a new build.

However, if new properties are going to be built anyway, it is possible to improve energy efficiency beyond the requirements of the current building regulations. Moreover, the improvements will be far simpler and less disruptive than making the same improvements to existing dwellings. This opportunity to exceed current building regulations is preferable to refurbishing existing homes to the same standard. Our modelling suggests that simple upgrades using tried-and-tested techniques can trim about a third from space heating energy requirements of a modern house.

[4] Spain B (2001) Spon's estimating cost guide to minor works, refurbishment and repairs, Spon Press, London, and Davis Langdon Everest, in Building, 2003.

# Categories of refurb, embodied energy

**Different categories of refurbishment**

It is naïve to think the choice facing local authorities and social landlords is simply "do we refurbish or demolish and replace this building?" There are three different categories of refurbishment (and there are still further options within each category):

| | Structure | Health & Comfort | Description of Refurbishment | Cost-effectiveness of rebuilding |
|---|---|---|---|---|
| **Category 1: energy-only refurbishments** | structurally sound | free of social and health problems | restricted to insulation, heating systems and draught-proofing | never cost-effective to demolish and replace the building purely for energy efficiency |
| **Category 2: typical refurbishments** | probably structurally sound | may or may not be free of social and health problems | insulation, heating systems and draught-proofing combined with other changes, which may have aesthetic motives | very unlikely to be cost-effective to demolish and replace the building purely for energy efficiency |
| **Category 3: comprehensive refurbishments** | may or may not be structurally sound | probably some social and/or health problems | energy efficiency measures incidental to a greater motive for refurbishing | complexity of refurbishment may make demolishing and rebuilding cost-effective |

The choice whether or not to rebuild only really applies to Category 3 refurbishments. CAR suspects that such buildings represent a small proportion of all social housing buildings, although they may still represent a significant number of dwellings (if, for example, most buildings needing comprehensive refurbishment are high-rise blocks of flats).

The 15 000 UK dwellings that are currently demolished and rebuilt each year probably fit in Category 3. Their owners have decided (on cost and other grounds) that it is preferable to replace them. The EST's recommendation of increasing the number of houses rebuilt each year to 50 000 would have to be aimed at houses in this category. It is impossible to say for sure if this is a feasible target without additional research. Even if the target is viable at present, the number of Category 3 buildings would diminish, so this target probably could not be maintained in the long term.

**Embodied energy**

It intuitively makes sense on energy grounds to reuse building materials on-site by refurbishing where possible. The energy required to produce the materials for a new building will be greater than for refurbishment.

The total embodied energy of a typical family dwelling has been estimated at 4000 $MJ/m^2$ (see table, below). (This value is difficult to translate into tonnes of $CO_2$ or kWh because it depends on the fuel mix, which was not cited.) Assuming the dwelling needs a major refurbishment 60 years after it is built, its embodied energy will account for "around a quarter of total energy use [over the whole 60 years, or even more for] a new, low-energy building" (Mulligan & Steemers, 2002[5]).

*Embodied energy and energy in use: comparative figures*

| | Embodied energy: typical dwelling as built | Embodied energy: major refurbishment, including some structural work | Annual energy in use in well-insulated home | Annual energy in use in poorly-insulated home |
|---|---|---|---|---|
| Energy consumption ($MJ/m^2$) | 4000 | 1700* | 450 p.a. | 900 p.a. |

*(Source: Mulligan & Steemers, 2002)*

The table indicates that embodied energy in a typical new home is about nine times the annual energy consumption in use – for space and water heating, lighting and appliances.

*The embodied energy figure is only indicative, because refurbishments can vary so widely, and embodied energy implications vary enormously in consequence. This figure was drawn from refurbishment of a four-storey block of 44 dwellings in Thetford. It is substantially higher than an energy-only refurbishment (Category 1), and equates to a Category 3 refurbishment.

However, the figure illustrates that a comprehensive refurbishment can account for energy consumption equivalent to four or five times annual energy in use, or close to half of the embodied energy of new build. (But note that there are many ways this figure could have been reduced - particularly long-term, through multiple refurb cycles.)

[5] Mulligan H, Steemers K (2002) Total energy use in refurbishment: avoiding the over-commitment of resources, paper given to PLEA Conference, Toulouse.

**What would be useful for LA's and Registered Social Landlords?**

Janet Young, from the Peabody Trust, said she needs a tool that allows her to 1. characterise her housing, and 2. identify the refurbishment options she faces. She would also like to be able to look across Peabody's whole portfolio to make a decision about which properties present the best opportunities for raising energy efficiency per pound. (In her terms, how many 'SAP's per £.) Janet thought this would also be valuable to local authorities.

(NB Peabody is unusual because it has a specific target, in terms of SAP ratings, for the average energy performance of its dwellings.)

**Combined heat and power**

Combined heat and power results in lower $CO_2$ emissions - especially if based on a renewable fuel source, like wood chippings. CHP (and community heating) is well suited to some residential buildings, like blocks of flats.

CHP is currently cost effective – in part because many buildings are inefficient and absorb a lot of heat. As building insulation improves, CHP will be less attractive. For this reason CHP is becoming less popular in Germany.

CHP is also vulnerable to changes in the cost of electricity. If electricity prices fall, the market for electricity sold to the grid will become less valuable, and could change CHP's now favourable economic position.

For these reasons, our panel of experts reached a consensus that CHP is high-risk. They said it is better to focus attention on the demand side (reducing the need for energy) than on the supply side (generating electricity and heat).

## Guidance material

The decision to refurbish or replace is complex and any guidance must reflect this. Decisions are not made on narrow cost grounds, partly because cost forecasting is so unreliable. Decision-makers need guidance to help them understand the relative importance of different factors, so that they can take a balanced decision. Energy efficiency is only one factor, and data about this must be simple and robust. We discussed these issues in the workshop, see next section.

The guidance is not simply intended to show when it is advisable to rebuild rather than refurbishing, but also to prevent unnecessary replacement when in fact refurbishment would be more appropriate and would allow more housing to be improved.

Further, the guidance material must take account of future changes that stand to affect refurbishment and new house-building – like the 2005 Building Regulations, which will insist on installing condensing boilers in all new houses and major refurbishment projects. There are other changes also that will give an extra stimulus to refurbishment, and which should also be covered in guidance:

The 'Decent Homes' standard – which comes into force in 2010. There are thermal comfort criteria in Decent Homes, but no references to SAP or NHER (National Home Energy Rating). This could become a major driver for housing refurbishment.

Disability Act – which will require building owners to make their buildings more accessible to people with disabilities. Some of these will force through comprehensive refurbishment sooner than building owners would otherwise have planned.

Energy efficiency certificates (so-called "MOTs" for buildings) – which may give LAs and RSLs an additional incentive to raise energy performance in housing.

## Workshop analysis

Three approaches were tabled for discussion. They all aimed to provide guidance to decision makers who are responsible for a particular stock of houses. They are less relevant to the formulation of policy on the refurbishment or replacement of housing.

### 1. Cost benefit analysis

**The approach** For any proposed refurbishment, the capital cost and annual fuel cost savings at today's prices can (in principle) be established. The present value of the stream of future fuel cost savings (based on a given discount rate and time period) can be compared to the capital cost, to give the net present value of the refurbishment. If the net present value is positive the refurbishment is cost-effective.

During the workshop, this approach generated very little enthusiasm. Negative comments included:

1. The landlord pays for the refurbishment, but the tenant gets the benefit of fuel cost savings.
2. $CO_2$ impacts are lost in a financial appraisal.
3. There is great uncertainty about future fuel costs.
4. Many factors that are relevant to the refurb/rebuild decision are hard to put in financial terms.
5. Financial appraisals give a spurious impression of authority and carry too much weight with committees.

**Conclusion** Cost-benefit analysis cannot be the primary component of guidance about refurbishment or replacement of housing.

### 2. Generic upgrade scenarios

**The approach** For generic upgrade scenarios, the typical impacts in terms of capital costs, fuel cost savings and $CO_2$ savings can be tabulated. Many such tables would cover most of the typical situations in the existing stock. The tables would provide robust data for decision making.

Feedback on this approach during the workshop included:

- Does not provide an explicit decision criterion.
- Rather coarse data is appropriate for strategic decisions.
- Emphasises energy efficiency and ignores other factors.
- Very few houses are totally unimproved, so tables are needed for range of current situations, not just houses in original condition.

**Conclusion** Generic upgrade scenarios are more acceptable than cost-benefit analysis, but simplify the decision about refurbishment or replacement of housing.

### 3. Self-assessment matrix

**The approach** A small number of critical factors affecting the refurb/rebuild decision (not just energy efficiency factors) are set out in a matrix, with a set of predefined 'levels' for each factor. A particular house or group of houses can be described ticking boxes in the matrix, indicating the appropriate level for each factor. The pattern of ticks can be compared to predefined 'template' patterns, giving an indication of suitable strategies.

The experts who came to the workshop felt this approach had some definite strengths. They made the following points.

- The matrix should appear logical, to establish confidence.
- The multi-attribute approach to the refurb/rebuild decision could be presented in other ways, eg. star diagram.
- Although it deals with several project-specific factors, the output is very generalised.
- Should the guidance identify more options, eg. disposal of stock.

**Conclusion** Guidance of this type would be very useful, but it must be logical and credible.

### Other issues for guidance material

Most local authorities have limited information about their housing stock. They don't know, for example, what the window dimensions of each property are. They may not even know what boiler efficiency or standard of insulation individual dwellings have. This means that any tables, if produced, would need default average values

The Single Regeneration Budget is a potential source of funding for refurbishment and housing replacement. The guidance may need to inform decision makers how best to make use of it.

## Implications for EST Policy

- In CAR's view, EST's longstanding policy of promoting energy efficiency in existing homes has been successful in improving the performance of the UK housing stock. However, there is more to do, and some homes still have inadequate insulation, draught-proofing, heating systems and controls.
- EST should continue to focus resources on bringing inefficient dwellings up towards current building regulations. This is more cost-effective than attempting to replace large numbers of houses.
- CAR offers several policy recommendations to EST. First to accept that energy efficiency alone is not a sufficient motive to demolish and rebuild housing. It is more cost effective to refurbish existing buildings – even including improvements that go beyond just energy efficiency.
- To justify a decision to demolish, there have to be additional factors – perhaps a mismatch between housing demand for particular forms and supply of those forms. Alternatively a desire to regenerate an area, or to build housing at higher densities may justify rebuilding.
- We recommend that EST prioritises, first, that all inefficient homes (say, those with SAP ratings below 30) are fitted with insulation and draught-proofing at least as good as the requirements of the 2001 Building Regulations, where practicable. Second, modern, efficient boilers and controls should be installed in these inefficient homes. Third, EST should work towards improving the efficiency of the much greater number of mid-range houses (say, those with SAP ratings between 30 and 60). These too should be encouraged towards refurbishment that reaches the performance required by current building regulations. Only when the poor performing and mid-range dwellings are up to scratch should EST turn attention to better-performing houses.
- If further research shows that there are indeed 50 000 dwellings in the UK that require comprehensive refurbishment each year, and if, moreover, these dwellings have poor energy performance (SAP<30), then we support EST's recommendation of a target for rebuilding these dwellings. However, we feel there is unlikely to be a continued need for rebuilding at this scale in the long term. A target based on the proportion of buildings needing comprehensive refurbishment would be easier to sustain (e.g. 20% of 'Category 3' buildings rebuilt each year).
- The EST should consider providing financial support for rebuilding buildings needing comprehensive refurbishment (Category 3). Such support could take the form of direct subsidies, granted on a case-by-case basis, given to local authorities or social landlords.
- Demolishing and rebuilding housing costs in the region of ten times as much as energy-only refurbishment .
- It is almost inconceivable that a local authority or social landlord would undertake more dramatic energy refurbishment in isolation. It simply isn't practical to fit interior

insulation without redecorating, for example. The actual costs of refurbishment are almost certainly much higher than those cited above.

- On the other hand, if a refurbishment is underway for some other reason – say, for structural reasons, replacing windows or doors – then the case for up-rating energy efficiency at the same time is easy to make. All property owners should be encouraged to upgrade insulation and draft-proofing when they carry out major refurbishment – even going beyond the 2001 building regulations.
- In a similar vein, if a building is to be replaced for reasons apart from energy efficiency, the opportunity should be taken to exceed current building regulations. Our modelling suggests that simple upgrades using tried-and-tested techniques can trim about a third from space heating energy requirements of a modern home.
- Regarding embodied energy, the total energy required to build a new home is in the region of nine times its annual energy consumption in use – for space and water heating, lighting and appliances. However, there are wide variations dependent on materials and form.
- Known refurbishment projects in the UK and overseas have displayed huge variations in cost – from 10% to 100% of the cost of new build.
- Embodied energy in refurbishment almost certainly exhibits similar variations. In one refurbishment that included some structural work, embodied energy was estimated at four or five times annual energy in use, or close to half of the embodied energy of new build.
- In addition, the EST should examine and help to resolve the constraints placed on refurbishment by planning and conservation area status. Overcladding, in particular, is viewed as a major threat to the appearance of traditional housing.

## Recommendations for future research

The choice between refurbishment and rebuilding is complex. In this short project CAR has only provided a context for future work in the field, along with ideas about how to support decision makers in local government and social landlords. We propose a logical staged approach to continuing the project, as follows.

**Stage 1 (baseline research)**

We need to establish:

1. how many social housing units there are in the UK that require comprehensive refurbishment
2. a robust set of housing types that represents all common forms found in the UK
3. accurate, up-to-date costs of refurbishment options and new build

4. the embodied energy in different types of new houses, and in refurbishment for energy efficiency and other motives (this need not be precise – indicative values are sufficient)

5. what improvements to energy efficiency are possible, in aggregate over the whole housing stock - as a guide to the EST for policy making and setting targets.

**Stage 2 (consulting LAs and RSLs)**

We need to consult local authorities and registered social landlords to establish:

1. how they make decisions, and what support they need to do this

2. how they would prefer this support to be presented ($CO_2$ emissions, cost, delivered energy, SAP ratings)

3. how much they already know about their housing portfolios

4. whether they would prefer generic upgrade scenarios to be produced on paper (in tables or as a graph) or on computer – within a spreadsheet.

**Stage 3 (preparing the tools)**

Design a self-assessment matrix for refurbishment and replacement strategies, in consultation with EST, and based on the outcomes from Stage 2.

Model energy use and $CO_2$ for all common existing house types with different levels of energy efficiency improvements, and with different floor areas.

Verify refurbishment costs from the current project, particularly with reference to different house types and floor areas.

Compile robust tables and/or graphs showing the costs and benefits (in $CO_2$ and fuel savings) of generic upgrade scenarios for different house types.

**Stage 4 (honing the tools)**

Test the self-assessment matrix with local authorities and social landlords.

Test the generic upgrade tables and/or graphs with local authorities and social landlords.

Use this feedback to revise both matrix and upgrade scenarios tool.

**Stage 5 (Producing guidance)**

Subject to approval in previous stages, embed the matrix and tables, graphs or spreadsheet into a guide for decision-makers in local authorities and social landlords.

# Appendices: Modelling data and costs of efficiency measures

**Appendix 1: Modelling data**

*General*

Degree-day model calculating useful solar gains by Solar/Load ratio method.

Degree days for 2002 Midlands region (about 15% lower than 30 year average)

*Standard U-values used*

Walls

| | |
|---|---|
| Solid 225 wall | 2.1 |
| Uninsulated cavity | 1.7 |
| Solid + 50mm | 0.5 |
| Cavity + insulation | 0.5 |

Roof

| | |
|---|---|
| Uninsulated | 1.5 |
| With 150 mm | 0.25 |
| With 250 mm | 0.15 |

Floors

| | |
|---|---|
| Suspended unins. | 1.5 |
| Solid uninsulated | 1.0 |
| With 50mm eps | 0.35 |

Glazing

| | |
|---|---|
| Single | 5.5 |
| Double | 2.8 |
| Low-e | 1.9 |

*Other data*

Boiler efficiency

| | |
|---|---|
| Low | 0.6 |
| High | 0.85 |

Weatherstripping 1.5 (1)* reduced to 0.75 ac/h
* 50s centre of terrace

Effect of ventilation heat recovery 0.75 reduced to 0.5 (effective)

Solar water heating performance 4m$^2$ saves 1000 kWh/year (heating)
PV system 8m$^2$ generates 800 kWh electricity/year

*Current Building Regs data used.*

| | |
|---|---|
| Roof | 0.25 |
| Wall | 0.35 |
| Windows | 2.0 |
| Doors | 2.0 |
| Floor | 0.25 |

*Boiler effic*. 78%

Fuel gas @ 1.25 p/kWh
Vent rate assumed 1ac/h
Internal gains 650W (based on area from SAP documentation)

*Floor areas*

| | |
|---|---|
| 1920s semi-detached | 76.5 $m^2$ |
| 1950s terrace | 85.6 $m^2$ |
| 4-storey maisonette | 85.7 $m^2$ (energy averaged between upper and lower maisonnette) |

**Conservation packages**

| | |
|---|---|
| Base case - | no insulation, single glazing, high infiltration rate (1.5 or 1) Low boiler efficiency |
| Low - | solid walls- no insulation, cavity wall 50mm cavity fill 150mm roof insulation, new boiler and controls |
| Medium | as above + solid wall insulation, extra roof insulation, draught stripping |
| Medium + | as above + double glazing and floor insulation |
| High | as above + low-e glazing and insulated doors |
| High + | as above + mechanical ventilation heat recovery, 4$m^2$ solar water heating panel and 8 $m^2$ PV panel. |

**Renewable energy packages**

| | Generates | tonnes carbon emission saved |
|---|---|---|
| 4$m^2$ solar PV panel | 800 kwh/y | 0.66 |
| 8$m^2$ solar water heating panel | 1000 kwh/y | 0.20 |

## Appendix 2: Costs of efficiency measures

*Low cost bundle (simple payback in <5 years)*

| **Measure** | **Approx. cost for 1920s semi** | **Approx. cost for 1950s terrace** | **Approx. cost for 1970s maisonette** |
|---|---|---|---|
| cavity wall insulation (where appropriate) | - | £210-£300 | £170-£265 |
| roof insulation (new) | £220-£250 | £210-£240 | £130-£150 |
| hot water insulation | £50 | £50 | £50 |
| replace boiler with condensing unit (raise efficiency from 78 to 88%) | From £150 | - | - |
| modern heating controls | £125-£250 | - | - |
| Totals | £545-£700+ | £470-£590 | £350-£465 |

*Medium cost bundle (simple payback in 5-10 years)*

| **Measure** | **Approx. cost for 1920s semi** | **Approx. cost for 1950s terrace** | **Approx. cost for 1970s maisonette** |
|---|---|---|---|
| solid wall insulation (external) | £1500 | - | - |
| replace boiler with condensing unit (raise efficiency from 78 to 88%) | - | From £150 | From £150 |
| modern heating controls | - | £125-£250 | £125-£250 |
| top-up roof insulation (to 250 mm) | £200-£230 | £190-£220 | £200-230 |
| draught-stripping | **£85-£110** | £85-£110 | £40-£60 |
| Totals | £495-£650+ | £420-£540+ | £300-£415+ |

*High cost bundle (simple payback in >10 years)*

| **Measure** | **Approx. cost for 1920s semi** | **Approx. cost for 1950s terrace** | **Approx. cost for 1970s maisonette** |
|---|---|---|---|
| Upgrade windows to low-e double-glazing | £3500 | £3000* | £2500 |
| Solar water heater ($4m^2$, generating 1000 kWh/y) | £1200 | £1200 | £1200 |
| Totals | £4700 | £4200 | £3700 |

*Source: National Energy Foundation (www.natenergy.org,uk). Other figures based on Housing Energy Efficiency Best Practice Programme/EST (2003) 'Domestic Energy Efficiency Primer', GPG 171.