New Tricks with Old Bricks

How reusing old buildings can cut carbon emissions

New Tricks with Old Bricks

Contents

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Key findings

This study compared the CO_2 given off in building new homes and creating new homes through refurbishing old properties. The key findings are:

Reusing empty homes could make an initial saving of 35 tonnes of carbon dioxide (CO_2) per property by removing the need for the energy locked into new build materials and construction.

Over a 50-year period, this means there almost no difference in the average emissions of new compared with refurbished housing.

Carbon dioxide (CO_2) emissions from new homes fall into two distinct sources: “embodied” CO_2 given off during the housebuilding process, and “operational” CO_2 given off from normal energy use in the house once it is occupied.

The new homes each gave off 50 tonnes of embodied CO_2. The refurbished homes each gave off 15 tonnes.

Well-insulated new homes eventually make up for their high embodied energy costs through lower operational CO_2 but it takes several decades - in most cases more than 50 years.

Embodied CO_2 is not widely understood but this study shows that it accounts for 28% of CO_2 emissions over the first 50 years’ lifetime of a new house.

Embodied CO_2 is an investment in the environmental sustainability of a house. Refurbished old homes have lower embodied CO_2 and therefore a distinct head start over new homes.

Empty homes in England provide an opportunity to create 150,000 new sustainable homes.

If the rate of VAT on repairs and renovation had been 5% instead of 17.5%, it would have cut the average cost of refurbishment by approximately £10,000 for each house.

Many house builders claim that new homes are four times more efficient than older houses. This study shows that refurbished houses can be as just efficient as new homes.

Policy context

Climate change

Emissions of CO_2 generated by human activity are believed to be the biggest single cause of climate change. As a member of the European Union, the UK is committed to reducing greenhouse gas emissions to 12.5% below their 1990 levels by 2012 under the Kyoto Protocol. The UK Government has made a further unilateral commitment to "move towards" a 20% cut in CO_2 emissions by 2010[1]. The UK Government's overall approach is set out in the UK Climate Change Programme and the Sustainable Development Strat*egy Securing the Future* (2005). More recently, in *Building a Greener Future*, the Government has announced its intention that all new housing should be rated according to the Code for Sustainable Homes, with a view to achieving 'zero-carbon' housing as a mandatory minimum standard by 2016.

Household emissions

There is a wealth of information readily available about the contribution of households to greenhouse gas emissions.

In 2004, the UK's carbon dioxide emissions stood at 559 million tonnes per year, with nearly a third (27 per cent) attributable to the energy used in people's homes.

The average UK home is responsible for between five and six tonnes of CO_2 emissions every year, approximately a third of which could be saved by adopting simple energy efficiency measures. This would knock around 10% off our national total - equivalent to the CO_2 emitted each year by more than 30 gas-fired power stations[2].

While there is an abundance of information, advice and action on the operational (daily use) emissions of housing, far less information is available about the energy and materials already locked into buildings and the carbon emissions they represent. Controversy surrounds the issue too.

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[1] *Securing the future The UK Government Sustainable Development Strategy*, The Stationery Office 2005.
[2] *UK Could Suffer £200 Billion Climate Change Damage By 2050*, Energy Saving Trust, 2004, www.energysavingtrust.org.uk.

Conflicting claims

"New properties are "greener" than older ones". - *Sunday Times* October 2006.

"New homes are more environmentally friendly and sustainable than at any time in recent history" - Home Builders' Federation 2007.

New homes are over four times more energy-efficient than older homes and therefore 'greener'. - *Smart New Homes* 2007.

"New homes can be up to eight times more efficient than a typical Victorian property." - Peveril homes 2007.

It is increasingly common for developers to make environmental claims for the buildings they produce. A significant body of wider opinion holds that demolition of existing housing and replacement with new housing (built to high energy efficiency standards) is broadly preferable in many cases to refurbishment. A key foundation of this argument is that the operational (in-use) carbon emissions of highly efficient newly build housing can be far lower than those from existing properties. Often these claims are well founded. It is undoubtedly true for example that new homes are better insulated than homes built in the past; when the majority of the UK's older houses were built there were no mandatory standards governing energy efficiency or thermal comfort. Some claims however are harder to quantify. Assertions of the superior environmental performance of new housing are sometimes used by developers and regeneration planners to justify supplanting existing homes with new homes. It is also sometimes used to explain building new developments when there is an existing supply of unused buildings that could be used.

This approach has profound implications for the whole housing stock. For example, the Environmental Change Institute at Oxford University has set out a "vision" in which the rate of house demolition in the UK would rise to 80,000 per year by 2016, continuing at that level until 2050, giving a total of 3.2 million demolitions from 2005-2050.[3]

A contrary argument also exists and is increasingly used by environmental campaigners and heritage organisations in promoting alternatives to new development. Their argument is that new buildings consume huge quantities of energy in their development, energy that could be saved by reusing existing buildings. In addition, the high standards of energy efficiency assumed for new buildings are entirely dependent on enforcement and achievement of very high construction standards.

There are also critical elements missing from the calculation: the carbon embodied in existing buildings, the energy required to demolish them and dispose of any waste (around 24% of all waste is generated by demolition and construction[4]), and the energy cost of extraction, production, transport and use of new materials – not to mention the wider environmental effects of minerals extraction and demolition and construction disturbance.

There are 288,763 long-term empty homes[5] in England [6] and, according to estimates by English Partnerships, there may be potential for over 400,000 residential units in

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[3] Environmental Change Institute, Oxford University, www.40percent.org.uk.
[4] *The Role of Historic Buildings in Urban Regeneration*,, House of Commons Housing, Planning, Local Government and the Regions Select Committee, 2004.
[5] A long-term empty home is defined as one that has been continuously unoccupied for six months or longer.
[6] Empty Homes Agency 2007.

unused commercial and industrial buildings[7]. Together these provide a huge potential supply of new housing.

Can both these arguments really be true? This study aims to find out.

These apparently conflicting arguments have been given new impetus by the government's proposals for housing growth. The government Green Paper *Homes for the Future More Affordable, More Sustainable* [8] consults on the proposal to deliver two million new homes by 2016 and three million by 2020 in order to meet projected increases in household numbers and increased demand for housing. It acknowledges that reusing empty homes can help meet some housing need.

But would there be a net environmental dividend to doing so, as environmental campaigners claim, or, as some developers claim, a net environmental cost?
Whilst there has been much research on the environmental impacts of housing, most has focussed on the use of energy used in the home once it is occupied (operational energy). Very little has been carried out into the environmental impacts of building and redeveloping homes (embodied energy). And until this paper none has considered the relative importance of each.

The Empty Homes Agency carried out a small piece of research in 2005[9], which from calculations attempted to estimate and compare the energy used in building a new home and refurbishing an existing empty house. As might have been expected, the results showed that substantially less energy was used in the process of refurbishing the empty house than in building the new house (90,000kw/h for the new house and 15,000kw/h for the refurbished house). The difference can be explained largely by the embodied energy retained in the empty house. Whilst much of the timber and fittings were replaced during the refurbishment, most of the bricks and mortar were retained. The refurbishment process therefore used fewer and smaller quantities of building materials than the new house. The energy consumed in producing and transporting these materials was therefore saved.

Whilst this study quantified the potential energy saving in developing two properties, it did not investigate the "operational" (or in-use) energy that would be used after the properties were occupied. It is likely that the new and probably better insulated house would have lower operational energy requirements. If so the apparent energy 'saving' of 75,000kw/h in the refurbished house could be reduced. Indeed it is possible that over years of occupation higher operational energy in the refurbished house could wipe away the embodied energy saving altogether. Similar points could be made about the wider housing stock. Whilst it is likely that refurbishing empty homes is likely to have a lower energy cost than building the same number of new homes, it does not necessarily follow that there will be an overall energy saving after several years of occupation.

The urgent need to cut greenhouse gas emissions demands that the housing sector play its full part. The question whether it is preferable to do so by demolition and rebuilding or refurbishment is fundamental, but there is little evidence by which to consider it. A desire to address this scarcity of evidence gave rise to this research. Specifically, by examining the relative importance of embodied and operational carbon, it offers an insight into the options for future management of our housing stock.

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[7] National Land Use Database 2006.
[8] Department for Communities and Local Government 2007.
[9] The Green House Effect published in *The Guardian* 2005.

The research

In an attempt to better understand these issues the Empty Homes Agency undertook a wider piece of research studying the development and projecting the future energy use in six homes. The results of this research are detailed here.

The research calculated the carbon dioxide (CO_2) emitted in the manufacture and transport of every material and component that was used in the construction of the new houses and the refurbishment of the existing houses. This is termed embodied CO_2. The research also projected the CO_2 that would be emitted by each house over a fifty-year period into the future. This is called in-use or operational CO_2. Adding these figures together for each house provided what we termed a lifetime CO_2 cost for each house. Fifty years was not intended to represent the expected lifespan of the house but to represent the likely period before a major refurbishment might be expected. This would provide the next opportunity after initial development in which the environmental performance of the house could be reconsidered and changed.

Results are given in kilogrammes of CO_2 emitted. We consider that CO_2 emissions are a better understood concept than measures of energy and so we have used them in presenting our results.

The case studies

Six case studies were chosen. Three were newly built houses and three were homes created through refurbishing existing properties. All were small semi-detached or end-of-terrace family houses. They were chosen not to be representative of the whole housing stock but because they represent the most common housing type in England today.[10]

The construction methods of the six properties varied, although all were built in traditional styles using construction methods that are commonly used. Some of the properties were timber-framed; others were of masonry construction. All of the new build homes were built by established house-builders and were built to at least 2002 Building Regulations standards.

The refurbished homes were selected because they provided reasonable comparisons to the new build homes. All were semi-detached family houses roughly similar in size and layout. The quantity of building work carried out in each of the refurbishments was substantial. In every case it was greater than the amount of work needed to refurbish an average empty home to a habitable condition.[11] It included re-plumbing, rewiring, in one case re-roofing, and extensions were also added to two of the houses. Part of the developer's objective in each of the refurbishments was to improve the environmental performance of the house.

Newmarket, Suffolk

A new 4-bed semi-detached house built by Persimmon Homes in a new development of similar houses built in 2006. It is a timber-framed construction with a brick façade built to 2002 Building Regulations standards.

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[10] 27% of English dwellings according to the *English House Condition Survey 2001*, ODPM 2003 www.communities.gov.uk/documents/corporate/pdf/145310.

[11] Based on surveys carried out in Kent and Greater London, which identified the average cost of comprehensive refurbishment of an empty home as between £5,412 and £6,800 (*East Kent Empty Property Initiative*, report of research by Fordham Research Ltd for Kent County Council, Swale Borough Council, Shepway District Council, Thanet District Council and Dover District Council, May 2005; and *Empty Homes in London 2005-6*, Greater London Authority, March 2006).

Ashford, Kent

A new 3-bed semi-detached house built by Oakdene Homes in 2006. It is a traditional brick and block construction. Again it is built to 2002 Building Regulations standards.

Stamford Brook, Cheshire

A new brick and block construction 3-bed semi-detached property built by Taylor Woodrow Homes in 2004/5. It was built as part of a scheme to test ways of improving on Building Regulations to inform the development of future regulations on thermal performance. This means that it has higher levels of thermal insulation and a more airtight construction than was required under 2002 Building Regulations. It also featured a mechanical heat-recovery ventilation system.

Nelson, Lancashire

A 3-bed end-terrace house built in about 1890. It was part of a terrace of seven previously empty and derelict houses that were refurbished in 2006/7 by Adactus Housing Group. The refurbishment was substantial, involving a complete replacement of all internal walls floors, windows and fittings and fixtures and structural repairs. A large amount of concrete was used in creating the new ground floor. The roof was also replaced although the original slates were reused.

St. Albans, Hertfordshire

A 4-bed semi-detached house built in approx 1950. The property was refurbished in 2006 by the property owners, St. Albans District Council, and was used as a demonstration "eco house" to promote the use of various sustainable building materials and products. The refurbishment included the addition of a single-storey, well insulated timber-frame extension with a sedum roof and roof-mounted wind turbine. Sunpipes were installed to allow natural light into rooms without windows.

Nottingham

A 4-bed semi detached house built in about 1895. This house is the largest of the six case studies. It was comprehensively refurbished in 2005. The property is the architect Gil Schalom's own home. An extension was built to the rear. The side and rear elevations of the house were externally insulated and rendered. Other walls were insulated internally using dry-lining plasterboard. The roof was also highly insulated and many other sustainable features have been added.

What we found

The study aims to better understand the total CO_2 emissions in creating and running a family house. The methodology not only estimates and quantifies the operational (in-use) CO_2 emitted in the everyday occupation of the six case study houses, but in addition quantifies the total CO_2 used in either building or, in the case of the three existing homes, of refurbishing and improving them prior to occupation.

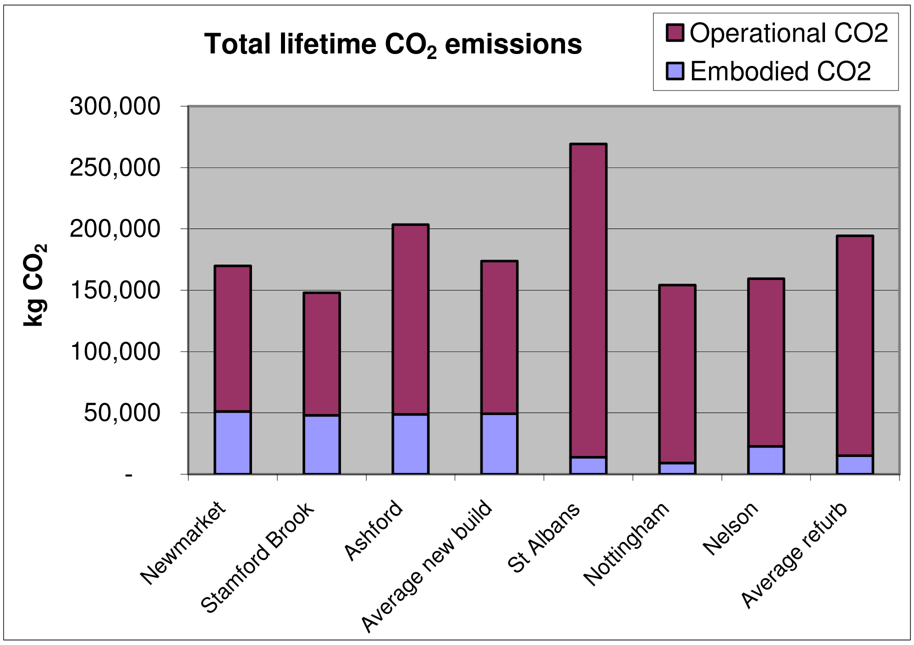
Lifetime CO_2 emissions

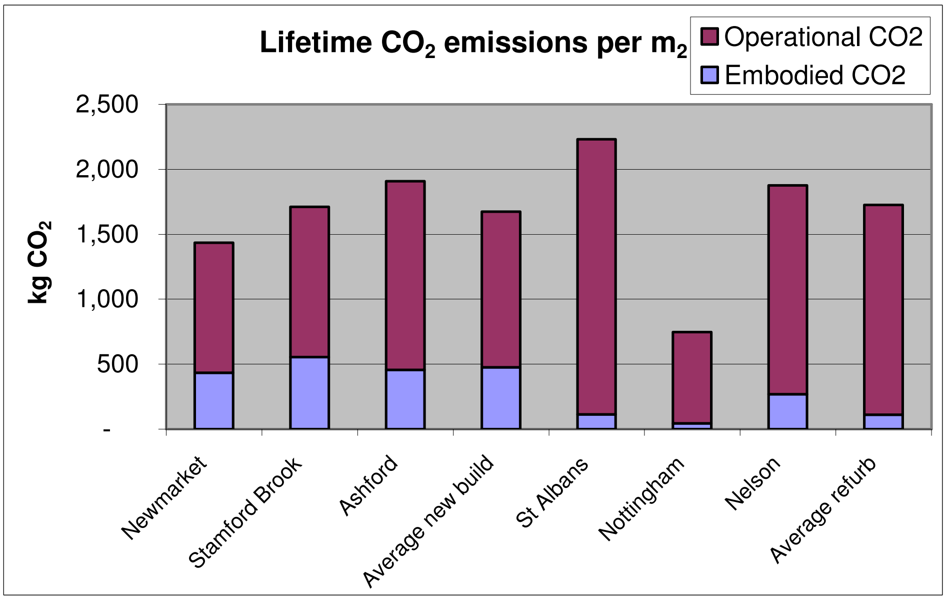
The results showed a wide variation of CO_2 emissions between the case studies. They estimate that each house will produce between 150 and 270 tonnes of CO_2 over its lifetime, comprising CO_2 emitted during their development and operational emissions over a projected 50-year life. The variations are partly due to the different sizes of the houses. To account for this the results are also presented in terms of CO_2 per m^2 of floor area.

Intriguingly, despite the variations in the case studies there was no clear distinction between the new build properties and the refurbishments. The average new build property emitted 174 tonnes of CO_2 and the average refurbishment emitted marginally more at 194 tonnes. On a CO_2 per m^2 basis there was almost no difference, both emitting 1.7 tonnes of CO_2 per m^2. The house with the lowest total emissions was a new build property but the house with the lowest emissions per m^2 was a refurbished house.

This does not fully answer the conflicting arguments over which is greener, new build or refurbishment. Indeed, on the limited evidence of this study it suggests that there may be little difference, at least over a 50-year period.[12] It does however suggest that refurbished homes can be just as "green" as new homes, but with the benefit of lower embodied CO_2. Although the operational CO_2 emissions of the refurbished houses in our study are higher, the one new home which 'catches up' with the two more efficient older houses' CO_2 performance overall only starts to do so 35-50 years after construction.

[12] The period chosen for comparison in this study is 50 years. It seems probable that many if not most new homes would require substantial refurbishment before 50 years had elapsed, however.





The development peak

Despite the similarities in the total lifetime CO_2 emissions, the way in which the total is comprised and the timing of when the CO_2 was emitted is very different. All the houses show a large "development peak" of CO_2 emissions when they were built or developed. This represents the embodied CO_2 of all the materials and components that were used in their construction. The figure represents the carbon cost of developing the properties. It does not include the embodied CO_2 of the original materials that were retained in the refurbished houses.

The size of the "development peak" varies according to how much and what sorts of materials were used. Some materials such as timber have relatively low embodied CO_2 costs because only small amounts of CO_2-producing processes, such as sawing, drying and transportation, take place. Other materials such as steel have very high embodied CO_2 costs because their production includes very energy-intensive processes including mining, extraction and smelting that emit high levels of CO_2.

The average embodied CO_2 emitted in the refurbishment case studies was around 15 tonnes. The new build case studies emitted an average of around 50 tonnes. In fact, as the refurbished houses were on average larger houses, the difference is even more pronounced. On an embodied CO_2 per m^2 basis development of the new build houses emitted approximately 4½ times as much as the refurbishments: 104 $kgCO_2/m^2$ for refurbishment compared with 475 $kgCO_2/m^2$ for new build. As with the earlier Empty Homes Agency research, this finding is not unexpected.

What is embodied CO_2?

Embodied CO_2 is the CO_2 that is emitted during the manufacture and transport of a product. It is usually expressed in kg of CO_2. It is therefore a measure of the environmental impact of producing it. The term embodied energy is sometimes used to convey the same concept. Whilst similar, the terms are not interchangeable. A product made using energy from a renewable source for example might have high embodied energy but low embodied CO_2.

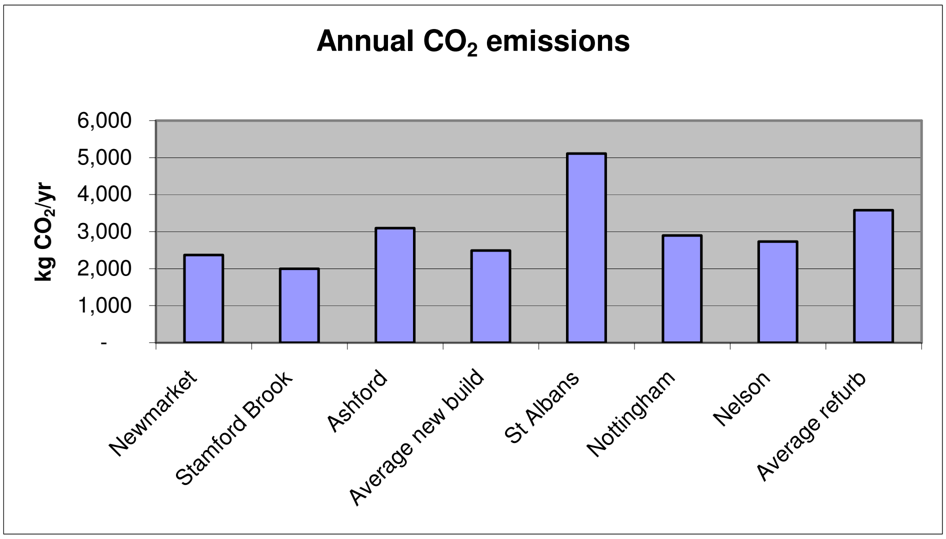
There are many environmental effects other than CO_2 emissions that occur in making products. For example emissions of toxins, water use and habitat loss, which are not taken into account or only obliquely considered in measuring embodied CO_2.

Projecting the operational CO_2 tail

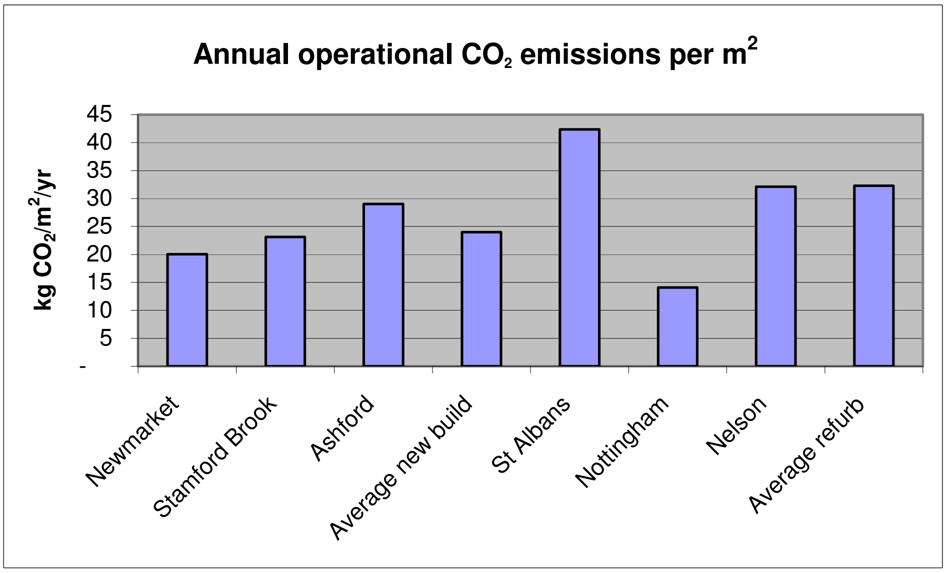
We also projected the likely operational CO_2 emitted by each house. Operational CO_2 is emitted through the direct use of fuel in the home through space heating and heating hot water. It is also emitted indirectly through using electrical appliances like washing machines, televisions, and lighting. We took into account both direct and indirect emissions. We made the projections using the established NHER[13] method to arrive at a likely annual rate of domestic CO_2 emissions from each house. Many factors affect this projection. We made assumptions about household size, occupancy rates and household behaviour but we made the same assumptions for each of the case study houses. This means any differences were due entirely to the physical properties of the houses. The two most significant factors were the effectiveness of thermal insulation and the size of the house.

We found that five of our six case study houses emitted less CO_2 than the average for houses in England. The average dwelling in England emits just over 5 tonnes of CO_2 per year[14]. This is not altogether surprising. England has an old housing stock: 39% of it was built before the Second World War.[15] Most of these older houses were built with very poor levels of thermal insulation and many have not been improved. In 2004 the average SAP (a measure used for measuring thermal efficiency) for English dwellings, on a scale of 1-120, was 51.8[16]. By comparison, new homes built at the same time as our case study homes would have needed a SAP rating of at least 90 to meet the building regulations in force at the time.[17] The houses in our study are all newly developed and it would be surprising if their thermal insulation performance were not better than average.

[13] National Home Energy Rating scheme (NHER), www.nher.co.uk.
[14] Domestic Carbon Emissions for Selected Cities, British Gas/Best Foot Forward 2006.
[15] *English House Condition Survey 2004*, DCLG 2006.
[16] *Ibid.*
[17] The Building Regulations 2000, *Approved Document L1 - Dwellings (2002 edition)* (as amended), The Stationery Office 2002.

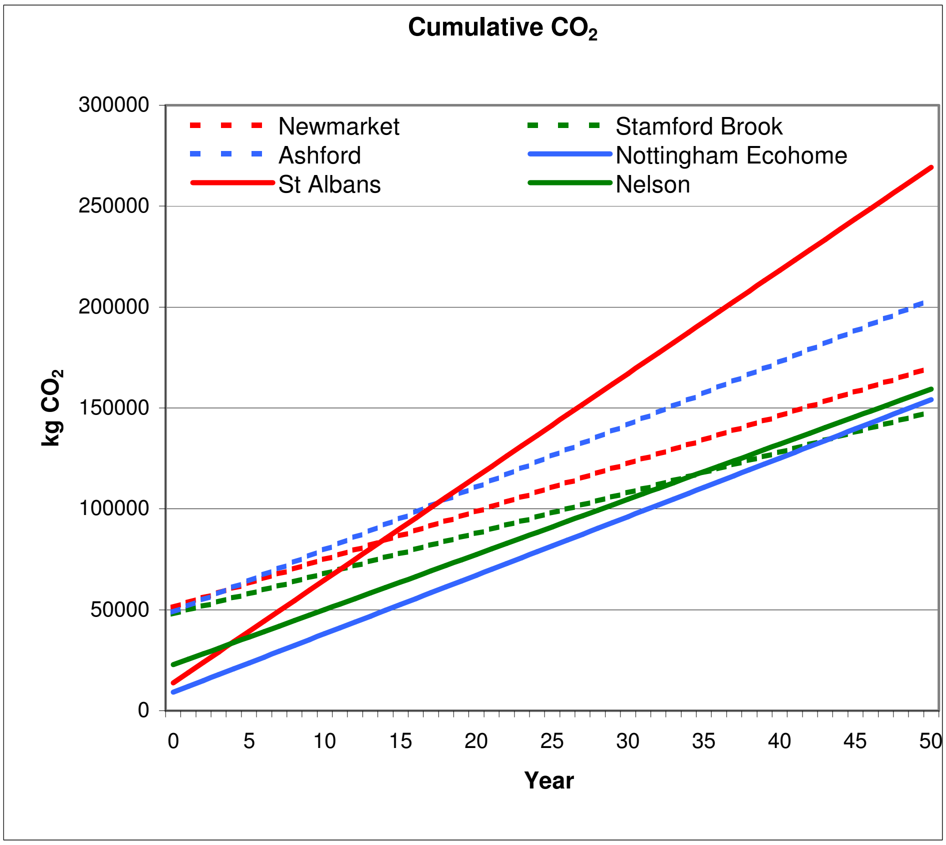


Overall, the new homes emitted less (2.5 tonnes a year) operational CO_2 than the refurbished homes (3.6 tonnes a year). Again this is affected by the size of the properties and on a CO_2 per m^2 basis the differences between the new build and refurbishment cases are less clear. On this basis both the highest and lowest emission houses were refurbishments.



Cumulative CO_2

The operational CO_2 is emitted each year the property is occupied. Whilst the annual amount appears quite small in comparison to the development peak, over many years the cumulative total, or "emissions tail", adds up to a substantial figure. We have plotted the cumulative total on a graph projecting 50 years after the houses were developed.



The graph shows a projection line for each of the six houses. The point at which they start on the y axis (kg of CO_2) depends on the amount of embodied CO_2 that was emitted during development (the development peak). The angle at which the line inclines depends on the amount of annual operational CO_2. The more that is emitted the steeper the incline. The six houses bunch into two groups on the y axis. The lower bunch are the three refurbished properties; the new homes with their higher embodied CO_2 start higher up the y-axis. This start point represents the point in time at which all of the properties have been completed but are not yet occupied. All of the CO_2 that has been emitted is embodied CO_2; none of it is operational CO_2.

As time passes, more and more operational CO_2 is emitted. After 20 years, more operational CO_2 than embodied CO_2 has been emitted. After 50 years the embodied CO_2 comprises just 10% of all the CO_2 emitted by the refurbished houses and 28% of the CO_2 emitted by the new houses.

The carbon investment

The graph helps show how CO_2-efficient the development of the different houses was. Embodied CO_2 can be considered a carbon investment in the house. High levels of embodied CO_2 could be considered a good carbon investment if they resulted in a home with low operational emissions. A house built in this way would start high on the y-axis but would show a shallow incline over time. The Stamford Brook house is the best example of this approach amongst our case studies.

Similarly a refurbished house with low embodied CO_2 could be considered a poor carbon investment if the resulting home had high operational emissions. The closest example to this approach is the St Albans refurbished house. This house had the second lowest level of embodied CO_2 emissions, but the highest level of operational CO_2 and the highest total CO_2 emissions of our case studies.

The remaining homes in the study (two new build properties and two refurbished homes) showed remarkably similar results. Whilst they showed very different levels of embodied CO_2 and thus different levels of carbon investment, the operational CO_2 emissions are very similar, as can be seen by the similar levels of incline on the graph. The lines for the Newmarket, Ashford, Nottingham and Nelson houses are very nearly parallel. In these two cases, refurbishments of Victorian houses were able to achieve operational CO_2 emissions as good as contemporary new build properties for a much lower embodied CO_2 investment.

What is the impact of housing on CO_2 emissions?

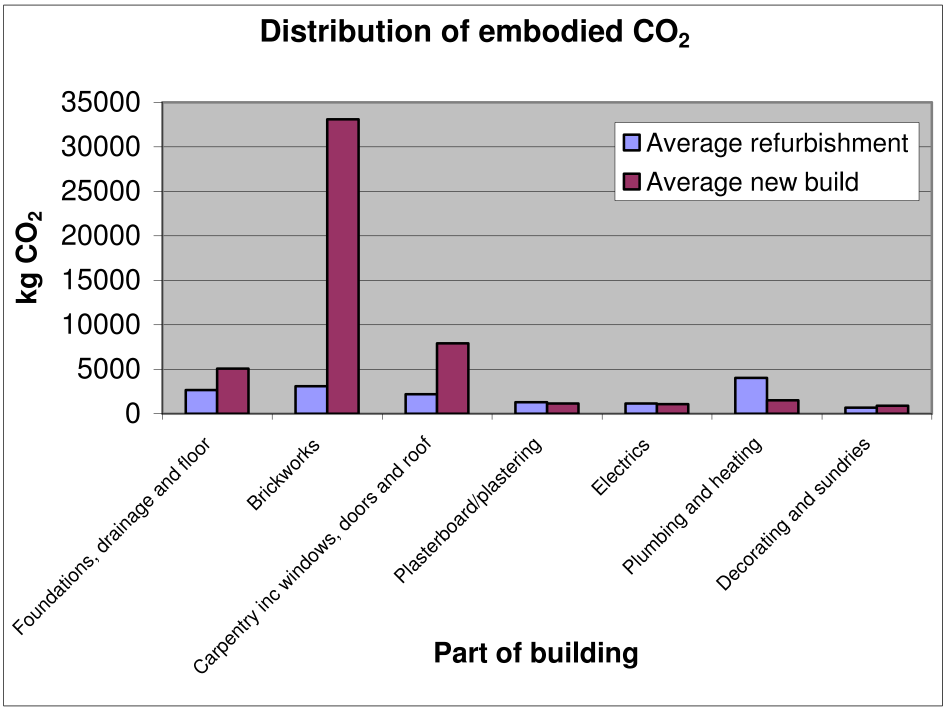
570 million tonnes of CO_2 are emitted in the UK every year.[18] 27% of UK CO_2 emissions are from operational running costs of homes.[19] That is 150 million tonnes of CO_2 a year from our homes' day-to-day emissions. This operational CO_2 comes from directly burning fossil fuels for cooking and space and water heating, along with indirect emissions from the generation of electricity for lighting and ever more electrical appliances.

By far the greatest proportion, around 50% of domestic CO_2 emissions, comes from space heating.[20] Reducing this ongoing emissions cost of current dwellings is the target of efficiency measures such as replacement boilers, retrofitted insulation and draught-proofing.

Where the embodied CO_2 is used in homes

To better understand where the embodied CO_2 was used we divided all the materials for each property into categories. As can be seen on the graph below, the bulk of the additional embodied CO_2 was used in brickworks (i.e. bricks, blocks and mortar). The distribution was similar for each of the new build case studies, despite one of the new build houses being timber-framed (it had a brick wall covering). On average there were 33 tonnes of brickworks per property - 68% of the total embodied CO_2 in the three new build properties.

[18] Baggott SL, Brown L, Cardenas L, Downes MK, Garnett E, Hobson M, Jackson J, Milne R, Mobbs, DC, Passant N, Thistlethwaite G, Thomson A, Watterson JD, *UK Greenhouse Gas Inventory, 1990 to 2004: Annual Report for submission under the Framework Convention on Climate Change*, AEA Technology Energy and Environment, 2006.
[19] *Building houses or creating communities? A review of government progress on Sustainable Communities*, Sustainable Development Commission, 2007.
[20] *Climate Change: the UK Programme*, The Stationery Office, 2006.

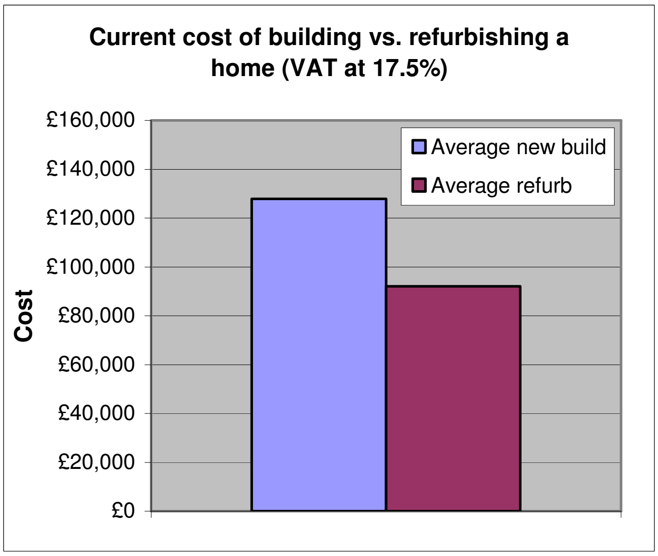


In most house refurbishments the majority of the outer walls are retained. This was the case in the three case studies. The brickworks were largely accounted for by extensions and a small amount of repair and replacement. This means that the proportion of brickworks is much lower than in new build houses. In the three refurbishment case studies brickworks produce only 10% of the CO_2 of a new build house: an average of just over three tonnes per house. Bricks do not intrinsically contain more embodied CO_2 than other materials but they take up a large proportion of building materials used. For the new build case studies the average weight of materials used in brickworks is 86 tonnes out of a total building weight of 160 tonnes – more than half. The average weight of brickworks in the refurbishments was just 5.5 tonnes.

In other categories the embodied CO_2 was broadly similar for new build properties and refurbishments. This is principally because large quantities of the materials were replaced during the refurbishments.

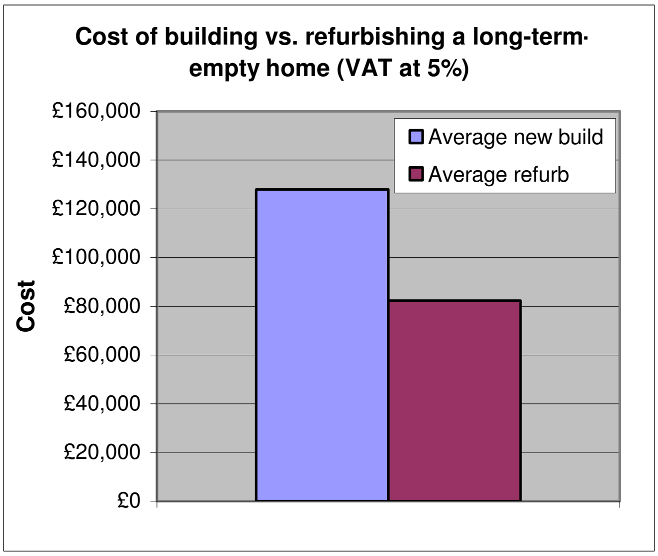
Financial implications

This study did not seek to compare the financial costs of building new houses and refurbishing existing houses, but the estimated average costs are detailed here. They show building costs only and do not take into account the cost of the land.

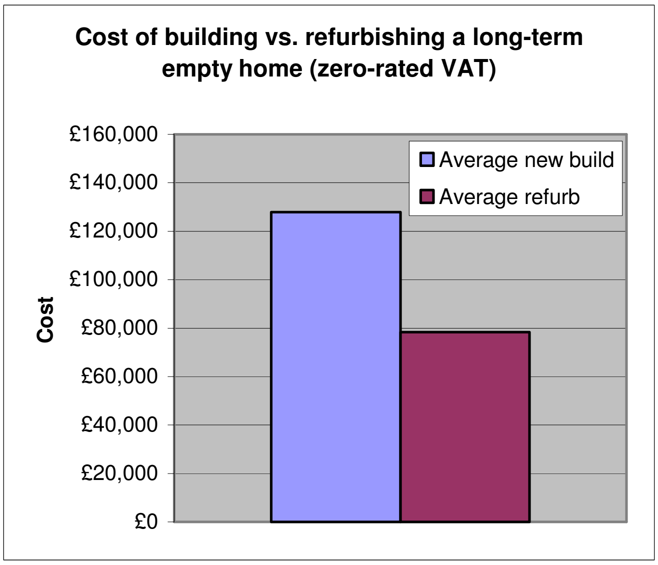


Different VAT rules apply to the two groups of properties. New build homes are zero-rated for VAT purposes. Refurbishment costs are charged at 17.5% VAT. The results show that the average refurbishment costs 39% less than the average new build.

Homes that have been empty for more than two years attract a lower rate of VAT for refurbishment costs. Whilst this did not apply to any of the case studies, had it done so it would have reduced the average cost of the refurbishments by approximately £10,000 each (see chart below).



Refurbishment costs on some homes empty for more than ten years can be zero-rated for VAT purposes. This however only applies to material costs where the refurbishment is a DIY project or to some cases where the resulting home is purchased by a social housing provider. None of the case study houses qualified. The chart below shows how the cost advantage of refurbishment over new build would have been further increased had they done so.



The UK has one of the oldest housing stocks in Europe. 39% of it was built before 1944, much of it in two periods of housing growth: one at the turn of the 19th and 20th centuries and another in the middle of the twentieth century. In many respects it has lasted well and continues to perform its task valiantly, much of it having provided homes for several generations and currently providing homes for 60 million people. 71% of homes in England meet the Decent Homes standard[21] - an improving trend.

Most of the UK's housing was built using methods and to specifications very different from modern houses. Prior to the mid 1970s most houses were built with very little if any added insulation. Thermal insulation that was achieved was largely through the properties of the structural building materials. Successive sets of building regulations have since changed this significantly, driving up levels of insulation to roofs, walls, windows and floors etc. in newly built homes. This process of improvement is set to continue with the government signalling that it will require all new homes built after 2016 to be zero-carbon. This means that homes must have zero net emissions of carbon dioxide from all energy use in the home. In practice this means that homes will need very high levels of thermal insulation to minimise heat loss and some form of renewable energy generation, whether on-site or elsewhere, to offset energy used in the home.

Whilst standards of thermal insulation for new homes will have been transformed in 40 years, there have been few retrospective requirements on the existing housing stock, Although the Government has announced plans for zero-carbon new homes, there are currently no specific plans to introduce any new requirements for existing homes in the future. At the time of writing Government proposals to reduce operational carbon emissions from the existing housing stock were expected in April 2008.

New homes from empty houses

The government has stated that housing supply in England needs to increase significantly. The Housing Green Paper: *Homes for the Future More Affordable, More Sustainable*[22] consults on the proposal to deliver two million new homes by 2016 and three million by 2020 The paper acknowledges that reusing empty homes can help meet some housing need.

[21] English House Condition Survey 2004.
[22] Department of Communities and Local Government 2007.

The most recent published figures show there are at least 675,000 empty homes in England.[23] This represents about 3% of the housing stock. The Empty Homes Agency estimates that over 300,000 have been empty for more than six months and 150,000 of these could be readily returned to use to create additional housing supply.[24]

Most empty homes are in relatively good condition. A study commissioned by Kent County Council in 2005[25] showed that average costs of returning empty homes to a habitable state were about £6,000 per property. A similar study commissioned by the Greater London Authority[26] found the cost to be just over £12,000.

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[23] Housing Strategy Statistical Appendix 2005/6, Department of Communities and Local Government 2007.
[24] Empty Homes Agency 2007.
[25] *East Kent Empty Property Initiative*, report of research by Fordham Research Ltd for Kent County Council, Swale Borough Council, Shepway District Council, Thanet District Council and Dover District Council, May 2005.
[26] *Empty Homes in London 2005-6*, Greater London Authority, March 2006.

Conclusions

The study shows quite remarkably that despite very different approaches taken to producing new homes, the total CO_2 emissions for each were very similar.

Previous studies and much of the accepted thinking on domestic CO_2 emissions have suggested that demolishing existing homes and building new homes to replace them will contribute to an overall reduction in CO_2 emissions. This study suggests that this is not so, and that refurbishing existing homes and converting empty property into new homes can yield CO_2 reductions by preventing emissions from embodied energy that would arise from new build.

Whilst embodied CO_2 emissions associated with building and developing and refurbishing homes are a relatively small proportion of the total CO_2 emissions from housing, omitting them from future projections of domestic CO_2 emissions is highly misleading, overestimating the CO_2 savings new homes can make and underestimating the potential of refurbishing existing homes and returning empty homes to use to help cut emissions.

Of course, future housing need cannot be met solely by refurbishing the existing housing stock. New housing is necessary and desirable, and future legislation is likely to reduce operational CO_2 emissions further. There is little, however, to suggest a reduction in embodied CO_2 from new homes is likely.

The cumulative CO_2 emissions in this study show that it is not simply the total CO_2 from housing that is significant; emissions from new homes create what we have called a “development peak”, meaning that CO_2 emissions are concentrated in the development or building stage. This effect is especially pronounced with new homes.

Appendix 1 Methodology

Objective

Much work has been carried out into the embodied CO_2 and embodied energy of materials. However little has been done so far to calculate the CO_2 costs of building whole houses. One study looked at the embodied energy of residential property development,[27] however no data were available for refurbishments. This report addresses that gap.

The object of the project was to calculate and compare the total CO_2 emitted in developing and running new homes over a fifty-year "lifetime" period. This includes both the embodied CO_2 and the operational CO_2. The project studied six individual properties. All were small semi-detached or end-of-terrace family houses. They were chosen not to be representative of the whole housing stock but because they represent the most common housing type in England today[28]. Three of the case studies were newly built houses and three were homes created through refurbishing existing properties.

Why 50 years?

The decision was made to measure the CO_2 emissions from the houses over a fifty-year "lifetime" period. This was not intended to represent the expected lifespan of the house but to represent the likely period before a major refurbishment might be expected. A major refurbishment is the next opportunity after initial development in which the environmental performance of the house could be reconsidered and changed. Many houses have lasted for hundreds of years but others are demolished after just a few decades, and all houses need maintenance and repair. Many components of houses have limited life spans and every generation or so a house will need a major refurbishment to keep it in a habitable condition. The frequency of these refurbishments varies. Portfolio landlords often programme refurbishments every 30 or 40 years. Owner-occupied property is often refurbished at the time of sale. For some properties the time between refurbishments may even be longer than 50 years. Whatever the interval, major refurbishments are the best and perhaps only time to reconsider the environmental impact of a house. They provide the opportunity to install a new heating system, improve insulation values, repair or replace windows and so on.

Over the lifetime of a house, CO_2 is emitted from a number of sources: embodied CO_2 in the materials used to build the house, domestic heating, lighting, cooking and electrical appliances, not to mention the infrastructure on which it depends, such as sewerage and roads.

Calculating embodied CO_2 costs of dwellings

For the new build properties plans, specifications and schedules of works were obtained from the house-builders/developers. For the refurbishments plans and specifications were obtained from the developers.

To calculate embodied CO_2 for all the materials used in the development of these properties we needed to obtain a complete breakdown of the materials and quantities that were used in their construction. The plans and specifications did not all provide sufficient details. We employed a quantity surveyor[29] to calculate the materials needed

[27] *Sustainable Homes: Embodied Energy in Residential Property Development, A Guide for Registered Social Landlords*, Hastoe Housing Association and the Housing Corporation, 1999.
[28] 27% of English dwellings, according to the *English House Condition Survey 2004*, DCLG 2006.
[29] Estimators Ltd, www.estimators-online.com.

from the plans. The quantity surveyor's specification provided quantities in numerical terms or by volume. Using standard tables these were converted into weight.

Researchers at Bath University have compiled an inventory of the embodied energy of all common building materials. Their Inventory of Carbon and Energy (ICE) provides data on the average carbon emitted in the manufacture of almost all of the materials detailed on the quantity surveyor's specifications.

ICE provides data for the energy used in the extraction, manufacture and transport of the material as far as the factory gate. For some materials the data extend to transport to the site. Due to the number of sources there is occasionally wide variation in figures in ICE for some materials, and where several are given an average has been taken.

By extracting the embodied carbon data for each material from the ICE inventory it was possible to calculate the embodied carbon needed for each component and material used in each of the case study houses. A total of the embodied carbon for all materials and components provided an estimate of the total embodied carbon in the development of each house.

Calculating operational CO_2 costs of dwellings

The study sought to calculate the carbon emissions for operational energy over a projected 50-year life for each dwelling. National Home Energy Rating (NHER) assessments were obtained for each property. NHER is the most commonly used energy rating system in the UK. It counts all the operational energy used in a home – i.e. space heating, water heating, cooking, electrical appliances and lighting – and converts it to the form of operational CO_2 emissions. This is an annual emissions rate in tonnes of CO_2/m^2. This was then multiplied by the floor area of the property to give an annual CO_2 emissions figure for each home.

The NHER system also takes into account the local environment. A postcode is used to enable the system to take account of climatic conditions that may be affected by altitude, topography and latitude. This helps to provide a more accurate result for a single property. However it makes comparisons of properties in different locations more difficult, as differences in results may be due to differences in location, construction or both. Our six case study properties were in different locations across the country. In order to make comparisons of construction easier, the NHER assessments for all six case studies were entered on the NHER software at the same postcode.

Calculating cumulative CO_2 costs of dwellings

The results for embodied CO_2 and operational CO_2 for each property were combined to provide an estimate of the total CO_2 emissions for development and use of the houses over a projected 50-year period.

Appendix 2 Limitations

The study sample is six houses. This is not a statistically significant sample and cannot be considered representative of England's housing stock.

Only one (Nelson) of the three refurbished homes had been empty for any significant period of time prior to refurbishment. The other two refurbished properties cannot therefore be considered as providing new housing and technically are not therefore alternatives to building new homes, (although the works involved in both were similar to the works that might be needed to bring derelict homes into habitable use).

All of the properties were developed while the 2002 Building Regulations were in force. Whilst many of the properties applied building methods and products that went beyond the requirements of those regulations, they may not comply with the 2006 Building Regulations.

There are many different methods for calculating embodied CO_2. The one used in this study uses the methodology used by Bath University's ICE model. It is an estimate of the CO_2 emitted during extraction, manufacture and transport of building materials. All models for estimating are potentially inaccurate. It is almost impossible accurately to quantify the carbon footprint of any product. Heavily manufactured products in particular may have supply chains operated by many different companies in different countries.

The breakdown from our quantity surveyor does not represent an exact inventory of the materials that were actually used in the development of each house, but an estimate based on standard constructions and materials. The actual houses that were developed from the plans used in the study may therefore have higher or lower embodied energy costs than the figures quoted in this study. However the method used for calculating the materials and quantities was the same for all case studies.

This study has not taken account of the energy used on site during construction or the possible end-of-life costs such as recycling or disposal of demolition waste. This means that the quantities of materials considered are likely to be an underestimate.

Embodied CO_2 was calculated on component material weight. CO_2 emissions associated with any further manufacturing have not been taken into account.

Some further omissions and assumptions were made in the calculations where embodied CO_2 data were unavailable. Generally these were items such as wall filler, adhesive and silicone sealant where small quantities were used and we considered their omission to be insignificant. The bitumen and felt on the flat roof of the St Albans house was omitted for the same reason.

The embodied CO_2 data for the Windsave wind turbine at the St Albans house were extrapolated from a journal article[30] that calculated the embodied energy and carbon of a similar turbine, the Swift.

The embodied CO_2 data for the solar panel at St Albans was extrapolated from a paper that gives a figure of 4.34 t CO_2 for a 2.7m^2 ATON system.[31] This is not for the brand of solar water heater that is actually installed and so may vary from the actual embodied CO_2 figure.

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[30] Rankine, R.K., Chick, J. P., and Harrison, G. P., 'Energy and Carbon Audit of a Rooftop Wind Turbine', *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, Volume 220, Number 7/2006, pp. 643-654, Professional Engineering Publishing 2006.

[31] Croxford, B. and Scott, K, undated. See also *Can PV or Solar Thermal Systems Be Cost-Effective Ways of Reducing CO_2 Emissions for Residential Buildings?*, UCL presentation 2006.

Other omissions are for products such as thermostatic radiator valves (TRVs), heating controls and smoke alarms, as the material mix is unknown. These would have added little to the overall total since they are omitted for all properties.

The NHER assessment model makes a large number of assumptions in calculating operational CO_2. Whilst these assumptions may result in inaccuracy, the same methodology and assumptions were applied to each of the case studies.

Another factor that ought to be considered is that the fuels and technologies used to provide energy for dwellings are likely to change over the next fifty years. Biomass boilers or combined heat and power systems would most likely lead to lower domestic CO_2 emissions for the same energy outputs.

Appendix 3 National policy relating to the existing built stock

Making best use of resources is a recurring theme in national policy, expressed as the philosophy of "doing more with less"; it spans housing, minerals, land, energy and climate change. A core theme is emissions of greenhouse gases, and carbon dioxide in particular. Here we cite just a few key references to illustrate the backing in national policy for making best use of existing buildings.

"The Government's objectives for minerals planning … are: To ensure, so far as is practicable, the prudent, efficient and sustainable use of minerals and recycling of suitable materials, thereby minimising the requirement for new primary extraction."

Minerals Policy Statement 1: *Planning and Minerals*, paragraph 9, DCLG November 2006.

"Conversions of existing housing can provide an important source of new housing. Local Planning Authorities should develop positive policies to identify and bring into residential use empty housing and buildings…".

Planning Policy Statement 3 (PPS3): *Housing*, paragraph 31, DCLG, November 2006.

"We…need to make the most of existing homes and buildings."

Housing Green Paper: *Homes for the future: more affordable, more sustainable*, July 2007.

"So let me show how we can put such a new environmental citizenship to work on the quarter of all emissions which come from our homes, saving five million tonnes of carbon by helping people reduce their own carbon footprint.

In the last Pre-Budget Report, I announced that within ten years all new homes would have to be zero carbon, and I provided a stamp duty exemption as an incentive to get there. But new homes are only a small percentage of the total. So today I want to extend our ambition to all homes. Over the next decade my aim is that every home for which it is practically possible will become low carbon."

Speech by the then Chancellor of the Exchequer, the Rt Hon Gordon Brown MP, to Green Alliance, 12 March 2007.

The Building and Social Housing Foundation (BSHF) is an independent research organisation that promotes sustainable development and innovation in housing through collaborative research and knowledge transfer. Established in 1976, BSHF works both in the UK and internationally to identify innovative housing solutions and to foster the exchange of information and good practice. BSHF is committed to promoting housing policy and practice that is people-centred and environmentally responsible.

The Empty Homes Agency is an independent campaigning charity, which exists to highlight the waste of empty property in England and works with others to devise and promote sustainable solutions to bring empty property back into use.

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