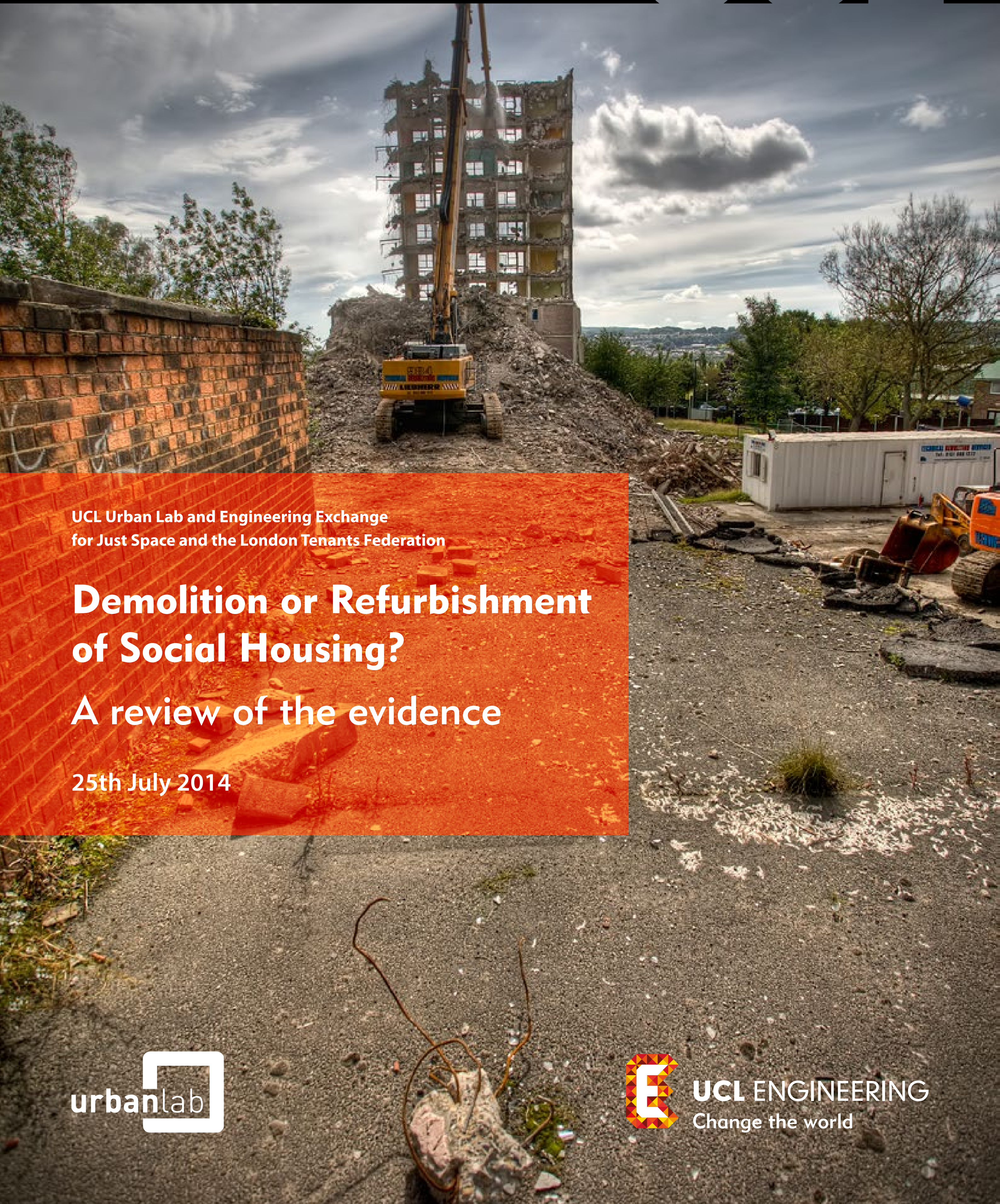


UCL Urban Lab and Engineering Exchange
for Just Space and the London Tenants Federation

Demolition or Refurbishment of Social Housing?

A review of the evidence

25th July 2014

urbanlab

UCL ENGINEERING
Change the world

Cover photo: m4nch3go, Flickr

UCL Urban Lab and Engineering Exchange
for Just Space and the London Tenants Federation

Demolition or Refurbishment of Social Housing?

A review of the evidence

25th July 2014

Authors:

Kate Crawford
Charlotte Johnson
Felicity Davies
Sunyoung Joo
Sarah Bell

urbanlab

UCL ENGINEERING
Change the world

Executive Summary

This report provides a review of technical models, evidence and case studies for decision making relating to the retention or demolition of social housing stock.

Technical assessments of building suitability for refurbishment or demolition are often based on models of building performance. These include energy performance of the building compared to standards for new buildings, and assessment of environmental and energy impacts of the building over its lifetime from construction to demolition. Decisions can also be based on a series of performance and cost indicators. All modelling and indicator based approaches require assumptions about the building and the economic and policy context in which regeneration will take place, which need to be examined and justified in each case.

Evaluation of the economic case for refurbishment is sensitive to the institutional factors such as the UK retrofit supply chain and market; tenure types and management capacity; access to finance and/or willingness to invest. Typical cost indicators are capital expenditure, operational expenditures and capital investment appraisal. Estimating the costs and impacts of refurbishment or demolition is complex, uncertain and subjective – especially where non-monetary costs and benefits have to be assigned a value. Financing mechanisms for refurbishment are less well established than construction.

The energy performance of a building is an increasingly important consideration in decisions to demolish or refurbish, and it has a big impact on the health of residents and the cost of their energy bills. Energy is used by residents as they live in a building throughout its lifetime. Energy is also used to manufacture building materials and construct the building in the first place and then in demolition, reusing, recycling and moving materials to dispose of them. Reducing carbon emissions associated with the built environment means reducing the emissions associated with the whole life cycle of buildings. However, refurbishment and retrofitting of buildings, including insulation, replacing windows and boilers, heating networks, and installing renewable energy, can improve the performance of existing buildings to near-new standards. Decarbonising the UK electricity grid will also reduce the climate change impacts of energy used in buildings, and will increase the relative importance of embodied carbon and energy in the lifecycle impacts of a building. Case studies demonstrate even hard to treat buildings can achieve high energy efficiency standards. The carbon emissions associated with building use depend on the source of energy used. Increased low carbon sources of energy to produce electricity on the grid in the future may reduce the environmental impacts of energy used in homes. Research has shown that there are often differences between the predicted and actual performance of buildings (performance gaps) and that people sometimes adapt their behaviour in ways that increase consumption after an energy efficiency project (rebound effects). Performance gaps and rebound effects are often not taken into account when assessing benefits to residents like a reduction in bills or improvements in thermal comfort. If future savings have been over-estimated, it is residents (rather than the professionals estimating the savings) who are doubly and disproportionately penalised, firstly, because what has been promised is not delivered and, secondly, because they pay the energy bills.

Relatively simple water efficiency retrofitting can achieve savings of 17.5 litres per person per day, compared with the London average of 160 litres of water used per person per day. Sustainable drainage methods can also be cost effectively retrofitted into existing buildings and estates, delivering a wide range of benefits including reduced overheating of buildings. The construction and demolition sector contributes 33% of all waste in the UK every year (47% in London). Much of this is due to demolition waste. The UK construction sector currently recycles 73% of its waste, but still contributes more than 4 million tonnes of waste to landfill each year. Recycling demolition waste reduces the environmental impacts of demolition, but refurbishment avoids waste to landfill and many of the environmental impacts of new construction.

Improving the quality of social housing stock is essential to reduce health inequalities in the UK. Housing has significant impacts on mental and physical health and wellbeing, and should be a key factor in regeneration decision making. Refurbishment can deliver improvements in housing quality at a faster rate than demolition and rebuilding of social housing, but health issues such as ventilation and indoor air quality can be complex issues to address in refurbishment. Refurbishment of buildings presents opportunities for the creation of jobs requiring a new set of skills that will be in demand if the UK is to meet its carbon emission reduction targets. Operation of renewable energy systems also provides opportunities for community development through refurbishment of buildings and estates.

It is clear that the ability for communities to engage in refurbishment and demolition decisions would be enhanced by a consistent and transparent approach to the reporting of lifecycle costs, energy and carbon, water and waste and monitoring the well-being of those affected by refurbishment and demolition. The literature reviewed here is emerging from different fields – engineers, energy modellers, planners and public health specialists – and shows some useful results but is often hard to disaggregate in a way that shows how the effects of refurbishment and demolition play out for different groups of people. However, many aspects of refurbishment and demolition are complex and interact with each other: what is needed is a more balanced inter-disciplinary view of what housing interventions mean for people and who the winners and losers are in the short and longer term.

Contents

1 Introduction

The demolition of homes is amongst the most contentious issues in urban regeneration. Decisions to demolish or refurbish buildings are often taken by professional experts and developers, without adequate engagement with local residents and communities. Demolition or retention decisions can not only cause conflict between residents and regeneration authorities, but can also cause conflict within communities. Where some people see dilapidated, unhealthy, anti-social buildings that should be knocked down, others see homes, communities and opportunities for renovation and refurbishment.

Good decision making in regeneration requires thoughtful assessment of financial and technical information, within a context of meaningful engagement with residents and communities. Decisions to demolish or refurbish buildings are rarely clear cut, and will invariably involve trade-offs between different objectives and values.

This report provides a review of main factors involved in decision making for refurbishment or demolition of social housing building stock. It summarises available evidence for environmental and economic costs and benefits, and provides case studies of regeneration schemes that involved refurbishment of social housing. Chapter 2 addresses key technical methods used in decision making regarding the retention or demolition of buildings, and Chapter 3 reviews the economic implications of such decisions. Chapter 4 reviews the energy and carbon implications of demolition compared to refurbishment, and Chapter 5 considers issues related to water and waste. Chapter 6 covers key issues related to communities and residents, focussing on health and wellbeing. The conclusion outlines key findings.

2 Regeneration decision making

Regeneration decision-making is a complex and contentious area of urban planning and policy making. This chapter focusses on the legislation, policies and objectives linked to planning and regeneration in the UK that determine whether social housing buildings are demolished or refurbished. These include areas such as energy, climate change, waste management, housing quality and health. The frameworks for supporting and evaluating decisions are considered in terms of environmental, economic and social outcomes. These different categories tend to be treated differently in the literature either because there are fewer data available, the data are uncertain or because the outcomes themselves are regarded as difficult to measure or quantify (see Box 1). In particular, this applies to the health, well-being, social life and educational impacts on individual residents as well as impacts on society at large such as the costs of health or care services that are linked to planning or housing policies (Roys et al. 2010)[1]. Where possible, this report draws attention to these gaps.

Two general approaches are involved in decisions about existing stock and whether to maintain (repair), refurbish (retrofit) or demolish and, possibly, rebuild. The first considers the building stock as a whole while the second addresses individual buildings and estates.

2.1 Whole building stock approach

The first approach is designed to support policy decisions and considers the whole (national) building stock or large (investor or sector-based) property portfolios. This level of analysis aims to answer questions like: what level of carbon emissions come from residential buildings in the UK; how and by how much could UK emissions from buildings be reduced; how much would it cost the UK to reduce these emissions?

Typically, models of the whole building stock are based on data such as age and condition of housing by building type and location. Tenure type is also included to give an indication of the people or institutions responsible for different categories of the stock. Typical housing types can then be subjected to individual building approaches (see Section 2.2) to analyse environmental performance.

There is disagreement over how useful any estimates of building lifetimes based on the whole building stock approach are for making societal or planning decisions about refurbishment or demolition. Although building lifetimes can be estimated by looking at numbers of buildings built and demolished over time in the whole building stock (like using birth rates and deaths rates to estimate average life expectancy of people in a population) (Kohler 2007), it has been argued that this implicit or effective building life (See Table 1) "has little to do with the actual longevity of housing and, despite suggestions to the contrary carry no direct implications for public policy towards the stock" (Lowe 2007, p. 413).

This is particularly relevant in the often controversial 'technical' debates about demolition exemplified by the arguments for and against more demolition. Table 1 below summarises some aspects of this debate to show how the data is used arguments are put forward and why.

1 This analysis categorises costs as "costs that could be quantified given better data" and "costs that exist but are probably not quantifiable" and identifies: costs to society at large (externalities) such as health care and care service costs; and costs to individual residents such as physical and mental health, social isolation, discomfort of living in buildings that need repairs, school achievement, personal insecurity or the costs of damage to uninsured possessions, accidents or hygiene conditions at home and the cost of moving.

Table 1: Arguments for and against demolition based on Whole Building Stock approaches

For Demolition (Boardman et al. 2005)	Against Demolition (Lowe 2007)
Argument • 26 million properties in total; • 20,000 demolished per year; • 20,000 ÷ 26m = **0.1%** demolition rate; • 26m ÷ 20,000 = **1,300 year stock lifetime;** • Average Standard Assessment Procedure (SAP) rating can only improve from 44 (1996) to 66 (2050); • +6% energy consumption change by 2050.	**Argument** • **Heritage value:** dwellings that will be the most difficult to insulate are likely to be those with the highest heritage value so unlikely to be demolished; • **Embodied investments:** significant energy and CO_2 investment in infrastructure for demolition and new build (especially high for greenfield sites); • **Urban systems and interdependence:** existing housing, particularly the oldest housing, is compact and has co-evolved with public transport systems and other systems, which in many cases are still operational; • **Urban design:** costs associated with loss of "intimacy and human scale of most remaining pre-First World War housing" (p. 425); • **Decarbonization of energy supply:** modelling of plausible improvements to buildings and energy supply and conversion systems shows level of CO_2 emissions in 2050 insensitive to the demolition rate.
Conclusion UK requires a fourfold increase in demolition rates from 20,000 per year to 80,000 per year.	**Conclusion** "The argument that higher rates of demolition are necessary to decarbonize the UK housing sector requires one to assume an implausible lack of progress in other areas" (p.422).

2.2 Individual buildings and estates

The second approach is designed to support decisions about individual buildings or estates. This level of analysis aims to answer questions like: what are the costs and benefits to different stakeholders of refurbishment versus demolition for this building now and in the future; and which are the most valuable refurbishment measures? This approach relies on a variety of methods for evaluating environmental, economic and social costs and benefits and prioritising different interventions.

In reality, building performance depends on the behaviour of people, indoor temperatures, energy consumption and carbon emissions. Building performance is complex because it:

- is dynamic (changes over time) because occupancy and weather patterns change from day to day and season to season. Although there may be patterns in these changes, they have random (or stochastic) characteristics too which means they cannot be fully predicted;
- is adapting to feedback from control systems and interacting with the behaviour of occupants with their own cost constraints, comfort preferences, ability or willingness to 'optimise their preferences', for example, by opening windows, turning on heating or setting timers and thermostats;
- depends on multiple systems that don't always add up to the sum of their parts, for example, good ventilation might mean colder temperatures; and
- relates to the building's original design (how well it is ever able to perform) and state of repair (how much performance might deteriorate over time or be affected by break downs).

To make sense of this complexity, mathematical models are used to support decisions. These models attempt to simplify complex processes by assuming they can be understood:

- as inputs and outputs (eg heat in and heat out);
- as standards (eg typical properties of insulation or key performance indicators); or
- over fixed timeframes (eg a period over which a typical weather pattern can be assumed).

Models usually rely on a variety of assumptions and on data that are already collected.

Box 1: Questioning a technical model

Models do not offer a perfectly accurate measure of performance or a perfect prediction of the future but they can help to compare different scenarios or indicate possible trends. Models can be critiqued by double-checking:

- Diagnosis: Are the parameters (the important factors or inputs in the model) and the relationships between different systems a logical and reasonable representation of the physical or social reality? What is included and what is excluded in the model? what is given more or less importance?
- Calibration: How well do the results coming from the model match real-life measurements, bills or monitoring?
- Benchmarking: Are the results comparable with what might be expected for a similar project or peer group sample (average, best practice or an acceptable minimum)?
- Model sensitivity analysis: Which are the most critical factors and assumptions in the modelling? Does changing each input parameter have the effect on output data that one might expect?
- Results sensitivity analysis: Which parameters have the most significant impact on the results of modelling? Can this be explained by the design of the model itself? Can this be explained by the physical or social reality?

2.2.1 Energy consumption modelling

It is useful to get a score or snapshot of a building's energy consumption. This helps to compare different buildings based on the same typical year of weather data and gives a way to evaluate compliance with Building Regulations. The UK's Standard Assessment Procedure (SAP) Box 2 is based on a model that combines a building's dimensions, surface properties (capacity to store and transfer heat), air leakage rates, efficiency and controls of boilers and other equipment, solar gains, hot water consumption and typical annual weather data (BRE on behalf of DECC 2011). The advantage of standard procedure is that it is a fast, relatively simple analysis that uses standard software tools. The disadvantage is that indoor comfort levels and occupant behaviour are fixed so SAP cannot account for new types of behaviour or adjustments to preferred levels of comfort after a refurbishment, particularly in housing where people have had expensive heating systems and indoor air temperatures lower than is healthy or comfortable. In other words, a refurbishment may mean that people are suddenly able to consume more energy (as much as they would have liked to consume before) and maintain higher indoor air temperature for the same cost (CAMCO 2011; Dimitriou et al. 2014). This is also known as the 'rebound effect' and is explained in more detail in Section 4.

It is also useful to understand how a building might perform in a real year or over its operational lifetime and to compare how different designs might compare in terms of performance. For example, modellers can change the overhang of a roof in a model or the insulation of a ground floor to see the relative effect that each change might have on overall performance and relate this to costs. Dynamic thermal simulation (e.g. TAS proprietary software) uses longer series of weather data and model the interaction of control systems and use patterns. This modelling takes more time, computational power and skill and experience to develop and interpret.

Box 2: The Standard Assessment Procedure (SAP) (Department of Energy and Climate Change 2014)

"The Standard Assessment Procedure (SAP) is the methodology used by the Government to assess and compare the energy and environmental performance of dwellings.

SAP works by assessing how much energy a dwelling will consume, when delivering a defined level of comfort and service provision. The assessment is based on standardised assumptions for occupancy and behaviour. This enables a like-for-like comparison of dwelling performance. Related factors, such as fuel costs and emissions of carbon dioxide (CO2), can be determined from the assessment.

SAP quantifies a dwelling's performance in terms of: energy use per unit floor area, a fuel-cost-based energy efficiency rating (the SAP Rating) and emissions of CO2 (the Environmental Impact Rating). These indicators of performance are based on estimates of annual energy consumption for the provision of space heating, domestic hot water, lighting and ventilation. Other SAP outputs include estimate of appliance energy use, the potential for overheating in summer and the resultant cooling load."

2.2.2 Life cycle modelling

Buildings do not just consume energy and emit carbon dioxide during their operational life: process of raw material extraction, transportation, construction, demolition and disposal all consume energy (see Figure 1). Life cycle modelling tries to take account of this consumption and its associated emissions by building an inventory of all the materials used and referring to indexes (large data sets of the carbon and energy emissions associated with different materials and products based on tests or research, for example, the University of Bath's Inventory) or rules of thumb (estimates based on experience or data from similar projects) (Sweetnam and Croxford 2011). This is covered in more detail in Section 4.3.

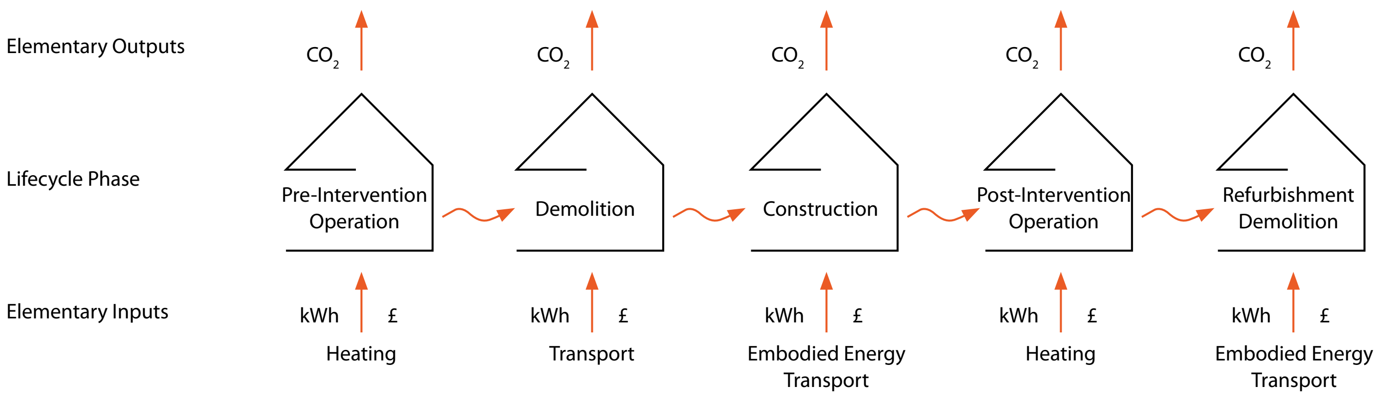


Figure 1: Lifecycle phases and flows (Sweetnam and Croxford 2011)

2.2.3 Life cycle performance indicators

The analysis and comparison of models often depends on extracting a variety of performance criteria from targets established in design standards (see Appendix B) to estimated or predicted performance for different options. These performance or comparison indicators are not necessarily included in planning proposals and are not always consistently applied in the literature. A glance at the case study summary in Table 2 shows that a variety of different indicators and units are used and cannot always be directly compared.

Table 2: Typical Key Performance Indicators are summarised below and usually involve cost, energy and emissions estimates per square metre (for easy comparison).

	Definition	Units	Reference or Case
SAP Scores or Ratings[2]	See Box 2		
Construction cost	Cost of construction works (to refurbish or rebuild)	£/m^2	(Sweetnam and Croxford 2011)
Operational cost	Annual fuel cost per square metre	£/m^2/ annum	(Sweetnam and Croxford 2011)
Embodied Energy (primary)		MJ/m2 kWh/m2	(Sweetnam and Croxford 2011) (Uzsilaityte and Vytautas 2010)
Operational energy (primary)	Annual total energy consumption per unit of the building area	MJ/m^2/ annum kWh/m^2	(Sweetnam and Croxford 2011) (Uzsilaityte and Vytautas 2010)
Embodied Carbon		kgCO_2/m^2	(Sweetnam and Croxford 2011)
Operational Carbon		kgCO_2/m^2/ annum	(Sweetnam and Croxford 2011)
Total energy consumption (embodied + operational)		kWh/m^2	(Uzsilaityte and Vytautas 2010)
Total CO_2 emissions		tCO_2	
Saved energy	% marginal primary energy savings during renovation measure lifetime.	%	(Uzsilaityte and Vytautas 2010)
Marginal improvement on baseline			(Bull et al. 2013)
Avoided emissions			
Cost per tonne of carbon saved			(Sweetnam and Croxford 2011)
Carbon cost effectiveness	Cost of carbon abatement for each measure based on the capital investment required to save 1 kg CO_2 in a given year (used where annual cost savings will be realised by the resident, not the landlord, analysis shows which will deliver the biggest carbon saving per unit of upfront capital investment)	£ CO_2/kg CO_2 saved per year	(CAMCO 2011)

The performance of a 'do nothing' scenario against refurbishment or against a 'demolition and new build' option is usually sensitive to assumptions about future prices and the building lifespan. In an analysis of refurbishment in Clapham Park, London, Sweetnam and Croxford (2011) found that modelling a shorter lifespan and fixed future fuel prices favoured smaller investments that paid back early in the lifecycle ie < 30 years (refurbishment); when they assumed that fuel prices would rise the model started to favour rebuilding over a 90 year lifecycle; and modelling based on a low discount rate (this is a low inflation scenario which makes money cheaper now than later) the model favoured low cost measures (now) that achieved modest savings (soon).

2 Retrofit research by Radian homes suggested that "rdSAP is inadequate to model true benefits of advanced retrofit" and that "kg/m2/yr or CO2 m2/yr makes a better target and gives fairer comparison than % emissions reduction targets against baseline" (CAMCO 2011)

2.3 Assessment frameworks and more complex modelling

Generally, refurbishment decisions and modelling are based on some analysis of the whole building stock and of individual buildings. Refurbishment measures for energy, carbon and operational savings typically include: insulation (cavity wall, solid wall, roof, loft and floor); high performance windows and doors; draft proofing and air tightness; high performance boilers and controls; communal heating; and energy efficient lighting and appliances (Davies and Osmani 2011).

The review of refurbishment case studies and literature suggests:

- Deciding on priority measures: refurbishment measures should be prioritised according to an energy hierarchy, ordered in terms of reduction and conservation of energy use first and only then considering renewable energy[3].
- Deciding on technologies: using proven innovation can deliver more positive carbon value or better abatement outcomes (CAMCO 2011).
- Optimising combinations: the case studies report a variety of ways to decide on levels of refurbishment (i.e. how much insulation will make the most difference to cost/carbon/energy?) or limited money (i.e. refurbishing which parts of the building stock will make the most difference to cost/carbon/energy?). These include:
    - scoring against established criteria;
    - modelling different combinations of technological measures (possibly including for stylised or reported/ monitored occupant behaviour);
    - modelling/evaluation a broader set of agreed scenarios over time (including fluctuating or rising fuel prices, costs of decanting residents, social costs of capital); and
    - more complex decision algorithms and Monte Carlo simulations[4] (Ferreira 2013).

This section demonstrates that the chosen assessment approach depends on the questions at stake and the data available.

Gaps in the case studies included:

- Lack of analysis of demolition and waste disposal (quantities, embodied energy, costs etc.). One study noted: "The construction and demolition industry produces approximately 33% of all the waste from industry in the UK each year. An astounding 19% of this waste is a consequence of over-ordering for new build" (Patalia and Rushton 2007).
- Lack of analysis of water consumption and embodied water.
- Lack of analysis of decanting or temporary housing costs.
- Lack of analysis of other non-technical factors.

3 CIBSE. Activity areas in a building, http://www.cibseenergycentre.co.uk/activty-areas-in-a-building.html

4 Monte Carlo simulations in this case use the same input-output models but generate and then use random input variables to see what happens to the outputs. For example, to look at the effect of fuel price, fuel prices over time (along with all other inputs) would be random within a specified range so that the model outputs can be analysed for worst, best and typical scenarios.

Table 3: Comparison of Different Modelling Approaches. Compiled using conceptual frameworks and analysis in (Bull et al. 2013; Ferreira 2013; Lowe 2007; Uzsilaityte and Vytautas 2010)

Scale of Interest	Individual Building (multiple criteria)	Individual Building (life cycle analysis)	Investment or Building Portfolio (priority or target groups and interventions)	Whole Building Stock (options appraisal)
Type of Question	How sustainable is my building refurbishment project?	What are the carbon emissions/energy consumption/running costs over the life cycle of my building for 2 scenarios?	Which Energy Refurbishment Measures and ERM combinations result in the greatest overall reduction to the life cycle carbon footprint (LCCF) and life cycle cost (LCC) for typical portfolio buildings?	What refurbishment measures have greatest impact on CO_2 emissions from existing dwellings? What might be the impact on CO_2 of combining these measures (insulation and strategic tech shifts in delivering heat) with partial decarbonization of electricity generation?
Method	Multi-criteria analysis based on comparing "situations that are flexible enough to incorporate different criteria based on the client's needs" (Uzsilaityte and Vytautas 2010), for example, BREAAM or other building assessment tools[5]	Model of an average unit based on: • Dimensions/properties of dwelling • Scenarios describing expected performance • Modelled performance using SAP calcs; • Estimated life-cycle costs using SAP; life cycle inventory; indexes; and rules of thumb • Economic cost of scenarios	Parametric model of typical unit based on: • Dimensions/properties of dwelling • Dynamic energy simulation • Set of parameters with assigned options[6] • Estimated life-cycle costs using simulations; life cycle inventory; indexes; and rules of thumb • Regression analysis for parameters with statistical significance on energy consumption, and size of effect	Modelling hypothetical 'stock typical'[7] based on: • UK building stock data to inform 2 Standard Dwelling Types for the UK • SAP 2005 to estimate the cumulative reduction in CO_2 emissions per dwelling (t/a) for typical solid walled (new boiler, super-glazing, re-roofing, external insulation) and cavity walled dwellings (new boiler, wall insulation, super-glazing, re-roofing)

5 For example: http://www.sustainablehomes.co.uk/shift/; http://www.insidehousing.co.uk/social-homes-a-third-more-efficient-than-uk-average/6527805.article; http://www.insidehousing.co.uk//6528487.article

6 wall; 4 roof; 4 floor; 2 glazing options; various infiltration rates

7 80 m2, semidetached house, heated with gas, with a glazing ratio of 25% (window area to total floor area); 50 m2 edge of a mid-floor flat, heated electrically, with a glazing ratio of 25%. Solid walled dwellings constitute 6.6m homes, 31% of total UK stock (Vadodaria et al. 2010)

Criteria and Weighting	Criteria defined, weighted and tested with stakeholders	Defined performance criteria or standards for emissions, energy and costs Specified design life Specified prices and Specified rate of inflation	Defined options but unspecified performance Specified design life Specified prices and Specified rate of inflation	Derived building performance and building type frequency in stock (building stock data limited[8]) Specified efficiencies of technology (eg boilers) Specified carbon intensity of energy sources (eg from the grid)
Optimisation	Maximising scores for a "finite number of alternatives, explicitly known in the beginning of the solution process"[9] against established criteria	Ranking of scenarios for minimised costs and maximised performance	Best fit correlation between variables (greatest significance, greatest effect)	Ranking of measures for maximised carbon savings on individual building Ranking of scenarios by emissions (summed across stock)
Type of Answer	Score and rating	Scenarios with scores, ratings, emissions, costs	Best fit combination of measures and associated marginal life cycle costs	Scenarios with energy consumption and emissions

2.4 Performance of building elements and systems

There appear to be limited data that allow refurbishment and demolition scenarios to be compared in terms of the costs and lifecycles of different building components. There is limited data available to allow refurbishment and demolition scenarios to be compared in terms of costs and lifecycles of different building components. Appendix A summarises indicative replacement cycles and economic life by building component. In addition, a number of papers mention the importance of structure and subsystems in in analysing building life-cycle impacts and performance.

2.4.1 Structures

Architects analysing a high rise refurbishment in the West Midlands note that longevity "can often relatively easily be enhanced by localised remedial works or more expensively over-cladding/over-roofing" and that "the decision for refurbishment should typically focus on localised problems, such as: carbonation, chloride content, de-lamination of panels or brick slips due to inadequate movement joints on blocks built with traditional frames." (Patalia and Rushton 2007). A 1992 survey of high rise refurbishment noted signs of ageing as "spalling concrete, cracked, flaking and stained facings and finishes" and also categorised construction typologies (but without further analysis of the implications of typology for refurbishment/demolition) (Trim 1992):

- **traditional method:** blocks built using either a traditional in situ concrete frame for taller buildings or load bearing brickwork (up to 10 storeys), and employing cavities.
- **direct works:** blocks were built by the authorities own direct works departments, usually employing similar methods to those of the traditional built blocks.
- **proprietary process:** blocks built by in-situ or prefabricated, 40 separate building processes identified including Reema[10], No fines, Tracoba, Simmcast, Bison, Myton etc.

8 Lowe (2007) notes: "An absence of empirical data unfortunately make it impossible to be certain that these reductions are being achieved in practice. While total CO2 emissions from dwellings are reasonably accurately known, there has been no systematic monitoring of energy use to determine the impact of successive revisions of the Building Regulations, or to determine the split between end-uses within the overall total. Some measurements of internal temperatures have been made (Summerfield et al. in press), which appear broadly consistent with SAP 2005,12 but there has been no systematic measurement of the thermal properties of dwelling envelopes in the UK stock. There is still less certainty with respect to demand for water heating and cooking." Lowe also concludes that solid-walled dwellings are not "thermally irredeemable" and that the emissions reductions achieved by demolition and new build have been over-stated.

9 Triantaphyllou, E. (2000). Multi-Criteria Decision Making: A Comparative Study. Dordrecht, The Netherlands: Kluwer Academic Publishers. p. 320. ISBN 0-7923-6607-7.

10 Reema (REED and MALLIK, a company that traded in Salisbury, Wiltshire between 1937 and 1968): system of building using prefabricated reinforced concrete panels which came into being in the late 1940s and was still in use well into the 1960s

2.4.2 Subsystems

Durability of subsystems is important in refurbishment decisions and in prioritising refurbishment measures because many of these measures "involve replacing existing subsystems and are characterized by high fixed and low marginal costs... unlikely to be economic unless applied towards the end of the life of each subsystem. Clearly refurbishment strategies that recognize this fact and take account of the maintenance cycle of each dwelling or group of dwellings will tend to be cheaper than strategies that do not" (Lowe 2007 p. 416). The Subsystems of greatest importance to life-cycle energy performance are:

- **heating:** expected to be replaced in less than 15 years, and may need replacing in less than 10 years.
- **windows:** the physical lifetime of window frames should be many decades, but sealed glazing units may begin to fail within 20 years.
- **roofs:** domestic roof coverings are normally expected to require replacement within 50 years;
- **walls:** re-pointing and re-rendering may be required every 50-100 years.

2.5 Supply chains and market transformation

The structure of the housing industry, supply chain and housing tenure all have an impact on the perceived and estimated costs, benefits, quality and risks of refurbishment projects. A number of structural or institutional aspects emerged from the case studies.

2.5.1 UK supply chain and retrofit market

There is currently low demand for retrofit products and services in the UK market, and a lack of regulatory drivers to develop new skills (CAMCO 2011). Social housing providers who decide to pursue retrofit and refurbishment options are taking on risk in this underdeveloped market. Risks relate to low levels of skills and knowledge about sustainable retrofitting in supply chains and in housing providers. Such risks could result in poor performance of retrofit installations, possibly leading to defects in buildings and poor health outcomes for residents (Swan et al. 2013). New supply chains contribute to high capital costs for energy efficiency materials compared to better established, conventional materials (Davies and Osmani 2011). Perceived inconsistencies in VAT charges by architects and property owners imply a favouritism towards demolition and new build over retrofit and refurbishment (Davies and Osmani 2011).

2.5.2 Tenure types and management capacity

Different landlords have different skills, incentives and control over upkeep. Social and institutional landlords generally have higher capacity for undertaking retrofit than individual owner-occupiers or individual private landlords (Thomsen and van der Flier 2011; Meikle and Connaughton 1994). Individual owners do not have the necessary information and ability to judge the long-term quality of the construction (Kohler 2007). In regards to retrofitting to reduce carbon emissions, there is a gap between the scale of the problem (global warming) and the decision scale (private, individual housing) (Debizet 2012). Market mechanism, incentives and standards are insufficient to shape/maintain the building stock. A combination of "public policies combined with differentiated forms of use and property rights and access to qualified information" is needed can assure a long-term capital conservation (Kohler and Yang 2007 p. 360)

2.5.3 Access to finance and willingness to invest

A lack of access to low cost finance and the budgeting of retrofit and refurbishment programmes by social housing authorities can present a barrier to implementation. The typical value of investment in energy efficiency and low carbon measures by social landlords is £5,000 - £12,000 per unit (CAMCO 2011). Social housing providers typically pay for refurbishment and retrofit through their maintenance budgets, rather than through borrowing (CAMCO 2011), or by cross-subsidising regeneration through the release of higher value land for other types of housing development. This review has not yet found systematic estimates or projections for future refurbishment costs. These will depend on the level of refurbishment achieved now and what can be achieved later, future energy supplies and prices, future environmental legislation and the mechanisms by which these future costs can be financed. In a future scenario where it becomes more common to borrow to finance refurbishment works, the land and housing assets held by social housing providers will be an important factor in securing loans – if these assets have been sold now to fund current projects, they can neither be sold again to fund projects nor used to guarantee loans to finance projects.

2.6 Key messages

It should be noted that there are a number of **limitations** to the data used in modelling:

- There is only a limited amount of data that disaggregates the environmental performance of different building components when modelling refurbishment and demolishment scenarios, including key factors such as structures (including how buildings were originally constructed) and Subsystems (such as heating, window, roofs and walls).
- Data are limited on both historic costs and future costs of refurbishment.
- A variety of different indicators are used in design standards which cannot always be directly compared when assessing planning proposals. 'Do nothing' scenarios are generally sensitive to assumptions about future prices and building lifespan.
- There is a lack of analysis of demolition and waste disposal, water consumption and embodied water, and temporary housing costs in assessments.

3 Economics

Any evaluation of the economic case for refurbishment is sensitive to the institutional factors mentioned in the previous section and will be examined against these: UK retrofit supply chain and market; tenure types and management capacity; access to finance and/or willingness to invest. This section looks at published case study data, costs and some of the perceptions and assumptions around them, and methods for comparing costs and financing.

The case studies and literature give a variety of pre- and post-project cost estimates for refurbishment and demolition projects (see Appendix A). For the purposes of appraising and managing projects, typical cost indicators are:

- **capital expenditures (CAPEX):** cost of acquiring, producing or enhancing fixed assets.
- **operational expenditures (OPEX):** the cost of supply and manufacture of goods and provision of services in the accounting period in which they are consumed. This includes depreciation of fixed assets and maintenance costs.
- **capital investment appraisal:** these are methods for understanding the value over time of an upfront investment and are often used by design teams to compare different technical options. Payback Period and Net Present Value are commonly used and guidance on their application in the building services industry is provided by the Chartered Institution of Building Services Engineers (CIBSE 2008).

As with the arguments for and against demolition given in Table 1, estimating the costs and impacts of refurbishment or demolition is complex, uncertain and subjective – especially where non-monetary costs and benefits have to be assigned a value. CIBSE notes that even for 'technical' or 'quantifiable' building systems and services: "capital appraisal is most influenced by items that have an accurate monetary value", "the advantages [of capital investments in building services] are difficult to evaluate financially, while the disadvantages are very easy to cost". These methods depend on some "tangible return" which for building operations are not positive profit or returns on investment over time but rather reductions in hypothetical future investments such as energy consumption, maintenance efforts or costs associated with shifts to cheaper fuels (CIBSE 2008).

These costs are different from financial indicators that are used to report business performance, profits and losses. This review has not yet found any refurbishment case studies that link specific projects to the business plans and financing options of owners, housing associations or developers. This review did not look at sources of finance for refurbishment schemes[11].

3.1 Case studies and cost benchmarks

Table 4 shows the data available for the 6 case studies reviewed for this study. Although cost data are also given per metre squared and per housing unit, offering the potential to develop benchmarks and cost comparisons, more data and clarity are needed on what costs include. Where these data are less developed - a feature of a less mature market - project and product costs estimated at the feasibility and design stages tend to be inflated to allow for this uncertainty.

11 However, more information on funding is available in the 2013 guide for funding for energy efficiency retrofits http://www.energyforlondon.org/tag/london-green-fund/, http://www.london.gov.uk/priorities/environment/tackling-climate-change/energy-efficiency/re-new-home-energy-efficiency

Table 4 Case study cost data

		Clapham Park Regeneration Project, London	**Sandwell Metropolitan Borough Council, West Midlands**	**Wilmcote House, Portsmouth**	**Daneville Estate, Liverpool**	**Tenement, Greenock**	**Borough Grove, Petersfield, Hampshire**
Time period (years)		30, 60, 90, 120	60	<30	30	50	50
CapEx		✔		✔	✔		✔
OpEx	**Total**						✔
	Decanting		No decant	No decant	No decant		✔
	Rental loss						✔
	Staff costs						✔
Net Present Value (NPV)		✔					
Payback Period		✔					
Utility bills		✔	✔				
Savings on utility bills				✔	✔	✔	

3.2 Maintenance and repair

Twenty years ago, housing associations were apparently "only just beginning to address the issues of longer term cost profiles and financing strategies for major repairs" (Joseph Rowntree Foundation 1995 p. 2). Since then, the management of repairs and maintenance - which also requires and results in growing knowledge about costs - has faced a number challenges (Audit Commission 2002) including: allocating resources to the most appropriate stock; delivering planned maintenance programmes and spending these budgets on time; controlling (relatively expensive) responsive repair work; involving tenants and leaseholders in decisions; managing and monitoring performance to get the best out of maintenance contracts. More recently, a number of the researchers involved in these earlier analyses have noted that Housing Associations now have long experience of managing repairs and maintenance so operating and management risks are regarded as "fairly easy to price" (Whitehead and Scanlon 2014).

Reliable cost data exist but may be regarded as commercially sensitive. Not all of these data are published or freely available to the public. CIBSE references a number of sources including published estimates and rules-of-thumb including the Building Cost Information Service[12] (data are embedded in an online calculator); Spon's mechanical and electrical services price book (£130); cost models and case studies in subscription journals (e.g. Building Services Journal); and specialist cost consultants.

12 http://calculator.bcis.co.uk/

Nationally, this means that estimating maintenance costs is more difficult than other operating costs like service charges, ground rents and utility bills (at least for the time being) because "there are no wide coverage databases of information publicly available to allow comparisons" and what historical data exist have to be "derived from similar installations or components and need to take into account various factors that will be specific to the proposed scheme. Some of these factors will be difficult to express in financial terms" (CIBSE 2008).

Monitoring, statistical modelling and management of preventive maintenance - of which refurbishment cycles form a part - is increasingly sophisticated with methods borrowed from the manufacturing sector and made possible by advances in Building Information Management (BIM) systems. These approaches use historical or real-time data on mean-time-to-repair and mean-time-between-failures for individual system components and then apply algorithms designed to automate a manager's decisions about whether to fix or replace items (CIBSE 2008)[13] or to allow maintenance personnel to respond more effectively to reports of damage or repair requests from tenants (Briller 2013).

3.3 Costs and impacts for residents

The difficulties associated with estimating the cost and value of better building systems are magnified for the costs and impacts on residents and wider society and include: quantifying "tangible" returns; sensitivity or bias to certain factors or highly subjective valuations "hidden" in technical models; valuation of future savings; and the complex interaction of individual and institutional behaviours.

3.3.1 Direct costs and benefits to residents

In general, for refurbishment, "[r]ecent studies point at the unwanted environmental, social and economic impacts of demolition and conclude that life cycle extension by improvement, renovation and renewal is a better and more sustainable solution" (Thomsen and van der Flier 2011, p. 360 citing Itard et al. 2006; Power 2010; Thomsen and van der Flier 2009b). However, benefits to residents tend to be quantified as savings or reductions in bills (plenty of data but usually based on estimating from models) or improved comfort/health associated with warmer and drier homes (an assertion based on assumptions about behaviour or health outcomes). Three main issues with the estimation of benefits to residents appear to be:

- lack of quantitative monitoring of bills, internal temperatures and occupancy patterns before and after projects to calibrate technical modelling of different refurbishment scenarios
- lack of qualitative or anthropological work on real occupant behaviour before and after projects; and
- as a relatively serious consequence of the above, and in an area of analysis where assumptions are highly sensitive to user behaviour, there are few possibilities for linking analysis of behaviour and post-occupancy performance with resident participation.

Together these issues may combine to over-estimate energy or carbon savings and under-emphasis on rebound effects. As suggested in the Portsmouth case study (Dimitriou et al. 2014): these are scenarios where energy consumption does not change after refurbishment because people opt to consume more, cheaper energy in order to be more comfortable or continue to consume and pay as little as possible for energy in order to manage strained household budgets.

Other factors that are particularly relevant for the scrutiny of refurbishment or demolition decisions are the impacts on residents of:

- **Delays in refurbishment and demolition works:** as with construction in general, there is experience of renewal processes taking longer than expected: "Time schedules are prone to delays and elongation due to external circumstances: economic cycles, changing housing markets, political change and other developments that cannot be influenced at the local level"(Wassenberg 2011, p. 377). This review found little case study evidence on the time needed for demolition and clearance or the individual and social impacts associated with these disruptions. Cost models are also likely to be sensitive to delays but this review did not find detailed analysis of this when scenarios were compared.
- **Decanting:** one of the case studies gives a detailed breakdown of the costs of moving residents out while works take place (see Table 5 below). An estimate of the same order, £10,000, but from different data is given for the costs of moving people out of poor quality housing to more suitable accommodation by the BRE (Roys et al. 2010). This review was not exhaustive but found little data in the refurbishment literature on the costs or time needed for the decanting process itself. Planners in Portsmouth rejected decanting based on the assumption that for refurbishment of an 11 storey high-rise with more than 100 dwellings, it would take 18-24 months to decant plus 12 months to demolish plus a period for new construction before residents could move back (Buckwell 2012). Radian Homes had a dedicated staff member and a liaison officer as part of the long term resident engagement process involved in refurbishment.

13 Related literature not reviewed here: (Gokce and Gokce 2013; Rankohi 2013)

- **Mixed tenure inhabitants:** this review but found only a few references to this issue in case studies. In one case this was referred to as a cost that falls to some residents of "the not-yet-paid-for mortgage for the original housing" (Wassenberg 2011, p. 376). Another case study reported that mixed ownership had caused delays as a result of different administrative procedures for distributing costs and gaining access to properties, but the delays were not regarded by the housing association as significant (Yates 2006).
- **Changes in available floor space:** the cost, value and/or impact on convenience and access of lost internal floor space or redesigned communal spaces (e.g. more accessible lifts, corridors or entrance ramps) was generally not mentioned, with the exception of the Greenock case study (Yates 2006)

3.3.2 Costs and benefits to society

Among the wider societal costs or benefits (see also Section 5.3):

- **Environmental (or project) costs of waste disposal in refurbishment and demolition:** This review found only limited analysis of the volumes, reuse and costs of dealing with demolition waste, with the exception of: a) a high-rise refurbishment case study (Patalia and Rushton 2007) and b) estimates of waste avoided in refurbishing 600 semi-detached houses in the Daneville Estate refurbishment (WRAP UK 2012). The authors of the Clapham Park study note that it was "impossible to obtain accurate information regarding the impacts and costs of the demolition phase of the rebuilding scenario, however as the results are already clearly in favour of refurbishment, additional cost, embodied energy and carbon are likely to have further confirmed this conclusion"(Sweetnam and Croxford 2011, p.13).
- **Social or market costs of carbon:** the social cost of carbon or "the price society should be willing to pay to avoid the (global costs of) damage a tonne of carbon causes over its lifetime by reducing emissions" was included for comparison with the 'cost per tonne of carbon saved' indicator used to compare scenarios for Clapham Park by combining monetary and carbon investment with 30, 60, 90 and 120 year lifetime savings (Sweetnam and Croxford 2011, p.4)
- **Longer/wider impacts of refurbishment or demolition:** a number of (early stage) frameworks for conceptualising this were covered in the review (Thomsen and van der Flier 2012; Thomsen and van der Flier 2011; Wassenberg 2011) but research into the longer, wider impacts of regeneration projects was not included.

Table 5 Costs associated with resident decant at Borough Grove (CAMCO 2011) 14 properties in total, each household decanted for 9-12 weeks

Item	Cost
Removals and storage for average 3-bed house	£2,000
Decant fit-out costs – including re-carpeting – new / relaid as necessary (new in lounge and dining room, following removal of chimney breast), also blinds, white goods etc	£3,000
Rent loss from "decant home" for 12 week decant period - £110/week for 3-bed house	£1,300
Resident costs (typically between £100-£500 per decant for services reconnection, post forwarding, etc)	£300
Inconvenience payment (under Radian decant policy)	£500
Resident Liaison Officer (approx £30k per annum averaged across 14 properties)	£2,100
Site office and presence office (averaged across 14 properties)	£800
Total	**£10,000**

Table 6 Total costs associated with refurbishment of Borough Grove (CAMCO 2011) 14 properties

Borough Grove, Petersfield, Hampshire					
Project Process and Methodology	**Phase**	**Pre-project**	**During Project**	**Post-project**	**Alternatives**
	Consultation	2004-5 Drum Housing Association consulted with residents of the estate	Resident Engagement Process (resident liaison officer)	Resident Feedback	2004-5 Drum Housing Association consulted with residents of the estate
	Modelling	SAP 2009, RDSAP and BREEAM		SAP 2009, RDSAP and BREEAM	based on previous experience of demolishing pre-cast REEMA type homes as well as construction of Code 4-5 new homes
	Monitoring	Air-tightness; Thermal imaging; internal temperatures, gas, water, electricity consumption	Construction waste	Air-tightness; Thermal imaging; internal temperatures, gas, water, electricity consumption	
	Occupant surveys			Resident Feedback	
	Training/ Dedicated Staff	build capacity among regional agencies, social housing providers, housing professionals and policy makers in the SE region,			
	Supply Chain Interventions	map regional activity on low carbon refurbishment exemplars and create a network for disseminating results including the establishment of a network of "Refurbishment Pioneers" in social housing, develop a conceptual finance model suitable for mainstreaming low carbon refurbishment within the region, provide targeted business assistance to SMEs and other key organisations.			
Size	**Form**	Semi-detached, concrete panel (Reema) construction, E-rated			
	Average unit size	85m² (est)			
	Bedrooms	3			
	Communal space per unit				
	No. of dwellings	14			
	Storeys	2			
	Floor Height				
	Total Floor Area	1,190 m²			

Time	**Date of Construction**	1950s			
	Original Design Life	30 year (outperformed this life-expectancy)			
	Construction time				
	Decant Period		9-12 weeks	9-12 weeks	
	Expected/Assessed Design Life		50 year period	50 year period	
Costs	**Total Cost of Works**				
	Cost/m²				
	Consultancy Fees				
	Cost per unit		£91,900 (£1,089/m²)	£91,900 (£1,089/m²)	£144,700 (£1,714/m²)
	Decanting cost		£10,060 per unit (£119/m²)	£10,060 per unit (£119/m²)	£10,030 per unit (£119/m²)
	Rent (loss or decant-related)	£110/week for 3-bed house			
	Sustainability features cost		£79,700 (£944/m²) incl VAT and site management	£79,700 (£944/m²) incl VAT and site management	£131,600 (£1,560/ m²)
	Internal staff time		2140 (£25/m²)	2140 (£25/m²)	£3,070 per property (£36/m²)
	Bills for residents	Bills £1000-1500/ year			
Resources	**Op Total Emissions t CO_2/yr**	7.2	2.1	2.6	
	Op Energy kWh/ m²/year				
	Op Water l/p/d	113	92	92	
	SAP Rating	(E) 47	(B) 90	(B) 85	
	Embodied Carbon				
	Embodied Energy				
	Embodied Water				
	Waste Haulage				
	Demolition, Excavation and Disposal				
	Concrete				
	Masonry				
	Rebar				

Box 3: Effect of rising fuel prices on Clapham Park simulation

Capital investment appraisal means weighing up the benefits on making an investment now, given benefits in the future. Two methods were used to model the effect of rising fuel prices on a comparison between refurbishment and demolition scenarios at Clapham Park (Sweetnam and Croxford 2011).

These methods are:

- Simple Payback Period: this gives the number of years it would take to pay for an investment using the savings generated each year, in this case savings on gas bills. To work out the payback period you divide the overall project cost (CAPEX) by the annual saving in the first year. A high payback period means the investment is large compared to the annual savings so the project with the lowest payback period is ranked best. Payback period is not based on realistic prices because the method assumes that fuel prices and prices in general don't change over time (inflation is zero) and it gives less weight to projects that might start paying back more in the long-term, either after other projects have paid back or at a time in the future when there is a dramatic rise in fuel prices but the investment has already paid for itself.

- Net Present Value: this gives an estimate of the value of investing in a project now. To work out the net present value, the year on year savings are added together and subtracted from the original capital investment. This is different from the payback period because prices in the future change in line with inflation. This reduces the bias towards projects that save money early in their lifetime. A low NPV is better than a high NPV because this means it is the cheapest current option for saving money in the future.

Sweetnam and Croxford compared 4 scenarios (although costs of demolition were excluded!): refurbishment versus rebuilding and with fuel prices steady or rising.

Assumptions in the Clapham Park model

		What does this assumption mean?
Gas Price Volatility	8%	This is the annual percentage rise in the price of gas: 8% is added to the price in the first year giving a new, higher price. At the end of the second year 8% is added to this higher price and so on (based on compound interest)
Discount Factor	2%	Discount rate is a way of accounting for inflation. Inflation is the % rise in general prices each year. When inflation is high, the money you have this year is worth less next year: you can't by as much stuff with it because stuff costs more.
Current Gas Cost (£/kWh)	0.03	This is the price of a unit of gas. The unit, kilowatt hours, is a unit of energy, like a calorie, and is the amount of energy in a certain amount of gas.

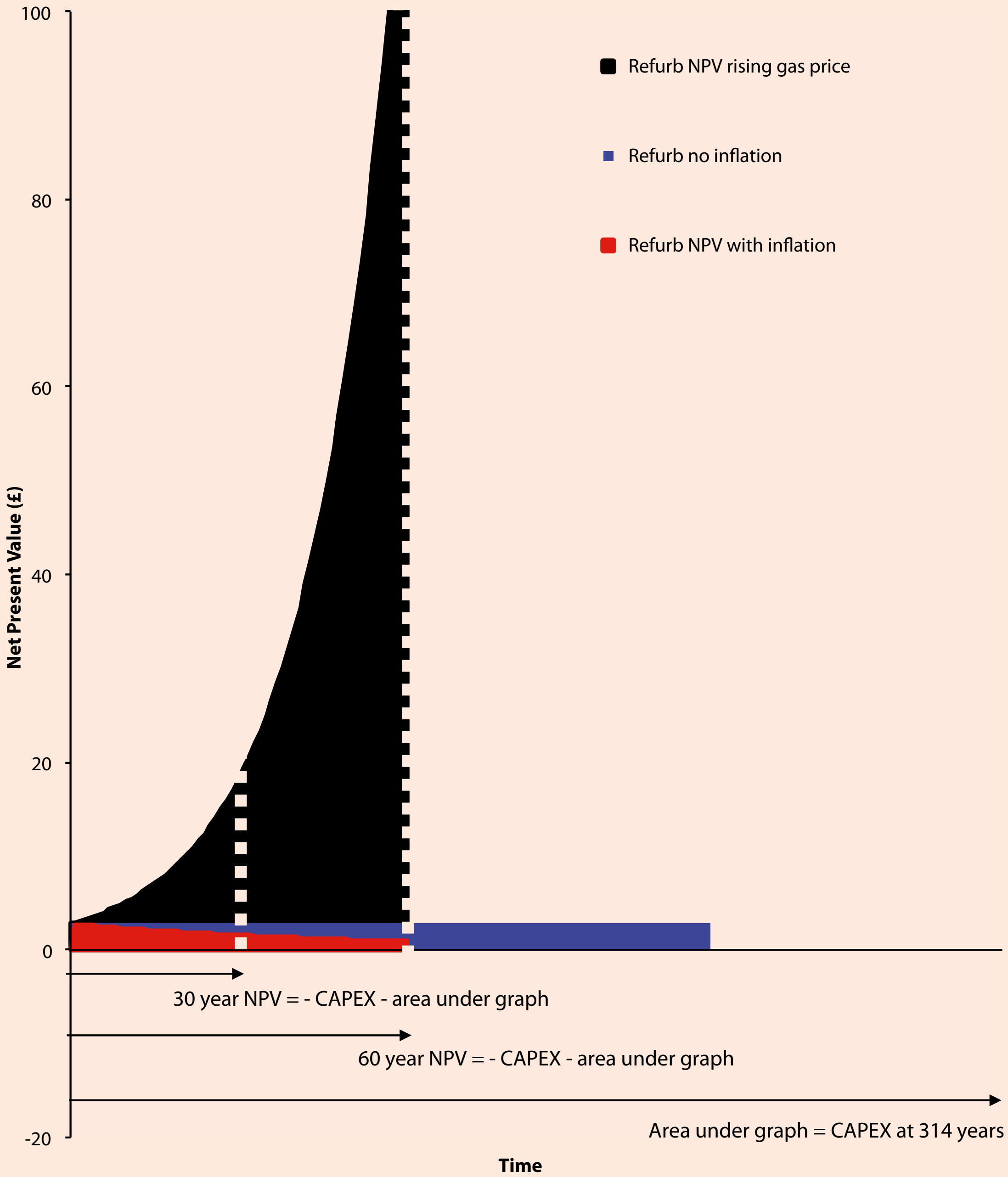
Results of the Clapham Park model

Best NPV	(dark green)
Second Best NPV	(light green)
Worst NPV	(dark red)
Second Worst NPV	(pink)

	Refurbishment		**Rebuilding**	
	Steady Prices	**Rising Prices**	**Steady Prices**	**Rising Prices**
Investment (£ 2010/m2)	847.4	847.4	1678	1678
Annual energy saving from consuming less gas (kWh/m2)	81.49	81.49	111.49	111.49
Annual saving on gas bills in 2010 prices (£/m2) Year 0	2.702208	2.702208	3.697008	3.697008
Simple Payback Period (years) **(no inflation)**	**314**		**454**	
30 Year NPV (£2010)	-787	-593	**-1592**	-1331
60 Year NPV (£2010)	-753	**1095**	**-1546**	**979**

The graph below illustrates the different ways that payback periods and net present values account for savings over time. The total future savings are represented by the areas under the graphs but in slightly different ways:

- payback period is the (blue) area under the graph showing constant annual savings each year
- NPV is the total upfront capital investment minus the area under the graph so the larger the area to deduct from the capital cost, the lower (and better) the NPV because the option is the cheapest thing to do now. In this case the largest area under the graph is for the refurbishment scenario with high price rises because investing in energy efficiency will save so much money in a future scenario where energy is more expensive.



Note: the economic models applied in conjunction with 'technical' models are generally very simplistic and used for comparative purposes. They are limited in the extent to which they are informed by and might inform a business or investment case. In particular, property and land values are not considered and alternative accommodation and relocation options are not considered.

3.4 Financing Investment

3.4.1 UK retrofit supply chain and market

Reflecting the undeveloped supply chain and market, a variety of technical, economic and social risks and "hidden costs" associated with refurbishment and retrofit remain and these appear to deter investment:

- **Prices:** the market is characterised by low fuel prices (for now) and so there is only low interest in savings from cutting fuel costs. The market is also characterised by low competition which pushes up product and supplier prices (CAMCO 2011);
- **Risks seen by designers:** a survey of UK architects identified and ranked perceived challenges to low carbon housing refurbishment: financial and business, design and technical, legislative, environmental and cultural (Davies and Osmani 2011);
- **Risks seen by owners, investors and developers:** Radian housing reported from stakeholder workshops[14] that "the amount of investment most social landlords would typically be prepared to make in energy efficiency and low carbon measures - is approximately £5,000 - £12,000" and identified: Technical risks (equipment quality lifetime; maintenance cost; warranties; efficiency; innovation; controls; perceived dampness; service levels); Economic risks (interest in Pay As You Save / Green Deal, small investments – high transaction cost, SMEs dominate the market, different loan products for different technologies); Social risks (realise the savings, sabotage projects, loss of space, appliance loads, appearance of property)

These suggest a need (alongside financing mechanisms) for a change in perceptions, awareness and behaviour throughout the supply chain. Concrete suggestions for individual projects focused on a "framework for quality workmanship" and targeting users with "behaviour change training... at the point of occupancy" (CAMCO 2011).

3.4.2 Tenure types and management capacity

Ownership and management are relevant to the measurement and perception of costs and risks because they affect how these are shared between investors and occupants in ways that can simultaneously:

- allow refurbishment to be financed (covering the cost of borrowing money),
- allow savings to be realised by tenants (especially those struggling with high energy bills) and
- encourage energy saving behaviour (especially if the cost of heating dwellings falls).

Inter-related factors of interest to refurbishment projects are:

- Recovering investments through rent: Radian homes cite "a lack of flexibility for social landlords to reflect the energy efficiency investment costs in rental increases" as well as potential unwillingness of tenants to pay, Radian's stakeholder workshop suggested that at least 50% of energy savings should be passed on to tenants (CAMCO 2011). This figure is not (yet) based on occupant surveys or modelling.
- Long payback periods for energy efficiency measures but short terms of tenure/high churn rates for tenants. This means that the community engaged in decisions over refurbishment may not see the benefits if they move elsewhere in the short term.
- Borrowing: as well as a reported unwillingness of developers to use mortgage-type financing for refurbishment and a lack of clarity about how the cost of financing would be shared with tenants, there is a lack of data (see the gaps in data on direct savings of refurbishment schemes) and confidence about whether the estimated future savings can be realised, which, if future savings are the basis for repaying loans (eg Green Deal), make borrowing difficult and risky.

3.4.3 Access to finance and/or willingness to invest: grants, subsidies and loans

Risky current costs and uncertain future savings limit financing because these are the conditions under which banks typically do not want to lend and developers are hesitant to borrow. Alternative sources of investment are grants, subsidies and loans that can be backed up or guaranteed in ways that help developers to make future payments, even if refurbishment schemes fail to yield expected savings; other costs or problems arise; or tenants are unable to pay.

14 "stakeholders including NHF, HCA, DECC, EST, PUSH, SEEDA, pioneering housing associations, local authorities, construction companies, energy suppliers, representatives of other private sector organisations and banks"

Box 4: Financing mechanisms proposed by Radian Homes

As part of the Borough Grove refurbishment, Radian Homes looked at different financing options and concluded that loan guarantees were "the most cost efficient form of subsidy" and could raise at least £20 from capital markets for a £1 subsidy. This is known as a leverage ratio of 1:20 (1 in for 20 out). Loan guarantees for these types of investment are not common in the UK but there is EU experience.

Another promising proposal was to set up a revolving loan fund. This operates like a large pool of money created by multiple, large investors (like pension funds) who expect long-term, low risk but moderate returns. From this large pool, small loans are made to many borrowers. The borrowers are quickly able to start (within 2-3 years, which is the time it might take for a refurbishment project to be completed, and quicker than, say, large infrastructure projects which typically attract similar types of large investors) and continuously (over quarterly intervals) contributing to the pool with their repayments and the pool slowly grows. The risk of investing in this sort of fund are lower than one off loans to refurbishment projects because the following flows in and out of the pool are carefully balanced to make sure it is never empty (in reality the pool is just a series of constant flows in and out rather than a static pool of tangible money):

- frequency (regularly and predictably),
- amount of each borrower's repayment (small size but high number),
- time between lending and when repayment can start (short)
- conditions that stop investors dipping in too soon to take out large chunks of investment

There is still a risk (probably accepted by investors) that an individual borrower might fail to repay but it would not affect the fund as a whole. This also means that these funds can afford to build in a period of "grace without reproach (typically up to 1 year)" which gives borrowers some flexibility. The risk that many borrowers fail to pay back would be low but if it happened the pool would be depleted so investors would arrange for this risk to be covered by a guarantee that works like insurance but is paid for by a government subsidy (eg 5% of the fund).

Radian suggest that this sort of mechanism is advantageous because for every £1 of subsidy, £150 of investment can be achieved over the long term, "(for a social housing provider) borrowing is made against the guarantee fund instead of property assets", it has worked well in the EU, can be based on a "pay as you save" approach against overall annual energy savings which means paying more in years where energy savings have been higher (e.g. very cold winter with high energy consumption making the savings from energy efficient systems higher in absolute terms).

3.5 Lifetimes: policy, modelling and finance time frames

Decision-making is sensitive to the assumptions and projections made about the life of a building. Expected lifetimes and time scales of interest are treated differently by different stakeholders involved in decisions (Figure 2):

- Economic analysis: stock, asset and portfolio analysis (e.g. building "survival rates" of the order 1,300 years);
- Research and case studies: longer range modelling (30-120 years)
- Energy policy: 5, 15 and 35 year timeframes to 2020, 2030 and 2050;
- Design: a specified design life (in order to raise and guarantee investment) and potentially cost-benefit analysis or NPV for evaluating design options (25-50 years)
- Investment, insurance and liability periods: 25 year mortgages, 6 year contract liabilities, 2-15 year product warranties.

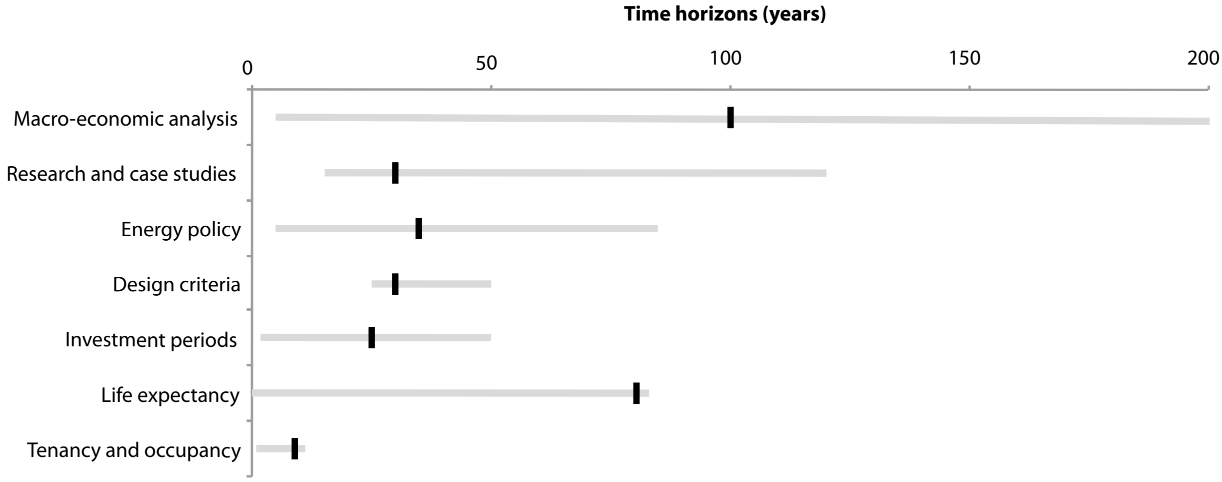


Figure 2: Time horizons of housing decisions and analysis.

The timeframes used by different decision-makers affect the critical thresholds at which one option wins out over another on economic, environmental or social grounds. These notional thresholds are illustrated in the following graphs for a number of the scenarios covered in this document. The graphs (Figure 3) on the following pages illustrate that:

- **Markets and prices:** whether refurbishment has lower cumulative emissions compared to new build in the long run depends on whether the practicable performance standards for refurbishment are the same or better than the standards set new construction. It is worth noting that the economic reasons for redevelopment (rising land and building values) have historically been largely independent of energy performance because location plays such an important role in determining these values and energy performance can be difficult for prospective building owners and occupiers to assess. Whether energy performance becomes more important in rent setting depends on how much choice occupants have about their housing and whether energy performance is really a driver in those choices[15] (see Figure 3: scenarios I to V)
- **Decarbonisation:** investment in decarbonisation of the grid might make a bigger difference in emissions per pound spent than improving the energy performance of buildings through refurbishment or new construction (see Figure 3: scenario VI)
- **Behaviour and performance:** justifications (targeted at building users) for either refurbishment or demolition that rely on over-optimistic assumptions about improved energy performance and lower bills, disadvantage tenants because a) land and building values rise independently and faster than energy prices so developers gain whether or not energy performance is improved and or bills fall; b) the time frames over which tenants see a benefit is longer than typical tenancies (see Figure 3: scenario VII).
- **Maintenance and repair:** reducing the embodied energy and carbon involved in construction, maintenance and repairs and making sure that major refurbishments perform better each time, mean that the cumulative emissions from refurbishment fall below those of new construction sooner (see Figure 3: scenario VIII)

3.6 Key messages

In the UK there is a gap in the capacity, willingness and confidence of decision makers to a) make transparent and be able to interrogate the assumptions in decisions about refurbishment and demolition and b) to invest in refurbishment (or other innovative options). This applies to policy-makers, built environment and planning professionals, as well as tenants, housing associations, developers and lenders. Part of this involves collecting cost data and analysing the impacts on different people and places over time of "doing nothing", refurbishment and demolition scenarios. This necessarily means research into the behavioural and technical realities of living through refurbishments and feeding what is learnt into ongoing relationships with tenants and into the design of other projects.

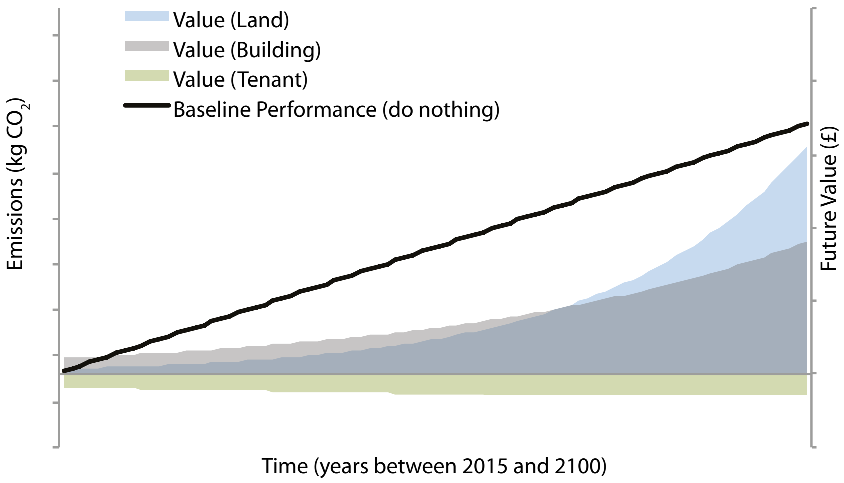
Figure 3 illustrates some of the relationships between time horizons of decision-makers and the thresholds at which one option wins out over another. This is based on notional scenario modelling in the absence of data, models and tools to support transparent decision-making. Table 7 summarises the different time periods over which decisions about housing and related policy are made.

15 For example, registered social landlords, housing associations and local authorities might expect higher rents where an investment in improvements has delivered better energy performance or hope to use higher rents to pay for future improvements. Whether this is realisable or reasonable in practice depends on who is paying rent; how rent is paid; what difference a change in rent or energy bills makes to household budgets compared to other factors (for example, changing location might affect associated transport and food costs, people choosing better indoor comfort means no cash savings or using the savings for other necessities means no spare cash to pay more rent); and who is able to opt out of the improvements or move to alternative accommodation. Meanwhile, buyers and private renters can in theory use energy performance certificates alongside other criteria, like location, when choosing housing but poorly performing buildings in good locations will still command high rents and the difference in rent between poorly performing and well performing housing in the same area may come down to other factors like the 'period features' in a poorly performing building.

I Base Case
"do nothing"

Assuming:

- no energy price inflation,
- low inflation on building value (rent)
- higher inflation on land values



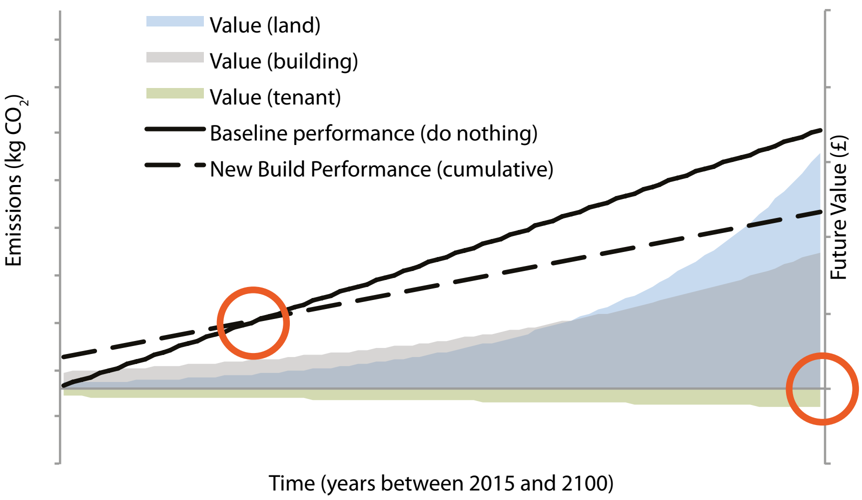
Cumulative carbon emissions and tenants bills increase over time.

Land and building inflation occurs over periods shorter than the life expectancy of buildings (and people). This is within the design life but much longer than average tenancies.

II Demolish and rebuild to current building standards

Assuming:

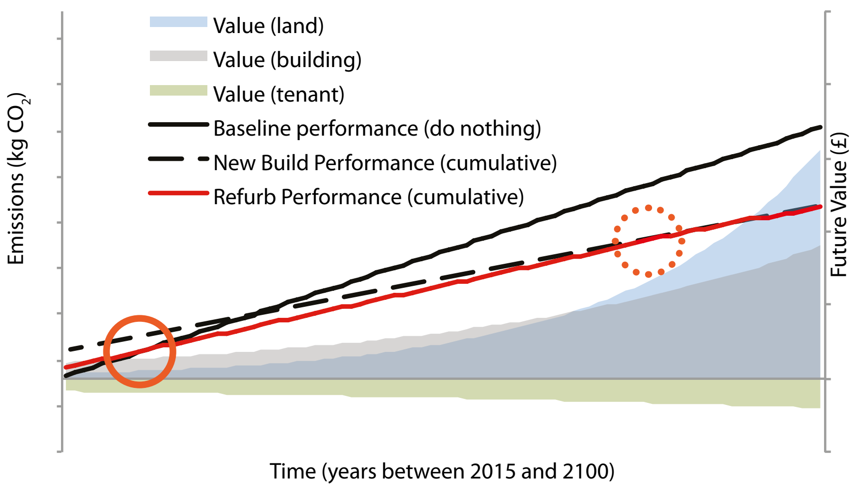
- as above
- relationship between new build and refurb performance is as per Clapham Park case study



The new building consumes embodied energy in construction but generates lower operational emissions over time. Tenants energy bills are lower than "do nothing". In time, the cumulative emissions from new build are lower than the "do nothing" scenario.

The better the energy performance of the new build, the sooner this happens. This may happen well within the life expectancy of existing stock and design life of newer buildings.

III Refurbishment



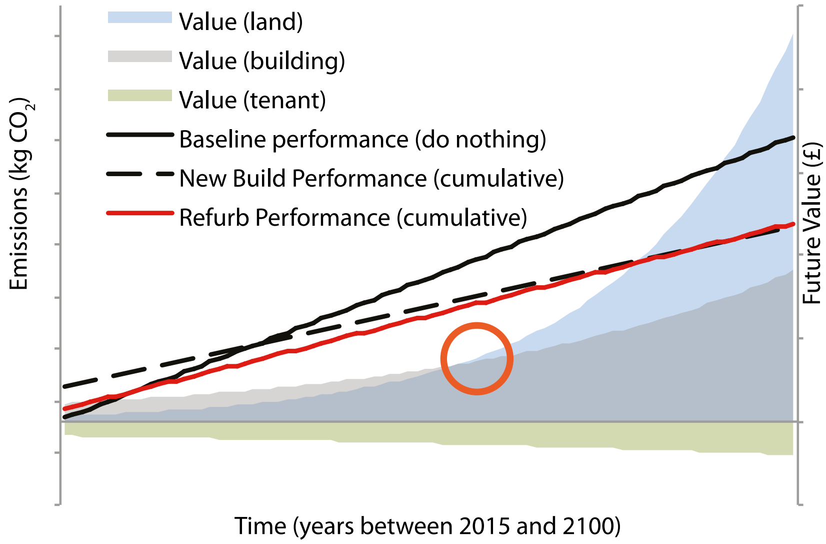
Refurbishment consumes embodied energy (but less than a new building) and tenants bills are lower than "do nothing". In time, the cumulative emissions from refurbishment are lower than "do nothing". **This happens faster than for the new build providing a refurbishment can perform as well as a new build. In the longer run, new builds may have lower cumulative emissions than refurbs, if new buildings have better energy performance. Reducing the embodied energy of new builds also means new builds overtake refurbs sooner.**

Figure 3: Impact of time horizons on decisions and analysis of housing options.

IV Land price inflation (relative to rent/ building cost inflation)

Assuming:

- no energy price inflation,
- low inflation on building value (rent)
- higher inflation on land values

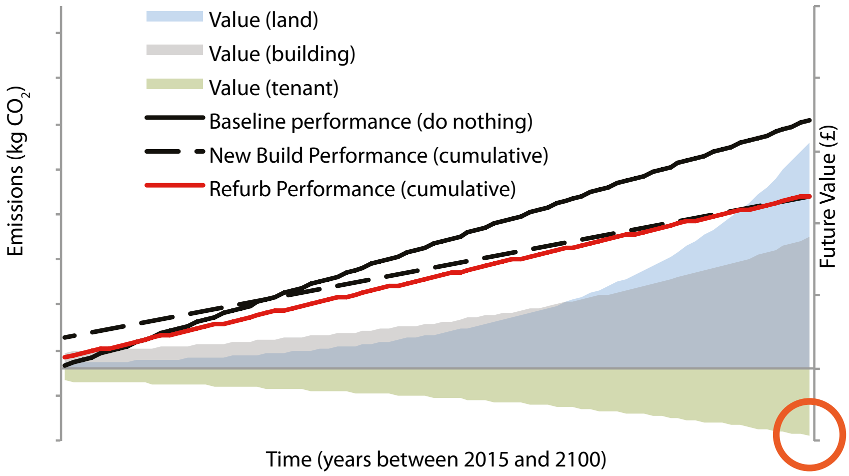


The decision to redevelop may be made sooner when land value inflation is higher than building inflation. **Neither of these factors is directly linked to the energy performance of buildings but it may be correlated if: a) poor energy performance reduces the ability of tenants to pay rent from their household budget b) poorly performing buildings command lower rents than other buildings in the same area.**

V Fuel price inflation

Assuming:

- moderate energy price inflation,
- low inflation on building value (rent)
- higher inflation on land values



Tenants in the "do nothing" scenario will face much higher future energy bills.

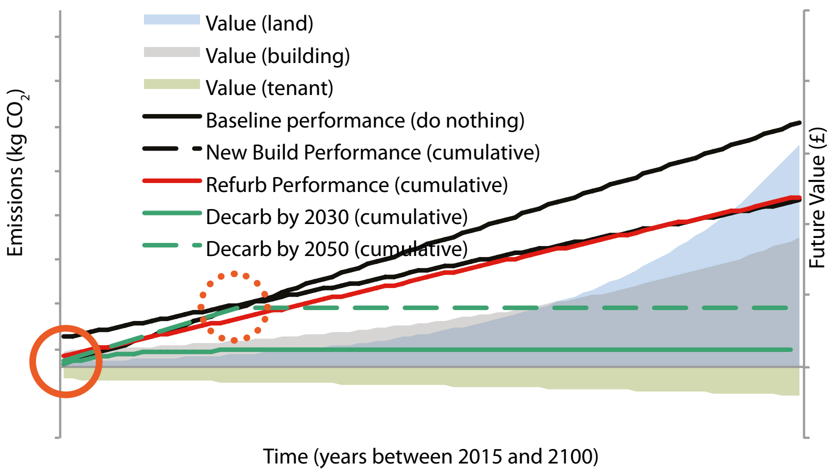
When average tenancy periods are short, the future cost of bills may not be paid by or valued by current occupants.

Higher inflation on energy prices means that people start paying higher bills sooner.

VI Decarbonisation by 2030 or 2050

Assuming:

- no energy price inflation,
- low inflation on building value (rent)
- higher inflation on land values

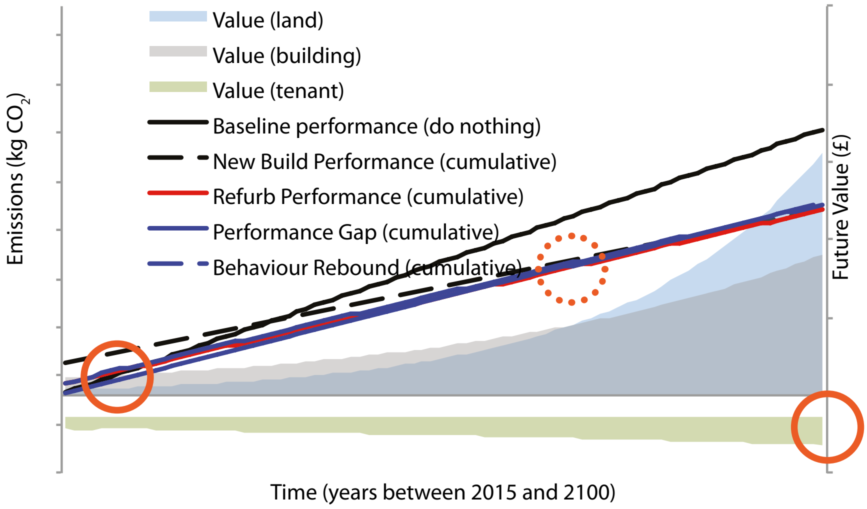


If the UK successfully decarbonises the national grid (relies on low or renewable sources of energy) and housing uses only electricity for heating and hot water, the emissions from un-refurbished buildings could be lower than new buildings that use energy from the current supply mix.

The bills paid by tenants do not take account of higher energy costs from the process of installing new energy generators.

Figure 3: Impact of time horizons on decisions and analysis of housing options.

VII Behaviour and Performance

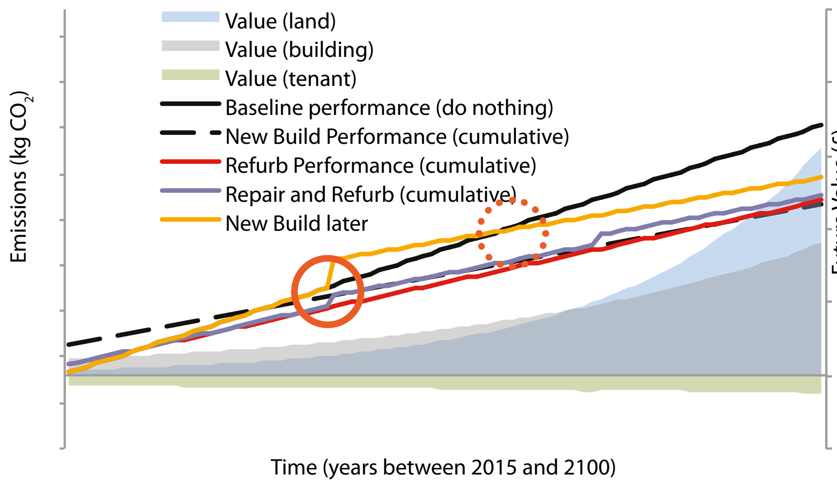


If the assumptions about energy performance are optimistic (there is no rebound effect and components and fabric perform as well as predicted), then a) the savings to tenants in the long run will have been over estimated (but land and building values unaffected); b)the moment at which new build or refurb perform better than doing nothing is later and the moment when refurb performs better.

VIII Repair and refurbishment vs building new build later

Assuming:

- new buildings and refurbs in 20 years time can perform 10% better
- repair uses 10% of embodied carbon of a refurb



Regular refurbishments would need to make a significant improvement to energy performance to reduce operational and embodied emissions over the long term. Lower embodied energy refurbs that improve energy performance result in lower life time carbon emissions.

If the decision to demolish and rebuild is deferred (eg for 20 years), the new building would still have to perform significantly better than a refurbished building to generate lower operational and embodied carbon emissions.

Figure 3: Impact of time horizons on decisions and analysis of housing options.

Table 7: Range of time periods (in years) over which decisions are made

Economic analysis: stock, asset and portfolio analysis	50	1300	Based on English Housing Survey: 50%+ of homes over 50 years old, 22% over 100 years old; building "survival rates" of the order 1,300, http://www.cotac.org.uk/conf_2012_pres/snicol/snicol2.pdf
Research and case studies: longer range modelling (15-120 years)	15	120	Range from 6 case studies analysed for this report, http://www.legislation.gov.uk/ukpga/1980/58
Energy policy: 5, 15 and 35 year timeframes to 2020, 2030 and 2050;	5	85	Based on 2020, 2030, 2050 and 2100 appraisal models, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48184/3136-guide-carbon-valuation-methodology.pdf
Design: a specified design life from the client's brief	25	50	Housing 25-30 years compared to British Library and Portcullis House 250 years. These periods are specified in order to raise and guarantee investment. They are also used for cost-benefit analysis or NPV for evaluating design options (25-50 years)
Investment, insurance and liability periods: 25 year mortgages, 6 year contract liabilities, 2-15 year product warranties;	2	50	Based on limitation act and white good warranties
Life expectancies: average for 2013	78	83	ONS data http://www.ons.gov.uk/ons/rel/lifetables/national-life-tables/2010---2012/sty-facts-about-le.html
People: median length of time in current residence (UK)	1	11	Social Trends 41 - Housing - Office for National Statistics, average (median) length of time that households in England had lived in their home was 8 years. Owner-occupiers had been in their current home on average the longest at 11 years, followed by social-renters at 7 years

4 Energy and carbon

The energy use and greenhouse gas (GHG) emissions associated with buildings are key concerns driving the assessment of whether to refurbish housing or to demolish and rebuild it. Chapter 2 has discussed how assessment decisions are made. This section of the report reviews evidence generated from research into the energy used and carbon dioxide (CO_2) emitted through the construction, refurbishment and demolition of buildings (embodied energy) as well as the energy used and CO_2 emitted through the use of the building (operational energy). It highlights some of the related issues associated with reducing energy and carbon emissions through interventions in housing, including potential benefits of 'a green economy' enabled through a retrofit industry as well as unwanted consequences such as inadequately ventilated buildings.

Key issues for the Retrofit vs demolition debate are:

- Can old homes be refurbished to the same energy performance standards as new homes? (Demand equivalence)
- How much does the embodied carbon of construction materials and processes add to the overall emissions of new and refurbished homes? (Lifecycle equivalence)
- Does new construction offer more opportunities for low carbon generation or supply switching? (Supply equivalence)
- Which socio-economic groups and housing types will be targeted through refurbishment programmes and demolition programmes? (Distributional equivalence)

4.1 Operational vs. embodied energy

The energy consumption associated with buildings can be analysed in two ways; operational and embodied. A building's operational energy is incurred through the use of the building. It refers to the energy used in heating, ventilating, lighting and appliances to maintain comfortable conditions in the building. The **operational energy** of a building depends on the condition of the building, the systems installed in it and the occupants' use of the building (Ibn-Mohammed 2013).

The **embodied energy** of a building refers to the energy used to extract, manufacture, transport, and assemble the materials for its construction. It sometimes also includes energy to deconstruct buildings and dispose of the materials (see Figure 4). There are also other environmental impacts of material use, including impacts on human health (see Section 6), and lifespan and maintenance requirements (see Section 2) which are aspects included in a building's Life Cycle Assessment (LCA).

Lifecycle assessment of UK houses shows that the global warming potential of energy and emissions during the lifetime of the building (operational) is significantly greater than the impact of construction of the building and demolition at the end of its life (embodied energy) (Cuella-Franca and Azapagic 2012). This means much research and policy is focused on understanding and reducing operational energy, however the embodied energy of construction materials and processes becomes more important if we increase low carbon sources of energy to provide the operational energy required.

Box 5: Energy, carbon, carbon dioxide and greenhouse gases

Energy	In physics, energy is defined as the capacity to perform work. It takes various forms, such as electrical, thermal, kinetic or nuclear. Inside homes we use two types: electrical energy for lighting and appliances and thermal energy to keep rooms warm and supply hot water. Electrical energy is typically generated at remote power plants and delivered to the home through the electricity grid. However generating electricity on residential sites is becoming more common through technologies that use renewable sources, like as roof mounted solar PV cells or wind turbines. Thermal energy is more typically produced in homes and most of us use boilers to produce central heating and hot water. Boilers burn fuel (usually gas from the national grid) to produce the thermal energy we use.
Carbon (C)	Carbon is an organic chemical element which becomes carbon dioxide (CO_2) when combined with oxygen. It is the carbon content in fossil fuels that burns to produce energy. Carbon is neither the same as carbon dioxide nor a greenhouse gas, but is often used as a shortened form of the term of 'carbon dioxide emissions'. The term 'Carbon' is used today as a scale to make comparisons across different types of energy sources and energy uses. We talk about the 'carbon intensity' of different fuels which means how much CO_2 is produced from different sources to perform the same work. Or we impose 'Carbon limits' to cap the amount of CO_2 and GHG produced within a defined area or activity.
Carbon dioxide (CO_2)	Carbon dioxide is a gas which is produced through plant and animal respiration, decaying materials and through burning organic matter such as fossil fuels. Burning fossil fuels such as coal, oil or gas to create energy to support human activities and energy demand, produces excessive amounts of CO_2 that cannot be absorbed through natural processes such as plant respiration. CO_2 remains in the atmosphere and is one of the main gasses contributing to global warming.
Greenhouse gases (GHG)	Greenhouse gases are present in the atmosphere that absorb radiation and reflect it back to the Earth as heat. This process raises the earth's temperature and induces climate change. Most common GHG are **carbon dioxide**, **methane (CH_4)** and **nitrous oxide (N_2O)** and **fluorinated gases.**

4.2 Carbon vs. energy

The two terms, 'energy' and 'carbon' are not interchangeable. The carbon dioxide (CO_2) and other pollution emitted in the air, depends on which fuel is used to provide energy. If the fuel is from a renewable source (a 'clean' fuel) than the carbon emissions are zero or close to zero. A building's 'operational carbon' can be high or low depending on whether the operational energy (used during the use of the building) is from a high or low carbon source. Likewise, if the fuel used to produce and transport building materials is from 'clean' fuel, its 'embodied carbon' (used during the construction, refurbishment and demolition of buildings) is lower than if a fossil fuel is burned or more carbon intense materials are used.

To date, a great deal of effort has been made to reduce the operational energy of buildings and the carbon emissions associated with this. For example, the UK government announced in 2006 that all new residential buildings will be net zero carbon buildings by 2016, that is, carbon emission from operational energy of buildings should be zero. This means that the operational carbon emissions need to be offset with renewable energy production on site and by other measures. It is easier (and cheaper) to offset a building's entire operational carbon when it is a low energy building and uses little energy to begin with.

Material choices are usually defined and considered at the early stages of a construction project. By planning carefully for a building's future maintenance and eventual end of life demolition, embodied carbon can be reduced. However at present, unlike operational carbon, there is no embodied carbon regulation or policy. Yet when considering the environmental impact of a building, as we reduce operational carbon, embodied carbon's impact will proportionally increase.

4.3 Embodied carbon and energy

Embodied energy has been a low-profile issue when it comes to the energy efficiency of buildings, compared to operational energy.

A number of recent review papers of the literature on embodied energy found:

- **Difficulties making comparisons between reported estimates:**
  - "The majority of the studies cited are not comparative, lack the level of detail required to make any comparisons and have inconsistent boundaries" (Monahan and Powell 2011)
  - This is because of inconsistency in methods of analysis, geographic location, age of data and its completeness and the time period over which energy consumption was modelled (Dixit et al. 2012)
- **Embodied Energy as a % of lifetime energy use:**
  - Sartori and Hestnes attributed the wide variation in the percentages reported for embodied energy as a proportion of total lifetime energy to different energy supply and industrials systems and climates concluding that "The differences [between 60 studies in 9 countries] are, indeed, simply too great to allow any further general conclusion" (Sartori and Hestnes 2007)
  - the percentages that are routinely cited for embodied and operational energy as a proportion of lifetime energy should not be applied generally and their reference and source material have to be carefully checked
- **Embodied energy estimates in the UK construction sector:**
  - There appears to be consistency in the estimates reported in research for the embodied energy of different materials and processes in the UK (Monahan and Powell 2011)
  - High rise buildings may have higher embodied energy than other types of building (Sustainable Homes 2014; Atkins Carbon Critical Masterplanning Tool reproduced with permission from Atkins in RICS 2012, p. 9)

Table 8 shows a comparison of several studies on embodied energy to show that embodied energy as a proportion of lifetime energy should be reported with care.

Table 8: Embodied energy as a proportion of lifetime energy

Source	Assumptions	Model Results
Cuella-Franca and Azapagic 2102	• Common existing UK housing: detached, semi-detached and terraced • Cradle to grave • Based on 2008/9 energy mix and energy end uses • Modelled over 50 years but assuming no change in energy mix, energy efficiency	Global Warming Potential from these houses proportionally: • 90% in use, • 9% embodied and • 1% end of life
Monahan and Powell 2011	• 3 bedroom semi-detached house • Cradle to site • Compared embodied energy between traditional (masonry cavity wall) and modern methods of construction (timber frame with larch cladding or brick veneer) • Modelled only embodied and primary energy consumed before operation and occupation so no modelling of operational energy	Detailed estimates of embodied energy for different materials that were consistent with previous estimates from the UK.
Sustainable Homes 2014	• No models, boundaries or time periods specified • Refers to BRE research from 1991 for typical 3-bed detached houses stating that energy in use would overtake embodied energy	Extrapolates from (out of date study on one type of UK housing) to claim that over 60 years, embodied energy accounts for only about 10% of the lifetime energy use of the building
Plank 2008 cited in Dixit et al. 2012	"Plank (2008) concluded that in the United Kingdom, a heating dominated region, the embodied energy accounts for only 10 percent of the total life cycle energy."	No details given in citation and original paper is pay-per-view. Unclear what type or age of housing, what year the data applies to, the projected lifetime of the building under discussion.

With improvement in energy efficiency potentially contributing to reductions in operational energy use (new buildings may be more energy efficient than older buildings but this does not automatically mean that their occupants will use less energy than those in older buildings) and a shift to renewable sources of energy and electrification of the grid, the percentage of embodied carbon and energy as a proportion of the total life time energy use is increasing. It is particularly significant for design and construction of sustainable homes (Thormark 2002 cited in Monahan and Powell 2011).

In addition, absence of regulations and policy to oversee embodied carbon and energy means that this is a challenging area for the UK's successful transition to a green economy. Indeed, in 2010 the UK Government Low Carbon Construction Innovation and Growth Team recommended to develop a methodology to measure impacts of embodied carbon and energy at design phase of building construction. During 2011 and 2012, a voluntary standard to measure environmental impacts of buildings, the European Standards TC350, which includes British Standards EN 15978:2011 for the assessment of the sustainability construction works, was published (Moncaster and Symons 2013).

There exist various ways to calculate embodied energy of buildings. Amongst the various methodologies, adopting a Life Cycle Assessment model is a recent trend. However, Dixit et al. (2012) point out inconsistency and incompleteness of data used in the LCA based analysis and summarize the reasons why it is difficult to obtain data thoroughly for the LCA in following ways:

- Difficulty and complexity in tracing all environmental impacts of building materials due to physical characters of buildings, variety of building materials used and complexity of construction process
- Difficulty in data collection and interpretation due to long life span and the dynamics of buildings such as alteration, renovation and replacements
- Lack of standards and reliable information in building production and delivery processes

Despite the controversies over a LCA based analysis, the BS EN 15978:2011 which is the most used method for embodied carbon and energy calculations in the construction industry (RICS 2012) as well as the European TC 350 Standards bases on the LCA model.

In BS EN 15978:2011, embodied energy measurement is delimited by 'cradle-to-gate', 'cradle-to-site', 'cradle-to-end of construction', 'cradle-to-grave', or 'cradle-to-cradle' boundaries, which are referred to as 'system boundaries' in a life cycle analysis of buildings (Figure 4). System boundaries show which processes of building construction works are to be included in embodied energy calculations. Cradle-to-gate measures energy use from raw material extraction till manufacture of the finished materials at factory, cradle-to-site from the extraction till transport of the materials to construction site, and cradle-to-end of construction form the extraction to transport, construction and assembly on site. Cradle-to-grave includes all processes over the total life cycle of buildings encompassing raw material extraction, production, delivery to site, assembly, construction, refurbishment and replacement, demolition, and disposal at the end of building life cycle. And, cradle-to cradle includes cradle-to-grave plus the process to convert the demolished products into new materials.

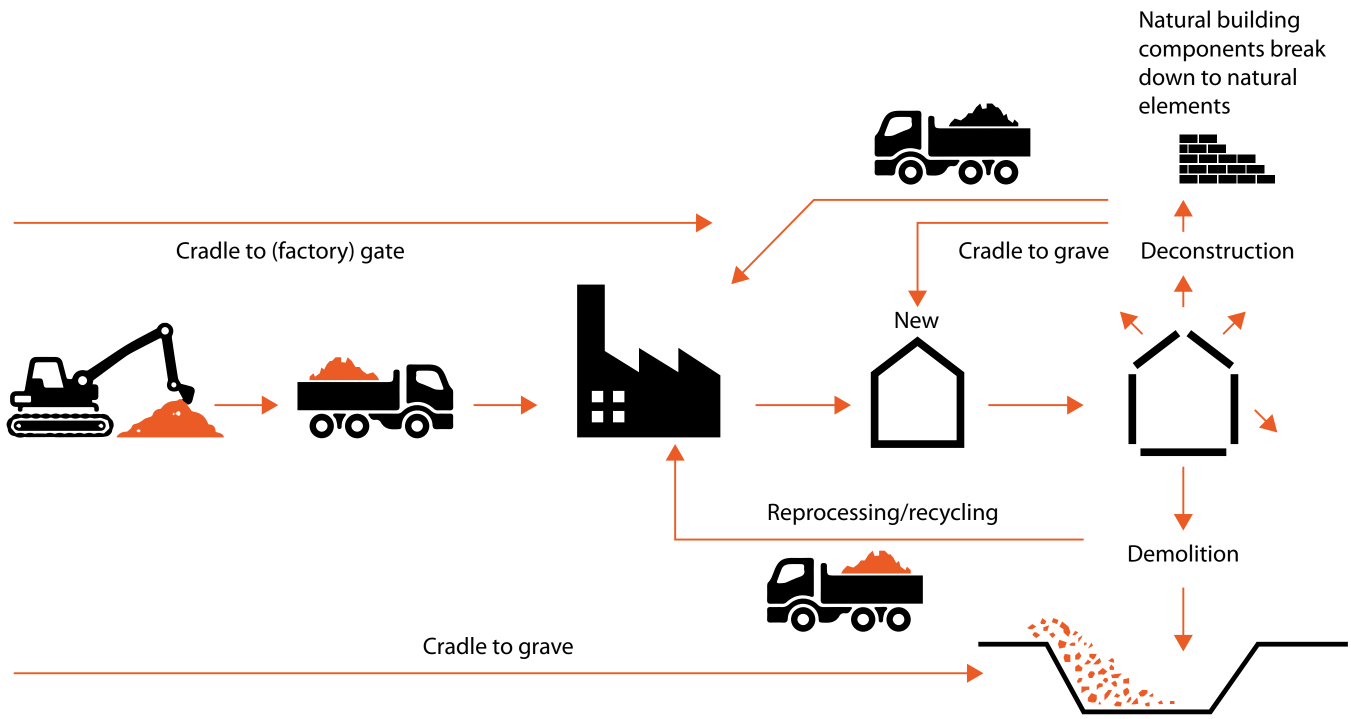


Figure 4: System boundaries in embodied energy analysis of buildings

Dong et al. (2005) compared the embodied carbon for retrofitting or rebuilding three example houses from the 1930s, 1960s and 1980s. They modelled the effects of insulating the attic and basement walls and sealing air leakage. The results should that for a "40-year life cycle, the rebuild option has a lower life cycle energy, global warming potential, and air pollution, which are predominantly associated with building operation. But the retrofit options have lower water pollution, solid waste generation, and weighted resource use, associated with material flows. The retrofit options alo have lower life cycle economic costs than rebuilding" (Dong et al. 2005, p. 1051)

Box 6: LCA based embodied carbon calculation at design stage (RICS 2012)

Step 1. Breakdown of building components:

The following building components are embodied carbon-critical and therefore embodied carbon analysis should be carried out by quantity survey and considered primarily when targeting embodied carbon reduction at design stage.

- Foundations
- Basement retaining walls
- Grounds
- Frame
- Upper floor
- Roof
- Stairs and ramps
- External walls
- Windows and external doors
- Internal walls and partitions
- Finishes

Step 2. Cradle-to-gate calculation

When types of building components, their size and number, and building materials are not yet known:

Calculation of embodied carbon of buildings is carried out by multiplying the floor area by the benchmark embodied carbon value. The benchmark embodied carbon values in CO_2e per m^2 is shown in figure 2 (with residential buildings boxed in red).

When types of building components, their size and number, and building materials are known:

A building material specific cradle-to-gate embodied carbon values are required for the calculation. The value is in the form of kg CO_2e per kg material. It is provided in the product's Environmental Product Declarations (EPDs) or can be obtained from the Inventory of Carbon and Energy (ICE) database from the University of Bath.

The quantity of material to be used can be estimated by multiplying the material density by the building component's volume. Then, embodied carbon is calculated by multiplying the quantity by the embodied carbon value. At last, the sum of the embodied carbon of each building components is the embodied carbon in the designed building.

Step 3. Utilising the LCA outcome

To identify embodied carbon intensive components and materials (RICS 2012).

The outcome of the LCA of buildings can be used to identify materials and building components whose contribution to the overall amount of embodied carbon is relatively high. Also, the building industry provided benchmark value can be used to evaluate the performance of construction project in comparison. However, the benchmark database from the industry is at premature stage, lacking reliability in the data used.

A building's life cycle impacts on environments are greatly associated with decisions made at early building design stages. A study (Cofaigh et al. 1999 cited in Basbagill et al. 2013) showed that wise decisions made on material selection, building shape and dimensioning, and orientation at the early design stage could reduce environmental impacts by 40% comparing to an exemplar of design. An LCA can be used as a tool to assist building designers in optimizing and making decisions about material selection and dimensions of building components to mitigate embodied carbon impacts. However, caution should be paid when utilizing cradle-to-gate embodied carbon analysis. Some cases, even cradle-to-gate embodied carbon of material is low, transport of material to site might increase cradle-to-site embodied carbon of material significantly. Also, though using large thermal mass materials could result in high cradle-to-gate embodied carbon, this may reduce the overall life cycle carbon emissions from buildings because it will reduce the need for cooling and heating. (RICS 2012).

4.3.1 Reducing embodied carbon

One of the common measures recommended for reduction of embodied carbon is to cut down the quantity of building materials. Additionally, RICS (2012) recommends to use "products with high recycled content, e.g. cement replacement materials such as GGBS (ground granulated blast furnace slag) or PFA (pulverised fuel ash)", to implement "low carbon design details, e.g. exposed concrete ceilings; aerated block work; rotary piles; voided biaxial slabs" and to replace with "low carbon alternatives to traditional building products". Figure 5 provides benchmark values for the carbon intensity of different building types.

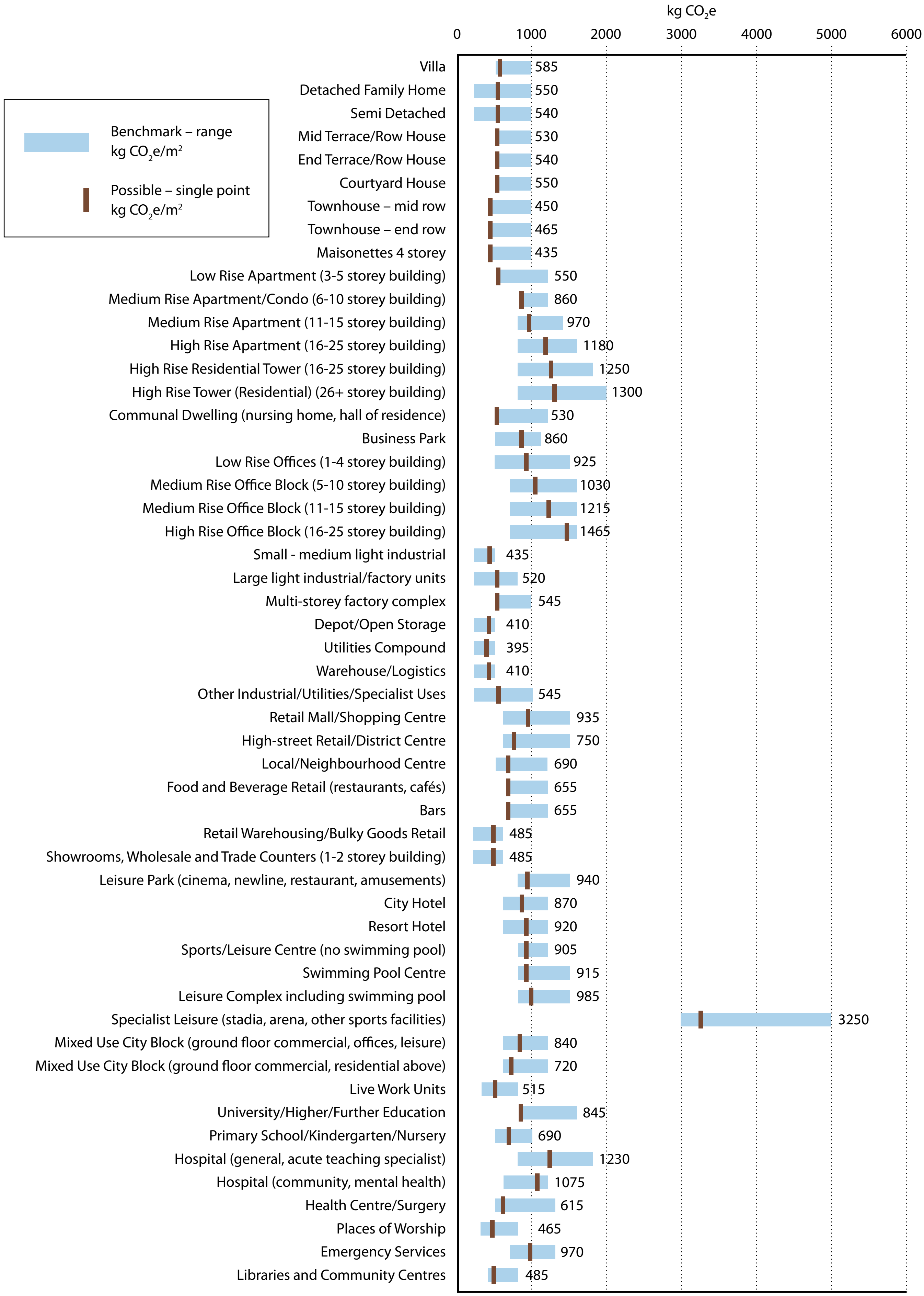
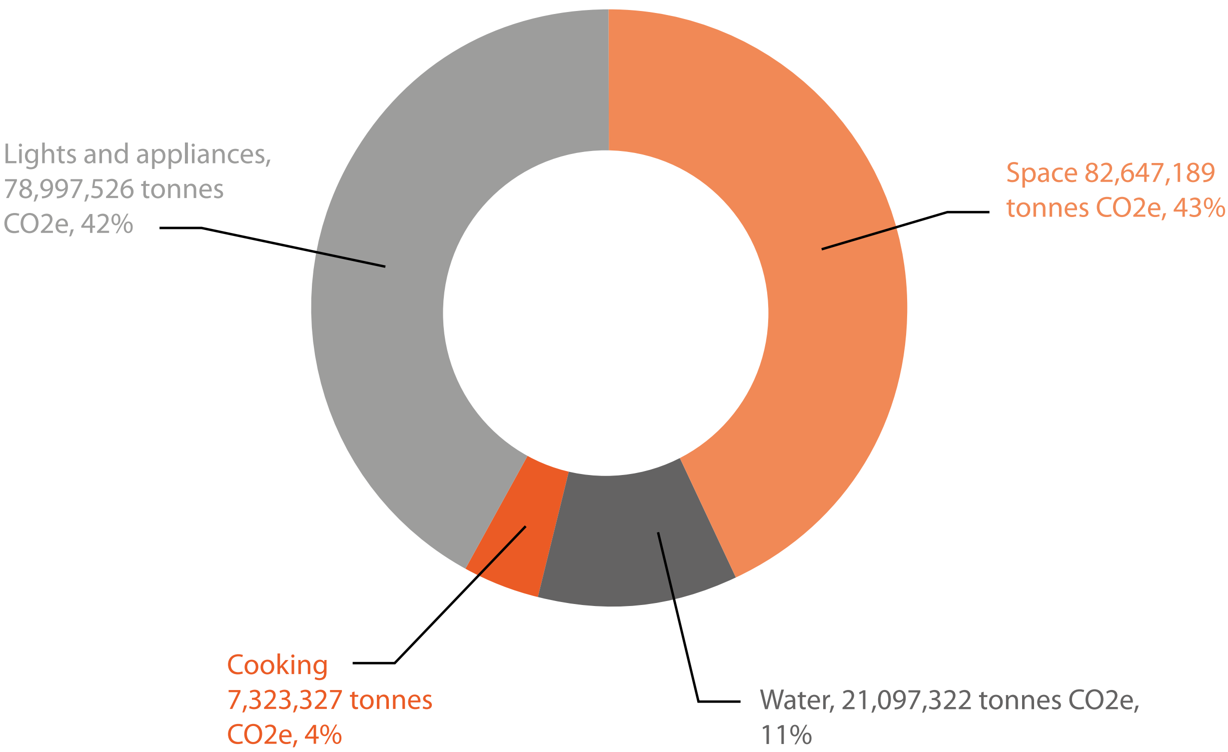


Figure 5: Embodied carbon benchmark values (Atkins Carbon Critical Masterplanning Tool reproduced with permission from Atkins in RICS 2012, p. 9)

4.4 Operational carbon and energy

The operational energy used in homes generates around 25% of the UK's greenhouse gas (GHG) emissions and reducing these is a key strategy for the UK (Palmer and Cooper 2012). As figure 6 below shows, the majority of this is produced heating our homes. The chart shows how the energy we need in our homes is split between different types energy services (called 'end uses') and is based on data for all UK homes in 2012.

Heating is the largest end use, followed by the energy needed for hot water in bathrooms and kitchens. Heating is a currently a key UK policy area with a number of policy and incentives schemes that attempt to reduce the amount of energy needed to keep homes warm, and change the way this energy is generated and supplied (see appendix xx for a list of policies and measures). DECC's 2013 report on heating states that 'the proportion of household energy used for water heating reduced from nearly 30% in 1970 to just 18% in 2011' (DECC 2013, p. 67). This is attributed to energy efficiency improvements such as better lagging and more efficient boilers, but also because we are using a larger proportion of the energy to heat our homes. Water efficiency improvements can also reduce the energy needed for our hot water systems, as is discussed in Section 0.



Domestic energy consumption by end use and fuel, in primary energy equivalents, 2012 data, converted to CO2e using Carbon Trust conversion factors for each fuel type
Source: DECC, Energy Consumption in the UK, Domestic data tables (2013 Update)

Figure 6: How homes use energy: A breakdown of operational energy by end use emissions for the UK housing stock in 2012[16]

The third largest part of a home's operational energy is from appliances. This is rising as we have more appliances in the home. Air conditioning systems are also included as domestic appliances. Cooling is not currently a major demand in the UK and the majority of residential stock uses natural ventilation. Electric air-conditioning currently accounts for less than 1% the energy used in the housing stock's (DECC 2013, p. 71) but this is likely to rise. The issue of ventilation becomes more critical when thinking about the summer overheating. Over-heating has adverse health implications, and raises energy costs through the need for cooling.

4.4.1 Reducing operational energy

Tackling operational energy focusses on two questions:

- How much energy does the building require to keep it warm, dry, lit and ventilated? (operational energy)
- What level of emissions are produced by the energy sources used by these systems that are keeping the building

16 Carbon Trust conversion factors available at http://www.carbontrust.com/resources/guides/carbon-footprinting-and-reporting/conversion-factors

habitable? (operational carbon)

Question one relates to demand side research and focuses on the energy and carbon emitted by the systems in homes and can include studies on specific technologies as well as studies on how people use them; such as behavioural studies focussing on attitudes and awareness of people using appliances (Abrahamse et al. 2005; compared with Darby 2001) and practice theory research focusing on the cultural factors that shape energy use in the home (Shove 2010; Shove et al. 2014; Wilhite 2008). Question two relates to supply side research and draws attention to the fuel sources used to produce the electrical and heat energy used in homes. Currently for UK housing this is predominantly natural gas, which accounts for 70% of the energy supplied to residential buildings (Pyrko and Darby 2010).

The UK government's strategy to reduce CO_2 emissions from the housing sector addresses both questions. It aims to reduce demand through energy efficiency programmes and building regulations, and it aims to switch to lower carbon supply through decentralised energy schemes which build up renewable generating capacity close to the housing source, and through decarbonising the grid supplied energy, for example by generating electricity from lower carbon fuels (e.g. natural gas), or renewables (e.g. wind turbines).

Supply side and demand side policies affect the amount of energy used and GHG emissions produced by new and refurbished buildings, but to different extents. This is discussed in the following sections.

4.4.2 Tackling operational energy through new build

New residential buildings can be designed to use very low levels of energy and make use of low carbon sources. UK building regulations specify the energy performance of new buildings and have become increasingly more stringent since first introduced in 1965. The newest buildings regulations will require all new buildings to be 'Carbon Zero' from 2016. This means the operational energy for new builds should be low and supplied from renewable sources.

The operational energy and associated CO_2 emissions of new buildings is lower than existing buildings. However, as discussed above, when considering the embodied energy and CO_2 emissions associated with the construction, the gains of improved operational performance can be lost over the lifetime of the building. This is particularly important if an old building has been demolished in order to be replaced by a new one. In addition as we switch to renewable sources to supply our operational energy we produce few CO_2 emissions, and the operational carbon of our buildings become less critical.

The reality of constructing enough new houses to accommodate the population also presents an overwhelming challenge, and has significant carbon consequences. New construction will not deliver the number of homes needed by the population, and research suggests that by 2050, 70% of the homes in use will be ones that already exist today (Power 2008). This means retrofitting established building also plays a key role in reducing the amount of energy consumed in the UK and the volume of GHG emitted.

4.4.3 Tackling operational energy through retrofit

It is technically possible to retrofit homes to have the low operational energy and carbon of new builds, as shown by the following case studies in Box 7.

Box 7: Case studies of retrofitting to reduce operational energy and carbon emissions.

1) Wilmcote House, Portsmouth City Council

Portsmouth City Council refurbished 3 **tower blocks, from 1968** with 11 storeys each. The decision not to demolish was based on the high costs of rebuilding and the difficulties of decanting and rehousing residents in the local area.

The total budget for the project was **£13 million**, including ECO funding.

The buildings were retrofitted to achieve **very low operational energy levels** equivalent to current building standards for new buildings (EnerPHit standard). The retrofit included external wall insulation, new heating systems, roof insulation and high performance windows. The **life of the buildings was extended by a minimum of 30 years**, and heating and hot water **costs reduced by 90%**, saving around £750 each year for each dwelling. In addition the refurbishment also rectified structural problems, improved the look of the buildings, expanded living space by enclosing walkways, provided secure communal space and 2 new units on the ground floor (ecda.co.uk, n.d.).

2) Victorian Terrace, Oxford (Retrofit for the Future project)

Two bed terrace owned by Oxford City Council. The retrofit included external and internal wall insulation, loft sunpipe, mechanical ventilation with heat recovery, new gas boiler and solar PV and thermal panels. The results produced an 80% reduction in operational energy, calculated by monitoring post retrofit consumption, and compared to modelled pre-retrofit consumption levels. Annual energy bills are estimated to be under £500

3) Edward Woods Estate, London Borough of Hammersmith and Fulham

Three, 24 storey blocks with 176 homes built in the 1970s. The total budget for the project was **£16.3 million**, with the money generated from the sale of 12 new penthouse flats constructed in the project and grant funding:

- GLA targeted Funding for energy saving £5.24m
- CESP Funding for energy saving £0.60m
- s106 (from previous regeneration scheme) £1.67m
- HRA capital £3.52m
- Capital Receipts £5.10m

Retrofitting existing buildings can provide other benefits, by maintaining the cultural heritage offered by the built environment and the personal attachment people feel for their homes and local communities. Unlike building from new, retrofitting can be quicker, less disruptive to residents and less dependent on dry weather conditions (Power 2008).

The residential sector has been seen by governments as easier to transition to a lower carbon future in comparison to transport and industrial sectors, however implementing a national programme capable of delivering this transition is proving difficult and predicted savings are not being achieved at the required rates (Davies and Oreszczyn 2012). Two key reasons are; firstly the difficulty in achieving the widespread changes needed for the built environment, and secondly the failure of installed improvements to achieve the anticipated savings. The former reason is associated with the need to establish a market and supply chain capable of delivering energy efficiency upgrades and total building refurbishments on a broad scale. The second reason is associated with the complexity of getting the technologies to function as designed (often called 'the performance gap') and understanding how households adjust to living in more energy efficient homes (often called 'the rebound effect') (see Box 8).

Box 8: Performance gaps and rebound effects: the difference between expected and actual operational energy reductions from refurbishment

There is typically a difference between the energy savings expected from energy efficiency upgrade and the savings achieved in practice. For example if an old boiler is replaced with one that is 20% more efficient, the energy needed to heat the home is expected to fall by 20%. However this is often not the case and research specifically on household heating pre and post thermal retrofits identify a set of reasons. These include the complexity of installing and operating low energy technologies in different types of buildings, poorly modelled predictions, different ways that residents understand and use new systems, and how they spend the financial savings they gain (Galvin 2014; Hong et al. 2006; Sorrell et al. 2009).

The Performance Gap: focusing on the technologies

The 'performance gap' refers to the difference between the calculated energy performance of the building as designed, and the actual performance of the building which is measured by monitoring how much energy is consumed by the technology or the building post-retrofit. The difference between the design (or modelled performance) and the energy can vary dramatically, over 200% in one study of thermal retrofit examples in Germany (Galvin 2014). A study of UK homes found that the introduction of new gas central heating systems, although theoretically more efficient had no impact in reducing the amount of fuel consumed (Hong et al. 2006). The Zero Carbon Hub found that issues affecting the performance gap for new construction were: the design process, procurement, construction, commissioning and completion, construction joint details and knowledge and skills (Zero Carbon Hub 2013).

Evidence of the performance gap is helpful in identifying potential problems with a retrofit, but is less helpful in identifying the causes of such problems. Reducing the performance gap requires more research into modelling techniques as well as more research on the design, installation and operation of energy efficiency upgrades.

The Rebound Effect: focusing on the consumers

The 'rebound effect' refers to consumer reactions to energy efficiency programmes. From an economics perspective, energy efficiency improvements make energy services (like heating) cheaper, and so may encourage people to use more, or spend the financial savings on other energy consuming activities (e.g. a household spends less on energy bills, so takes more flights). This means incentivising energy efficiency may not deliver expected energy savings (Sorrell et al. 2009).

Empirical studies of energy efficiency in homes have shown that part of the rebound effect can be explained by occupants choosing to heat their homes more. Milne and Boardman (2000) have argued that 'most households in the UK are not warm enough' and making heat more affordable will help households heat their homes more adequately. This portion of 'rebound' is called 'comfort taking' by DECC (2012) can be recognised as a positive outcome of energy efficiency programmes which are evaluated for their impact on fuel poverty and reducing ill health and not only on carbon savings generated.

However empirical studies have also found that not all increased levels of heating post-retrofit rises in heating are intentional but some are due to poorly installed controls rather than choice (Love 2013; Milne and Boardman 2000). These studies show that the rebound effect can be reduced through better engagement with residents about efficiency upgrades in their homes.

4.5 Demand

Research analysing how to reduce the energy demand of the residential buildings sector includes:

- increasing the uptake of energy efficiency measures;
- improving the technical efficiency of the system, e.g. installing a new boiler;
- improving the operation of an installed system, e.g. by improving the system's controls and helping people understand how to program their heating efficiently;

- switching to a different form of heating system, e.g. removing electric heaters installing a wet system and connecting to a communal boiler or CHP unit; and
- a combination of these.

4.5.1 Space heating

Studies looking specifically at retrofitting heating technologies have found some disappointing results. Analysing the impact of the government scheme 'Warm Front' example more efficient gas central heating did not produce expected reductions in fuel use, even after discounting the 'comfort taking' of fuel poor residents (Hong et al. 2006).

4.5.2 Domestic hot water

This is typically covered as part of domestic heating systems. Water efficiency measures can also deliver energy savings as people use less hot water in their daily activities (discussed in Chapter 5).

4.5.3 Cooling

Overheating problems can be created or increased when high energy performance standards for buildings are achieved that reduce winter fuel costs but which fail to address the impact of summer sun (AECOM 2012).

- Residential buildings built around the 1960s and small top-floor purpose-built flats are prone to overheating.
- Newly constructed highly insulated houses have also been found to have the potential to be at higher risk of overheating than older, less well insulated houses.

Overheating is a risk for both new builds and for refurbished housing unless summer solar shading is provided in the building's design or refurbishment.

4.5.4 The importance of controls

Currently 90% of UK homes have central heating, but of these only 49% have a full set of controls (TVRs, timers and room thermostats) and private rented accommodation is the least likely housing type to have controls (Munton et al. 2014). There is an assumption that improving heating controls (e.g. having easy to use thermostatic radiator valves, timers and room thermostats) will reduce energy used in homes, but the evidence is weak. DECC's 2011 Energy Follow Up Survey found that installers rather than residents are more likely to decide about the controls installed and where they are put. When residents do use their controls the evidence suggest it is to adjust their thermal comfort, rather than save energy (Munton et al. 2014).

This suggests that improving residents' understanding of the equipment in their homes is critical to achieving energy savings and improving thermal comfort (Love 2013). This is an issue which exists for residents in new buildings as well as existing ones, therefore **the retrofit process offers an opportunity to engage residents and help them understand how their homes use energy**. This may not be the case if residents are relocated or purchase newly built flats.

4.5.5 The whole system approach

In addition to investing in individual technologies, upgrades or energy efficiency installations, an alternative approach to refurbishment is to adopt a 'whole system approach' which views the building as a system and seeks to comprehensively rework all aspects to achieve the maximum reductions in operational energy. This approach has been taken on individual homes, as well as on estates such as Wilmcote House and Edward Woodward Estate.

The Technology Strategy Board (TSB) guide to making retrofit work suggests that taking a 'whole system approach' is necessary to achieve significant CO_2 savings (Technology Strategy Board 2014). Through this approach three of the 40 buildings they studied were retrofitted to achieve an 80% reduction of $C0_2$ and another 23 achieved 50-80% reductions.

With the Green Deal and new Energy Company Obligation, current government policy is trying to encourage a whole system approach, but there are problems with the way assessments are carried out. The assessments should identify a set of measures, but have been found to exclude high cost measures such as solid wall insulation, or floor insulation.

4.5.6 Energy Performance Certificates

Energy Performance Certificates (EPCs) rate a building on an A to G scale (similar to energy labelling for white goods) to reflect fuel costs under standard occupancy conditions. In January 2013 it became mandatory for landlords and owners of new buildings and existing buildings to provide EPCs when homes are sold, leased or rented.

The regulations require an EPC to be given free of charge to the person who becomes the buyer or tenant of the building.

- An EPC shows the energy efficiency rating on an A–G rating scale for a building
- The EPC includes recommendations on how to improve energy efficiency.
- The EPC may also include information showing which of the recommendations would be eligible for finance under the Green Deal scheme.

Social and private landlords **must provide** new tenants with an EPC for their home.

4.6 Supply

4.6.1 Decarbonising the grid

The energy used in homes can produce different levels of GHG emissions depending on the fuel source (also referred to as the carbon intensity of the fuel). Technologies like heat pumps use electricity to provide heating in homes. These can be lower carbon than using oil burning stoves and so can help homes which are not connected to the gas grid become lower carbon.

There are concerns about increasing electricity powered heating given the proportionally high level of coal used in the UK to generate electricity, however Pyrko and Darby (Pyrko and Darby, 2010) have argued that rising UK dependency on carbon intense electricity is pushing renewable energy generation up the political agenda.

4.6.2 On-site renewables

There are a range of technologies that can be used to generate heat or electricity from renewable sources and which are small enough to be used on individual buildings or estate. These include solar photovoltaic cells which generate electricity and solar water heating systems to supply hot water for bathrooms and kitchens.

The government is supporting the development of on-site renewables through building regulations which allow on site renewables to offset the carbon emissions from the energy used by the building's operation. The government is also providing feed in tariffs which means that groups or home owners can earn income by generating low carbon heat or power (see Appendix B for details of the policies)

Box 9: Dumfries and Galloway Housing Partnership (DGHP) and Air Source Heat Pumps (ASHP)

DGHP is a registered social landlord with 10,300 homes, 1 600 of these are off gas grid. In 2011 DGHP successfully competed for the Renewable Heat Premium[17], winning £175 000 to trial renewable heat technologies in 17 off grid rural homes. DGHP retrofitted the homes and trialled individual biomass boilers, Ground Source and Air Source heat pumps. All homes achieved the 2020 CO2 targets of 42% emission reductions and generated savings on household bills. Tenants with heat pumps were happy with comfort and cost savings, but the biomass boilers were also well liked and were lower carbon. This is because the heat pumps are powered by electricity from the grid which has a higher carbon intensity than biomass.

DGHP decided to install air source heat pumps throughout their off grid stock because it was the most affordable option at £6,000 per installation. Households can expect to save around £340 a year on bills. The housing provider could not afford to spend more on lower carbon technologies like biomass boilers.

If the carbon intensity of the electricity grid is reduced, the homes will also see their operational carbon reduce. An air source heat pump lasts up to 20 years, and grid decarbonisation may take longer than this.

17 This scheme has been replaced with the Renewable Heat Incentive, see Appendix B

4.6.3 Decentralised energy and heat networks

Decentralised energy and heat networks provide an alternative option to reduce GHG emissions from the housing sector and the UK government is currently supporting the development of heat networks throughout urban areas of the UK (Hawkey et al. 2013; Hawkey 2012). These are not limited residential buildings, but can include them, providing opportunities for lower carbon heating for new and existing residential buildings. Providing central heating and hot water on a large scale for buildings can be more energy efficient and more cost effective than using individual boilers to heat and provide hot water to every home in a building. However the upfront costs of investing in the infrastructure can mean that this option is excluded from the start, even if the operational and user costs are lower following the installation and the life span of the generating system is longer.

It is easier to lay the underground pipes for a heat network when building from scratch, however new low energy buildings should not require much heat in comparison to existing buildings. This means heat networks can be considered as a retrofit option to help existing buildings reduce their operational carbon levels. Heat networks can provide heating more efficiently and with lower emissions than other sources like electric heating. The network infrastructure has a longer life span (60 years+) than the generating plant used to supply the heat (25 years for gas combined heat and power) and can transition to lower carbon sources over time.

Box 10: Pimlico district heating network

The Pimlico district heating network pipework has lasted for over 60 years and during this time the generating plant has been changed three times. The carbon intensity of the heating supplying these buildings has changed according to the fuel source and efficiency of the generating plant. Today the service provider uses combined heat and power technology which is more efficient than heat only boilers, and which generates income by selling the electricity to the national grid. This keeps the costs down and today residents in Pimlico connected to the system benefit from low heating prices.

Communal heating systems often already exist in social housing, but typically are provided by a 'heat only boiler'. It is more efficient to use a combined heat and power (CHP) unit which generates both heat and electricity. The electricity generated can be used on site, or sold to the national grid with revenue subsidising the cost of the heat produced. The most cost effective time to replace a boiler is when it comes to the end of its life, but investment decisions should take into account the projected savings on fuel use, revenues generated and carbon emissions reduced, not only the upfront capital costs of the technology. Heat networks become more cost effective when including mixed developments and the heat market in the UK is growing, and extending beyond its current focus on social housing.

District heating is an established technology and European markets have developed low cost domestic heat exchangers that give residents control over their individual heating supply and reduce existing concerns around freeloading, overheating and distributional losses. The EU directive on metering and billing transparency comes into force in June 2014 and provides further incentive to upgrade existing communal heating infrastructure (DECC 2014) (see Appendix B for details of heat policies).

DECC is supporting CHP uptake and currently has a £6million fund (November 2103 – April 2015) for Local Authority grants for heat network feasibility studies. A £10million Urban Communities Energy Fund (UCEF) will be launched this year to support communities wanted to generate their own heat and power. Further support takes the form of regulation, for example the London Plan requires developers of new buildings consider the feasibility of connecting to District Heating schemes.

More research is needed to answer:

- Are existing residential estates suitable for heat network extension and what are the costs?
- What are the carbon and financial costs and benefits of removing heat only boilers and adding buildings to heat networks?
- What life time?

4.7 Research on associated issues

4.7.1 Energy efficiency programmes and uptake of measures

As well as regulating building standards, the current UK government approach to increase energy efficiency (EE) uptake in the residential sector relies on the private sector marketing achievable EE gains as cost effective. There are also obligations on energy companies to supplement the lower-income and more rural areas where measure may be less market viable (Hamilton et al. 2014). Innovative financial products (e.g. the Green Deal) have been created to reduce market barriers, but concerns have been raised that other uptake barriers exist (for example the inconvenience of installing EE measures) and that a voluntary programme will not achieve sufficient coverage (Mallaburn and Eyre 2014).

Studies focused on the decisions taken by owner-occupiers have confirmed that home renovations tend to be carried out as part of daily life and fitted into a cycle of wear and tear maintenance. This means measures which improve internal aesthetics such as retrofitting a kitchen or bathroom are more widespread than the installation of measures that are purely for energy efficiency gains such as window fittings and insulation (Gram-Hanssen 2014). However, focusing on the uptake and prevalence of energy efficiency measures in the UK between 2000 and 2007 Hamilton et al. (2014) have shown the impact of regional schemes targeting fuel poverty and social deprivation on getting building fabric interventions (such as wall and loft insulation) into the UK housing. The study also identifies the role of industry standards and building regulations, relating the increase in condensing boilers to the 2005 building regulations amendments.

Research has found that tenure helps explain different levels of energy saving measures installed. Homes belonging to Registered Social Landlords (RSLs) have proportionally more loft insulation installed than other public and private sector housing (Utley and Shorrock 2008) . After this group come owner occupiers then local authority renters, and the worst performing housing is currently owned by private landlords. This illustrates the 'tenant-landlord problem', 'the mismatch between the party paying the costs of installing energy efficiency measures (the landlord) and the party receiving the benefits (the tenant)' (Druckman and Jackson 2008, p. 3179)

This problem is being addressed by incentives such as the Green Deal which spreads the costs of the energy efficiency improvements over the lifetime of the installed upgrade. This means that renters receive the benefits of EE improvements, and contribute to the costs through their bills. When they move on, the next renter will continue to pay for the improvement. Renters can now find out in advance what the energy performance of their home is because Energy Performance Certificates are now mandatory for all new and existing homes that are sold or rented.

From a retrofit or demolish perspective these findings raise a number of issues:

- Cheaper measures may have already been installed by RSLs and Local Authorities (LAs) making the cost of future upgrading higher
- Demolishing existing buildings in the public sector and not-for-profit is less likely to get rid of the worst performing stock.
- Demolishing existing buildings in the public and not profit sectors may have higher embodied carbon because these homes may have proportionally more energy efficiency materials already installed

4.7.2 Deep or shallow retrofit

Without established standards, there remains uncertainty over the level of retrofit that should be aimed for and is achievable. Retrofitting buildings for energy efficiency can range from low cost measures such as loft and cavity wall insulation, to complete refurbishment of the building and energy systems. As discussed above, the cheaper measures are likely to have already been installed by RSLs and LAs.

The Energy Savings Trust has analysed different options in its report 'Roadmap to 60%: eco-refurbishment of 1960s flats', which divides retrofit in low, middle and high cost activities. They find that a 60% reduction in CO_2 emissions by 2050 can only be achieved by 'deep retrofit' measures, requiring extensive work to the building fabric. Their study finds this costs £10,000 per unit, with a turnaround time is six to eight weeks and that there will be additional costs to relocate residents through this period. However deep retrofitting standards were achieved in Wilmcote House without having to relocate residents (see Box 7).

When achieving deep retrofit levels, the embodied carbon of the construction materials and processes becomes more significant, however deep retrofit demands a bespoke design and complex mixture of technologies, structural changes and user engagement to ensure the levels of savings are achieved (Konstantinou and Knaack 2011).

The need for an integrated approach that can bring together the different stakeholders from the construction sector, the housing sector and residents, is recognised as critical to rolling out a wide reaching retrofit programme. Achieving this in practice is hard (BRE and Energy Saving Trust 2012).

In their 2012 report 'Refurbishing the Nation' BRE and the Energy Saving Trust highlight the following points as key to increasing the roll out of refurbishment programmes at the scale required to meet UK climate change commitments:

- Develop refurbishment standards
- Improve skills among smaller and local construction sector contractors
- Design refurbishment in line with local housing types
- Promote easy-to-use and low tech solutions
- Improve funding streams and business case

4.7.3 Retrofit and the green economy

An energy efficient refurbishment industry needs to be developed which is capable of meeting this challenge for the UK building stock to contribute significant emissions reductions and energy savings. A report by BRE and the Energy Savings Trust on this challenge states:

The government estimates that 5,000[18] homes will need to be refurbished per day, in order to meet its 2050 carbon reduction target. Equally, this presents massive employment opportunities, with the Energy Saving Trust estimating that more than 100,000 insulation jobs could be created (BRE and Energy Saving Trust 2012).

4.7.4 Generating income through retrofit

Deep retrofit provides an opportunity for landlords and tenants associations to generate additional income. In the case of the Edwards Woods estate, the refurbishment process added 12 penthouse flats to the buildings which were sold to help subsidise the refurbishment works. The project added solar PV panels to generate electricity for the lifts and corridor lighting so saving the costs of buying this electricity from the grid. It also created new commercial premises on the ground floor let to voluntary organisations (Bates et al. 2012).

Box 11: Feed-In-Tariffs in Brixton Renewable Energy Project

In Brixton, the social enterprise 'Repowering London' is generating income by installing solar panels on the roofs of tower block housing and selling the power to the grid. This community owned renewable generation is supported by government 'feed-in-tariffs' which supplement the sale of electricity (see Appendix B for details and links to the policies, and http://www.repoweringlondon.org/ for details of the project).

4.7.5 Unintended consequences

Using the building stock as the vehicle to deliver the UKs carbon savings has some consequences. (Davies and Oreszczyn 2012) suggest there are 7 'known, but poorly understood' consequences:

1. Indoor Air Quality (IAQ) problems associated with reduced ventilation: for example, particulate matter, radon, VOCs, moisture (resulting in mites and mould) and environmental tobacco smoke in domestic buildings. This is why good, controlled ventilation is crucial when upgrading or building more airtight dwellings.
2. Higher energy prices due to increased use of decarbonised supply leading to fuel poverty and associated health effects.
3. Energy efficiency improvements without adequate solar shade increasing the risk of summer-time overheating which can result in impacts on health
4. Energy efficiency improvements resulting in increased GHG emissions due to the 'rebound effect'.
5. Changes to the hygrothermal properties of building fabric resulting from ill-considered or executed improvements in thermal properties, causing cold bridges, condensation, mould growth and decay.

18 Other calculations put this figure at 2,000 buildings a day (26 million buildings over 35 years, every 365 days)

6. The use of distributed energy technologies moving energy generation into urban areas and hence potentially intensifying the urban heat island.

7. Health and safety issues associated with refurbishment increasing the potential for elevated fire risk.

4.8 Key messages

This chapter has reviewed the energy and carbon issues relevant to the debate over whether to retrofit existing housing stock or demolish and rebuild it. The key messages are:

- Existing buildings can be retrofitted to achieve the same energy performance standards as low energy new builds
- The energy performance of both retrofitted and newly built low energy buildings depends on residents' understanding the systems in their homes. Retrofit may provide opportunities for user engagement, but these opportunities are not currently being taken
- The carbon emissions associated with the energy used in homes depends on the fuel sources used. Policies to decarbonise the national grid and to encourage on site and community based low carbon are currently in place and as these increase the relative contribution of embodied carbon of the construction materials and processes for demolition and rebuild become more significant
- Retrofitting existing buildings can provide income generating opportunities
- Social housing currently has more energy efficiency measure installed than housing stock in the private rented sector

5 Water and Waste

Most of the debate about the cost and environmental impacts of demolition compared to refurbishment focuses on energy and carbon, but it is important not to lose sight of other environmental impacts and costs. Construction of new buildings requires water, concrete, steel, timber, glass and many other materials, which all have environmental impacts during their production. A detailed life-cycle assessment of buildings, including building assessment tools such as BREAMM, should cover a range of environmental impacts, including impacts on biodiversity and the use of materials from local and sustainable sources. This review does not address the full environmental impacts of refurbishment or demolition, but focusses on the key issues of water and waste.

5.1 Water

Water is often overlooked in regeneration schemes, but it is a very important environmental issue to be considered in construction, refurbishment and use of buildings. Water is used in construction and by residents during the lifetime of the building, and it is also important to consider how sewage and storm water are dealt with in new or refurbished buildings.

The south-east of England is a water scarce region. London receives less rainfall each year than Rome and Istanbul. On average, water consumption in London is 162 litres per person per day. With a growing population it is important to reduce the amount of water each person uses every day by improving water efficiency. Reducing the amount of water used by the construction sector, particularly in producing concrete, will also help relieve pressure on stressed water resources. A study of an Australian home, with much higher per capita daily water consumption than the UK, showed that water used in construction was greater than the water used directly by the occupants over the lifetime of the building (Crawford and Pullen 2011). 'Embodied water' is therefore more significant than water use in the home throughout its lifetime, in contrast to the current situation for 'embodied carbon' compared with lifetime carbon emissions.

At the same time as we are dealing with water shortages, London's drains and sewers are overflowing because of increased volumes of water running off roofs and hard surfaces during storms. This is caused by paving and building over green spaces, which stop the water infiltrating the ground, and more intense storms, which are consistent with climate change predictions. This additional runoff causes sewers to overflow into the Thames and other rivers, and contributes to local flooding.

Improving how water is managed in housing estates can have many benefits for residents and the local environment. Improving water efficiency in homes can reduce water and energy bills. Better management of storm water can improve local green spaces, reduce overheating and improve residents' health and wellbeing.

This review will consider two water issues in relation to refurbishment or demolition and construction of social housing: water efficiency; and drainage.

5.1.1 Water efficiency

Water efficiency is unlikely to be considered in decisions to demolish or retain housing in regeneration schemes. However, water efficiency should be considered in designs for new buildings and in retrofit and refurbishment programmes. Water efficiency is covered by Part G of the Building Regulations, requiring all new homes to be designed for an average consumption of 125 litres per person per day. Considerable reductions in water use from the current London average of 162 litres per person per day can also be achieved in existing buildings by retrofitting and refurbishment, particularly of kitchens and bathrooms. Bathrooms and kitchens have shorter lifespans than buildings, providing opportunities to install more efficient appliances. There are also a number of measures that can be implemented without the need for full renovation.

Waterwise and the Energy Savings Trust (2012) calculated that retrofitting homes with water efficient shower heads, tap aerators and cistern displacement devices on existing toilets can save 5.5 – 17.5 litres of water per person per day. These devices can be easily installed by homeowners or during a short visit by a trained installer, and they are often provided free of charge by water companies, who are obliged to help customers reduce water demand. For an average household paying for water via a water meter, with 2.3 people these simple measures can result in savings of £29 on their annual water and energy bills, 8,380 litres of water and 36kg of carbon dioxide produced by heating water. For a family of four the annual financial saving is estimated to be around £56.

Higher water savings can be achieved when bathrooms are renovated, such as during Decent Homes improvement programmes. A report by Waterwise (2009) for the GLA showed that approximately 80% of social housing properties had at least one bath but no shower installed. Retrofitting a shower into social housing properties has been shown to save 39 litres per property per day, and replacing old toilets with dual flush toilets can save 61 litres per property per day. Waterwise recommend that mixer showers are preferable to electric showers, which can increase residents' electricity bills.

Box 12: Tap Into Savings

The Tap Into Savings programme was run by Waterwise and Global Action plan, in partnership with water companies and social housing providers in Surrey, the West Midlands and Essex in 2010 and 2011. Working with EcoTeams of residents, more than 4,500 homes were visited and provided with water and energy efficiency devices and advice. The programme resulted in an average daily saving of 40 litres per home (Waterwise 2012).

5.1.2 Drainage

Overflowing drains and localised flooding during rain storms can be amongst the most unpleasant and dangerous experiences for residents. Broken, blocked or under-capacity drains can be part of the justification for demolition of housing where repair or replacement is costly. Replacing and repairing drains can be difficult and expensive where they are buried underground or difficult to access within buildings.

Social housing providers are responsible for drains on their properties and must maintain them in good order, but these drains connect to sewer networks owned by Thames Water. Managing surface water is also the responsibility of Local Flood Authorities, and Local Authorities also have an increasing role to play in managing drainage through the planning process.

New developments and regeneration schemes will be required to include Sustainable Drainage Systems (SUDS) wherever possible. SUDS aim to reduce the amount of water flowing into the sewers, which helps to prevent flooding and overflows. SUDS measures include green roofs, rainwater harvesting systems, permeable paving, rain gardens and using green spaces to store water temporarily during storms. These measures can also provide water for gardening or toilet flushing, reduce overheating in summer and improve the quality of the local environment. Islington Council is also promoting SUDS as a means of reducing subsidence, which effects a number Homes for Islington properties (Islington n.d.).

Retrofitting SUDS to existing buildings and estates should be considered in any regeneration scheme. Retrofitting SUDS can alleviate drainage and flooding problems by reducing the volume of water flowing into local drains, thus reducing the need for demolition as a means to solve drainage problems. For instance, if the volume of water flowing into drains can be reduced by retrofitting a green roof or rainwater harvesting systems, then existing drains will be able to function more effectively.

The GLA, Local Authorities, Local Flood Authorities and Thames Water are all interested in promoting SUDS in London, and can provide guidance and funding for SUDS schemes on social housing properties. SUDS measures can be cost beneficial over their lifetime compared with conventional drainage solutions. Permeable paving and green roofs have been shown to be less costly than conventional options over their full lifecycle due to extended lifetime and lower maintenance costs (Gordon-Walker et al. 2007, livingroofs.org n.d). Rainwater harvesting provide an economic benefit through reduced water charges (Gordon Walker et al. 2007). Subsidies and grants for improving adaptation to climate change and reducing storm water runoff can contribute to financing SUDS schemes.

Box 13: Ethelred Estate Green Roof

In 2005 the roofs of 10 buildings, comprising 253 flats, on the Ethelred Estate in Kennington were replaced with green roofs. The Ethelred TMO opted for green roofs as they offered a lower life-cycle cost compared with conventional roofs. They also provide additional benefits including reduced storm water runoff (livingroofs.org n.d.).

5.2 Waste

Construction and demolition in the UK generate the largest amount of waste each year of any sector. In 2008 the construction sector generated more than three times as much waste as households, accounting for 35% of all waste generated in the UK (DEFRA 2011). A further 30% of all UK waste in 2008 came from the mining and quarrying industries, with approximately 84% mineral extraction used to provide materials for construction (Cuella-Franca and Azapagic 2012). Waste management in the construction sector has improved considerably in recent years due to policy changes related to the EU Landfill directive. In 2010 73% of construction and demolition was in the England was recycled as aggregate (DEFRA 2012), with 4.28 million tonnes sent to landfill (Hobbs 2012).

Using recycled aggregate in new construction reduces waste to landfill and the environmental impacts of new construction. A study of UK houses showed that recycling materials at their end of life reduced global warming potential by 2-3% (Cuella-Franca and Azapagic 2012). Refurbishing existing buildings avoids demolition waste to landfill and reduces the need for new materials, particularly concrete, steel and bricks. This also avoids costs associated with landfill, recycling and new materials.

Box 14: Daneville Estate, Liverpool

The Daneville Estate is owned by Liverpool Mutual Homes (LMH) and consists of 600 properties. Tenants and residents of the Daneville Estate were consulted regarding options for regeneration and it was decided to refurbish rather than demolish all properties, including 63 homes which had been vacant for 30 years. Refurbishment was shown to be cheaper than demolition and new build, and avoided producing 45,000m3 of demolition waste. Structurally unsound homes were refurbished using a structural external wall insulation system, which avoided demolition as well as improving energy performance (Wrap UK 2012)

5.3 Key messages

Water and waste are often overlooked in decisions about retrofitting or demolishing homes as part of urban regeneration schemes. This section has addressed these issues and the key findings are:

- Considerable reductions in water use can be achieved by refurbishing bathrooms and kitchens.
- New developments and regeneration schemes will be required to include Sustainable Drainage Systems (SUDS) wherever possible in order to reduce the amount of water flowing into the sewers. This in turn can reduce the need for demolition to solve drainage problems. Retrofitting SUDS and other green infrastructure to existing buildings and estates should be considered in any regeneration scheme.
- The construction sector generates 35% of all waste in the UK; waste reduction is thus a key priority. Waste management has improved considerably, with 73% of waste from construction and demolition recycled as aggregate. Using recycled aggregate in new construction reduces landfill waste and the environmental impacts of new construction. Additionally, recycling materials at the end of houses' lives may reduce the potential to contribute to global warming by 2-3%.
- Refurbishing existing buildings is the best way to reduce waste: this avoids demolition waste and reduces the need for new material, avoiding associated costs of landfill, recycling and new materials.

6 Residents, Communities and Wellbeing

The decision to demolish or refurbish housing clearly has major impacts on residents and the wider community. Regeneration projects broadly aim to improve living and economic conditions, but the means to achieve this and the distribution of costs and benefits are often highly contentious. This section explores the impacts of demolition and refurbishment on residents and communities from a health and wellbeing perspective.

6.1 Wellbeing

The decision to demolish and relocate residents in social housing is contentious and has been debated not only in the UK but elsewhere. Public housing in America carries the same debate (Cooper et al. 2014). Some have called for residents to stay in place, particularly since the early 2000s (Cooper et al. 2014). Evidence on the relationship between housing and wellbeing is emerging but further research in this area is needed before clear conclusions of the relative benefits of refurbishment compared to demolition and rehousing.

A number of frameworks for the assessment of wellbeing exist. Whitehead and Dahlgren's (1991) holistic 'determinants of health and wellbeing' on neighbourhoods has been selected for this review, and is shown in Figure 7

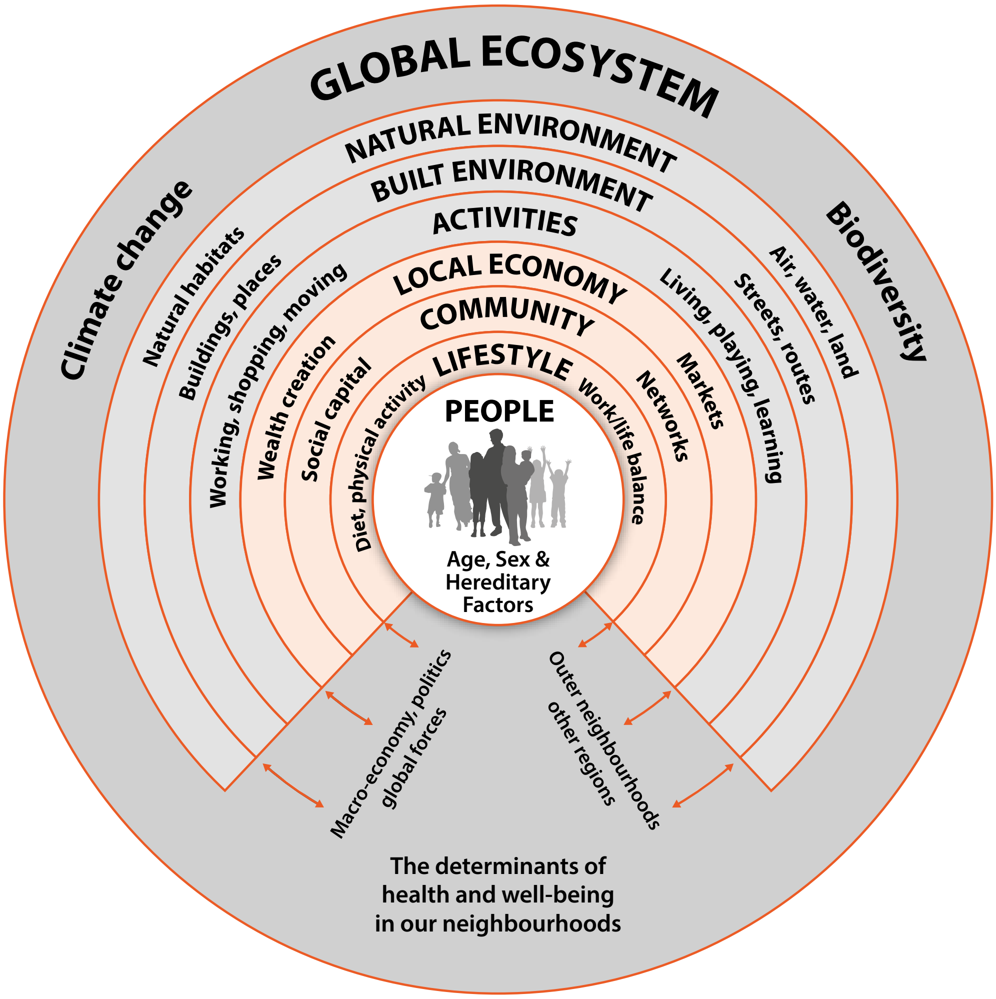


Figure 7. Holistic framework of health and well-being (adapted from Whitehead and Dahlgren (1991))

The six domains outlined in this framework (natural environment, built environment, activities, local economy, community and lifestyle) have been used as indicators against which to collate the literature on demolition or refurbishment.

The literature review is based on searching the PubMed database[19] and personal communication with experts in the field (pers. comm. Peter Craig and Hilary Thomson at SPHSU on 14/05/14, and Matt Egan and Mark Petticrew at LSHTM on 21/05/14).

Relevant results have been summarised using the six domains of wellbeing. A number of search results returned literature related to housing and health and not necessarily demolition or refurbishment, which have been omitted. The literature reviewed included meta-analyses, in-depth case studies and review or comment pieces in peer-reviewed journals and reports.

6.1.1 Natural environment

While this report has focused on the built environment and its relationship to wellbeing, the natural environment also plays an important role. Literature linking demolition and refurbishment to wellbeing from the perspective of the natural environment appears to be limited. Demolition could provide an opportunity for green space in otherwise dense, concrete urban areas. The likelihood of demolition leading to conversion of the land use to green space is debatable given the value of land in inner city areas and this land value as a driving factor for demolition. There appears also to be limited evidence on the short and long term (or intergenerational) impacts on wellbeing of waste entering the natural environment as result of demolition.

6.1.2 Built environment

This section has been divided into internal space, high rise and sense of place.

Internal space

Issues of internal space have been raised by the literature. Positive impacts for people that move into dwellings with more space have been reported (Thomson et al. 2012). However older housing tends to have more generous standards of space than new build (Power 2010); reducing the likelihood that residents will move into larger homes when relocating after demolition.

High rise

There is a lack of research assessing the health effects of changes in housing type on wellbeing (Thomson and Petticrew 2005) with the exception of high rise. While this review found a number of sources looking at the health and wellbeing impacts of high rise housing the findings were mixed.

A number of sources highlight that high rise living has been linked to poor mental health and stressful conditions including social isolation, crime, reduced privacy and a lack of opportunities for children to play safely (Thomson and Petticrew 2005). However other reviews have stressed the limited evidence base, lack of clarity and ability to establish any causal link (Thomson et al. 2012) (Thomson and Petticrew 2005). Findings in this area of literature can also be contradictory, for example, one study found that living in high rise is actually more disadvantageous for adult-only households compared to families or elderly households (Kearns et al. 2012).

Positive impacts of living in high rise further counter the traditional link of high rise to poor wellbeing. Interviews with residents indicate that some enjoy the views and security offered as a result of living on higher floors citing this as their main reason for wanting to stay in their accommodation (Kearns and Darling 2013; Lawson and Egan 2012). In addition, high rise living reduces commuting time (where it is located close to employment) and can ensure sufficient density to support local businesses (Thomson et al. 2012), this can improve social integration (Power 2010).

Sense of place

Two studies commented on the negative impacts demolition has in terms of sense of place. Demolition sites are often unsightly and generate poor perceptions of an area which affects resident morale and local businesses (Power 2010). The physical deterioration associated with demolition sites can also be detrimental for social relations (Mason et al. 2012).

19 Pubmed is a free search engine that can be used to access various medical databases. Search terms can be used to find references and abstracts on topics in life sciences and biomedicine. Twenty seven combinations of search terms were entered into the database, 'demolition and wellbeing' resulted in the largest number of hits (224) although a large number of these were deemed as irrelevant. Demolition, refurbishment, social capital, social networks, social cohesion, health and wellbeing were all searched for in various combinations.

6.1.3 Activities

Although some residents after demolition and relocation report improved educational opportunities (Thomson et al. 2012), demolition can be detrimental to local services and community facilities as a number may leave the area as a result of demolition (Power 2010). One case study looking at demolitions in Chicago noted that demolition and relocation may have net zero effect on education (Jacob 2003). On the other hand, refurbishment of housing has led to reductions in reported absences from school and work (Thomson et al. 2012). Renovation may also be less disruptive as area services can usually continue to operate (Power 2010).

6.1.4 Local economy

Those that move from deprived areas to improved housing in middle-income areas reported an increase in employment opportunities (Thomson et al. 2012) however demolition can negatively affects businesses over a wider area (Power 2010). In comparison renovation and infill building as opposed to large-scale demolition and new build supports local economic development as it involves reinvestment in declining neighbourhoods using small locally based building firms that usually hire local workers. In a context of high rates of economic inactivity in urban areas, despite low official unemployment, this development can generate new jobs, skills and motivation within demoralised communities (BMVBS 2007; Winkler 2007).

There is evidence from research, practitioners and policy makers that refurbishment of buildings significantly contributes to job creation. The Energy Saving Trust's Home Economics Report from 2011 estimates that over 100,000 jobs can be created via the insulation industry for existing housing (Energy Saving Trust 2011). A study commission by the European Climate Foundation in Hungary found that employment benefits are higher when the refurbishment of the building has higher energy saving specifications. Job creation through the refurbishment market will significantly benefit small to medium businesses as these are the ones most involved in refurbishment and retrofitting interventions in the UK (Killip 2013).

6.1.5 Community

This section has been subdivided in line with distinctions made in the literature into: general impacts, perceptions and satisfaction. This review treats the term 'community' as a broad theme covering notions of social capital, social cohesion and networks.

General community impacts

Some studies suggest residents see demolition as an opportunity for a fresh start in a new area with new social relations (Patalia and Rushton 2007). In the GoWell study conducted in regeneration areas of Glasgow, aspects of community were rated higher for those that moved out of the area after demolitions (Go Well 2011) leading to the conclusion that relocation after demolition can stimulate neighbourliness and greater social support (Mason et al. 2012). This evidence runs contrary to the more typical opinion that demolition leads to or further intensifies existing social blight (Lopez 2009); or to the fragmentation of existing communities that hold considerable social value (Power 2010).

It must be emphasised that the balance of evidence is inconclusive on the positive impacts of demolition on communities. In the same GoWell the 'remainers' (the groups of residents that stayed in the area) experienced decline in their social environment with reduced social contact, degradations in levels of trust in each other and a loss in their sense of safety (Mason et al. 2012). However findings are mixed as those that remained also reported a greater sense of social harmony. Residents also expressed increased levels of anxiety when moving away from an area where they had existing social relations. This was in spite of the improvements expected from the demolition (Lawson and Egan 2012). Additional meta-analysis reviews of literature further support this claim (Thomson et al. 2012). Refurbishment case studies have demonstrated an ability to improve social relationships (Lawson and Egan 2012), this is especially particular of warmth improvements (this may be due to improvements in usable space although causal links between warmth improvements and improved social relations are not completely clear), (Thomson et al. 2013; 2009)[20]. Whether and how these impacts might translate into health improvements has yet to be determined (Thomson and Petticrew 2005).

20 Although it should be noted that this could only be because warmth and energy efficiency was studies – there may be additional social benefits from other refurbishment interventions.

Perceptions

Demolition is not always perceived negatively by residents. As already mentioned, some residents have perceived relocation post-demolition as an opportunity for a fresh start and have reported a greater likelihood of being able to make changes such as starting a new job as a result of this new start (Lawson and Egan 2012). Indeed, improvements in general appearance of an area post demolition are linked to increased levels of neighbourhood satisfaction (Petticrew et al. 2009; Kearns and Darling 2013; Go Well 2011). Negative perceptions of an area may also be a driver for residents to be happy to move (Kearns and Darling 2013). In contrast, resident perceptions of an area have also been reported to decline after demolition. This was found in Wave 2 of the Go Well study with the most notable decline being in relation to overall condition, overall space and external appearance of the home (Mason et al. 2012). Residents perception of control is an important factor in overall perceptions of demolition, the Go Well study found people were less satisfied with demolition and relocation if they had a limited capacity to make choices. One study noted how residents often felt the decision to demolish had already been made when they were consulted (Kearns and Darling 2013), this could affect satisfaction as residents may have already resigned to the notion of demolition. The temporal relationship between demolition and resident perception and satisfaction is of interest, however few studies have mapped how this changes over time – this may be an area worth exploring in further detail.

Satisfaction

Living in an area of poverty or decline can have a self-perpetuating effect on resident satisfaction (Davidson et al. 2008) and may be a reason why those that relocate have positive perceptions of demolition. As already mentioned, there are a limited number of case studies assessing perceptions of refurbishment works post-completion. Some studies have sought to understand which aspects of regeneration have the biggest impact on resident perception. One report found that the extent to which residents view demolition or refurbishment negatively depends in their own housing intentions, the process of movement and degree of control they have and their own personality and disposition (Lawson and Egan 2012).

6.1.6 Lifestyle

This section focuses on health indicators and has been divided into physical and mental health. Evidence on the links between general housing quality and health is emerging. The BRE Trust commissioned a report to create a methodology of calculating the health costs of poor housing. The report found that if works were done targeting the worst health and safety hazards in the poorest homes in the UK the NHS could make savings of £56 million a year (Garrett et al. 2014). Tyler et al. (2012) have also tried to value and estimate the expenditures on community development and homelessness.

The specific health impacts of demolition or refurbishment also remain poorly understood (Thomson et al. 2012). Positive impacts of relocation following demolition on self-reported health are small (Petticrew et al. 2009), although studies suggest this may be because evidence has been measured using time periods that are too short: longer term studies may show greater health impacts (Thomson et al. 2007). There is uncertainty around who benefits from demolition: some studies report increased improvements in health but do not highlight that this increase is experienced by a different population (Thomson et al. 2012).

The health impact of demolition on the elderly has been described as negative (Power 2010) with the importance of being able to age in place emphasised (Windle et al. 2006). Indeed, the announcement of demolition has been shown to have a detrimental impact on health. One study recorded the changes in GP consultation after announcement of demolition, claiming that after adjustments had been made for other changes in health that consultations increased by 20% (Halpern and Reid 1992). The process of moving has been described as a stressful and health damaging event by some literature, this is compounded if residents are not fully informed due to a sense of uncertainty and lack of control (Thomson and Petticrew 2005).

Refurbishment generally tends to have more positive association with health with few reports showing adverse effects of refurbishment (Fenwick et al. 2013; Thomson et al. 2009). A number of studies have measured the effects of warmth and energy efficiency improvements on health and have shown these to be positive post completion of the works (Bryson et al. 2007; Chapman et al. 2012; Gilbertson and Green 2008; Howden- Petticrew et al. 2009; Thomson et al. 2012).

Physical health

While links between housing and general health has been covered in limited detail there are fewer studies that link health impacts of demolition or refurbishment to specific physical conditions most probably due to the difficulties around measurement. Respiratory health is often discussed in this area. Most studies seem to link warmth and energy efficiency refurbishment with positive effects on respiratory health (Thomson et al. 2012) although some have highlighted negative impacts and emphasise the conflicting evidence (Thomson and Petticrew 2005).

Mental health

The WHO report mental health issues to be one of the world's biggest diseases. The relationship between mental health and housing it is poorly researched and some have called for this to be outlined as a new field in research (Popkin et al. 2002).

The evidence around the impacts of demolition and refurbishment tends to favour refurbishment. Positive links between demolition and improved psychosocial health have been found in the Go Well study in Glasgow (Go Well 2011). A study of residents in Atlanta found significant improvements in depressive symptoms for those that relocated although they stress the validity of this evidence as they had no control group to compare these depressive symptoms with (Cooper et al. 2014).

These positive links are countered by a number of studies. Deterioration in feelings of vitality, increase in self-reported stress, anxiety and depression have been acknowledged in existing literature reviews, particularly when feelings of control are limited (Mason et al. 2012). A lack of information and control leads to uncertainty and feelings of powerlessness by residents which have knock on impacts on mental health (Bryson et al. 2007; Cole and Flint 2007).

In contrast many studies have reported positive impacts on mental health post-refurbishment works (Thomson et al., 2012). There are a number of reports analysing the impacts of the Warm Front Scheme on mental health, all of which found positive improvements of mental health for residents (Gilbertson and Green 2008; Howden-Chapman and Chapman 2012; Webb et al. 2013).

Box 15: Go Well Project, Glasgow

Go Well is a research programme investigating the effects of housing renewal strategies in Glasgow on the health and wellbeing of communities. It is collaboration between Glasgow Centre for Population Health, the University of Glasgow and the MRC/CSO Social and Public Health Sciences Unit.

The programme is planned to take place over the course of 10 years (2005 – 2015), this provides opportunities for much needed studies into health and wellbeing that take place over a longer term period. A large number of studies have already been published and can be found online at http://www.gowellonline.com/.

The studies focus on six regeneration areas in Glasgow and compare impacts between 2 cross sectional samples of residents. The 'outmovers' are those residents that have moved out of the regeneration areas and the 'remainers' are those that have lived in the same regeneration area since 2006. As part of the regeneration strategy 19,100 demolitions are planned.

6.1.7 Discussion

A number of issues have emerged as a result of conducting this review.

Weak evidence base

This review has highlighted the weak evidence base linking the impacts of demolition and refurbishment to resident wellbeing. Although this study has found some sources indicating impacts of demolition and refurbishment on wellbeing many of these sources, particularly those that conducted systematic literature reviews, noted that the evidence base linking housing improvement to health is weak (Petticrew et al. 2009). Additionally, the 'extreme heterogeneity' and poor quality of data limits opportunities to synthesise existing data and while the quantity of studies has increased in recent years – albeit marginally - the difficulty in synthesising remains (Thomson et al., 2001; 2006; 2009; 2013). The impacts of warmth and energy efficiency improvements in health has is being increasingly reported most probably due to the growing interest at a government level in retrofit as a means to curb the impact of the contribution of existing housing to GHG emissions.

Housing renewal, demolition and refurbishment are poorly distinguished

There was difficulty distinguishing between refurbishment and demolitions when reviewing some of the literature. Many sources include housing demolition as part of their assessment of housing improvements thus making it difficult to draw any clear conclusion. This was the case with a number of sources that were systematic reviews including Thomson et al. (2012) and Thomson and Petticrew (2005).

Short term vs long term

A number of sources indicate the differences in long term and short term health impacts and the need to distinguish between them. One study describes their inability to detect long term health impacts as a limitation and recommends more studies with longer follow up periods (Thomson et al. 2013). This study also recommends looking at impacts on socio economic determinants of health as a valuable indication of the potential for longer term health impacts. The long term and short term health impacts may be an important distinguishing factor when considering demolition or refurbishment.

Evidence gaps

There were a number of gaps in the literature which again supports the idea that this area of research lacks clarity. This is particularly apparent in the literature discussing the impacts of high rise on wellbeing.

Box 16: Fusion 21, Merseyside

Fusion 21 are a procurement consortium based in the Wirral, Merseyside. They provide training and skills to the local community in retrofitting buildings. For example, their work with the Helena Partnership generated 119 jobs: http://www.fusion21.co.uk/case-studies/procurement/helena-partnerships-founder-member/

6.2 Resident empowerment and involvement

Studies advocate for improved community engagement in housing renewal projects and that this is an essential component in ensuring residential wellbeing. This was emphasised in a number of reports reviewed through the WHO survey on housing and health (Thomson and Petticrew 2005).

Studies linking mental health to regeneration strategies – both for demolition and refurbishment - have noted the stress and anxiety invoked on residents as a result of poor or little information and uncertainty in regeneration plans for the area (Bryson et al. 2007; Cole and Flint 2007; Halpern and Reid 1992; Kearns et al. 2012; Mason et al. 2012).

A number of case studies demonstrate this:

- Residents in East Baltimore reported a lack of notifications and awareness around the plans for large scale urban development, this prompted a report into residential demolition practices (Bowie et al. 2005)
- The majority of tenants interviewed as part of one of the Go Well studies had not been involved in the consultation process on plans for the area. Most residents seemed surprised about being asked whether they had been involved in demolition proposals and options for the area as they saw this something the Glasgow Housing Association would decide. A number of residents felt the decision to demolish had already been taken and that their participation in meeting would not have made any difference (Egan and Lawson 2012; Kearns and Darling 2013).

This lack of involvement by residents has tentatively been suggested as a failure to empower residents and achieve any sense of community ownership from the housing improvement process (Kearns and Lawson 2009).

Information campaigns have been shown to be an important component when involving residents (Lawson and Egan 2012; Popkin et al. 2002; Howden-Chapman et al. 2005). However there are additional barriers to community participation that must be considered (Marmot 2010).

Addressing the concerns of residents reduces the negative short term impacts on mental health and helplessness (Egan and Lawson 2012) while also contribute in the long term to more sustainable communities (Howden-Chapman and Chapman 2012). It is in the interest of policy makers, local authorities, social landlords and others responsible for the implementation of renewal schemes to consider such issues. Failure to do so limits the capacity of urban renewal schemes in improving communities (Huxley et al. 2004).

Box 17: Hope IV, USA

The HOPE VI housing plan is a scheme instigated by the US department of housing and urban development in 1992 and still in operation. Its aim is to regenerate social housing projects in America that are considered to be the worst in the country. A core driver of the scheme is to relocate residents from this housing into mixed-income developments. A number of sources found in this review studied HOPE projects in different US cities and have come to various conclusions.

- A report on the demolition of public housing in Atlanta under the HOPE VI project found that while there was strong support for demolition and redevelopment from HUD department and Atlanta city officials, there was also strong opposition from public housing resident groups. Despite this opposition plans were approved for the demolition (Oakley et al. 2013). While the study did found that residents were happy with their housing improvements post relocation it also advises policy makers that resident satisfaction is not linked to perception of neighbourhood level characteristics. This supports the arguments against displacement of communities as a result of demolition.
- Another study identified the concern residents had as to how they were treated as a group of public housing tenants. The level of appropriate treatment from authorities affected residents overall satisfaction with the scheme. This was found to be of greater priority than their individual situations and outcomes (Goetz 2013).
- Some respondents in studies have also been found to express a wish to return to the regenerated development post completion. This was more likely to be the case for residents who had been living there longer, were receiving disability benefits or were older. Confusion, suspicions and mistrust were identified as major challenges at different HOPE schemes. Further research into the mental health impacts associated with displacement and relocation were recommended (Popkin et al. 2002).

6.3 Health inequalities

Poor housing quality has long been known to have a negative impact on the health of individuals and the public. The analysis of health inequalities in the UK shows reduced life expectancy and poorer health outcomes for those on lower incomes in the UK compared to those who are better off. The Marmot Review was one of the key reports analysing this problem, and strongly advocates improving existing housing conditions as a means to reduce health inequalities in society (Marmot 2010)

Various studies reviewed for this report also highlighted the potential housing interventions carry in reducing health inequalities (Thomson et al. 2009; Macintyre et al. 2003). However, failure to report the differential impacts of housing interventions on social and economic inequalities makes current evidence base in this area weak (Thomson et al. 2013). This is important to note for future studies into the impact on housing improvements.

6.4 Key messages

It is difficult to draw clear cut conclusion in favour of refurbishment or against demolition as a result of this review. This is due to the poor evidence base as indicated by a number of well-regarded sources along with limited reliability and poor distinctions between demolition and refurbishment.

While the community impacts of demolition and refurbishment are especially mixed the lack of adverse health impacts of refurbishment on mental and physical health indicators provides additional support for housing improvements favouring refurbishment over demolition.

Understanding the impact of demolition or refurbishment on residents is complex as health and wellbeing is broad and interdependent on many different factors. Most of the studies surveyed have addressed this and made clear that there is an apparent gap in understanding this. Much needed research is needed to clarify mixed findings and ambiguity on the literature.

Refurbishment increases comfort for the individual. Reports show improved physical and mental health as a result of refurbishment, particularly around energy based improvements. At the community level, reports suggest a reduced sense of isolation and that social capital can be maintained as a result of refurbishment. However this is not always guaranteed particularly if the neighbourhood and surroundings remain in decline. Housing improvements have to take place alongside other area based interventions in order to be truly effective and to reach maximum potential. Such an approach requires multidisciplinary collaboration with different departments in local authorities working together.

There is some evidence that relocation post demolition can improve wellbeing, particularly if the resident moves to an area with improved socio economic characteristics. Challenges have also been made to traditional perceptions of breaking up community networks as a result of demolition with some studies showing an improvement in social relations. However, demolition and relocation can also compromise the mental health of residents with evidence of increased reporting in stress, anxiety and depression post demolition. This stress is linked to feelings of powerlessness and the lack of control or opportunity to engage with the housing authority about the move.

This suggests that involvement of the community in the decision making process, regardless of the outcome, is essential in order to reduce impacts on wellbeing, particularly mental health. Social factors therefore must be incorporated into the decision making process.

7 Conclusions

The case studies and evidence reviewed in this report indicate that refurbishment of social housing can deliver significant improvements in energy, environmental and health performance, leading to costs savings and improved living standards for residents. The overall lifetime costs of refurbishment may be lower than demolition and construction, with less disruption to local communities and residents. Engaging residents in regeneration decisions has resulted in successful refurbishment of a number of hard to treat social housing properties and estates in different parts of the UK.

7.1 Evaluating the economic case for refurbishment

Estimating the costs and impacts of refurbishment or demolition is complex, uncertain and subjective. The typical cost indicators used in assessment refurbishment and demolition projects are: *capital expenditures* or CAPEX (the cost of fixed assets); *operational expenditures* or OPEX (the costs of goods and services); and *capital investment appraisal* (understanding the value of an investment over time).

As more experience has been gained in managing repairs and maintenance, management risks are easier to estimate, although estimating maintenance remains difficult. Key issues for management of repairs and maintenance include:

- allocating resources to the most appropriate stock;
- delivery of maintenance programme on time and on budget;
- controlling responsive repair work;
- involving tenants and leaseholders in decisions; and
- managing and monitoring performance.

There is a growing body of research suggesting that extending the lifecycle of buildings by refurbishment is preferable to demolition in terms of improved environmental, social and economic impacts.

In the literature covered by this review, benefits to residents are mainly confined to assessment of potential reductions in bills or improved thermal comfort. This means that the performance gap (differences between predicted and actual performance of buildings) and the rebound effect (where people adapt their behaviour in ways that increase consumption after an energy efficiency project) both of which would reduce projected savings are not included in the modelling. Where future savings are over-estimated, it is the occupants who are penalised, firstly, because what is promised is not delivered and, secondly, because they pay the energy bills By contrast, there is usually no automatic or direct penalty for designers, developers or facilities managers whose buildings do not perform as they predicted. The limited scope of such assessments in the literature is partly due to a lack of quantitative monitoring of before and after refurbishment projects, and of qualitative work on occupant behaviour.

There are also difficulties in estimating the costs and impacts on residents, particularly around: quantifying tangible returns; valuing future savings; and the complex interaction of individual and institutional behaviours. Key issues affecting residents include:

- delays in refurbishment and demolition work (which generally takes longer than expected);
- moving residents during works taking place (there is little comprehensive data on the cost or time involved);
- complications of mixed tenure and sharing costs fairly between residents and over a wide variety of occupancy periods.
- The costs of rehousing tenants, the time taken to do so, and the resulting pressure on other local housing resources should be included in economic analysis of demolition compared to refurbishment.

Assessing the impacts on wider society remains difficult. Key issues are:

- the environmental costs of waste disposal
- the social or market costs of carbon
- longer-term impacts of refurbishment or demolition

Further work is needed to gather more data and analysis in all these areas.

The UK supply chain and retrofit market is under-developed and suffers from increased risk due to lack of knowledge. There are a variety of technical, economic, and social risks and hidden costs associated with refurbishment. Prices and perceived risks amongst architects and designers, owners, investors and developers are all factors in the undeveloped supply chain and market. There is a need for a change in perceptions, awareness and behaviour throughout the supply chain, supported by appropriate policy frameworks.

Tenure types and management capacity, in particular the different skills and priorities of landlords, affects how costs and risks are shared between investors and occupants; how refurbishment can be financed; how savings can be realised by tenants; and how energy-saving behaviour can be encouraged. Particular issues include recovering investments through rent, and the tension between short-term tenures and long payback periods for energy efficiency.

Access to finance and willingness to invest in refurbishment: the risk of current costs and uncertain future savings mean there is a reluctance to both lend and borrow. Grants, subsidies and guaranteed loans could address this.

There is a need to address the capacity, willingness and confidence to make and explain decisions about refurbishment and demolition and to invest in refurbishment on the part of tenants, housing associations, developers and lenders. In part, this can be tackled through: collecting more data on costs; undertaking further analysis of the impacts of different scenarios on different peoples and places over time ('do nothing' / refurbishment / development); and research into behavioural and technical realities and wellbeing outcomes of living through refurbishments to inform other projects.

7.2 Improving energy performance and reducing carbon emissions

Residential buildings generate greenhouse gas (GHG) emissions through two processes: occupants' use of a building (*operational energy*); and the extraction, manufacture and transportation of materials for a building's construction and demolition (*embodied energy*). The greatest impacts on global warming are likely to be through the energy consumption and emissions of a building during its lifetime rather than its construction and demolition. However **the embodied energy of a building will become more significant** as the UK achieves more stringent building standards and takes steps to decarbonise electricity generation.

Current buildings standards mean that newly constructed homes are likely to be more energy efficient than older buildings but this does not automatically mean that their occupants will use less energy than those in older buildings. However refurbishment of buildings can achieve similar levels of energy performance to new buildings whilst avoiding the GHG emissions of demolition and construction of new buildings. Major refurbishments of existing residential buildings will need to comply with nearly zero energy emission standards from 2016.

The operational energy of residential buildings contributes 23% of the UK's greenhouse gas emissions. Retrofitting to reduce energy consumption can also deliver other benefits, including reduced fuel bills and increased thermal comfort, and can be done by:

- Improving energy performance through improvements to the building fabric, installing more efficient appliances and controls, and improving occupant understanding of how energy is used in the home;
- Switching fuel sources, such as using renewable resources on-site to generate heat or power, or connecting to neighbourhood energy supplies such as low carbon heat networks.

7.3 Water and waste

The environmental impacts of refurbishment compared to demolition are not only about energy and carbon, but also about the environmental impacts of the production of water, concrete, steel, timber, glass and many other materials used in the construction of new buildings, and the impact of the waste that is generated through demolition and construction.

Water is often overlooked in regeneration schemes but is a vital issue in terms of: how it is used in construction; how it is used by residents; and how sewage and storm water are dealt with. Water efficiency should be considered both in designs for new buildings and in refurbishment programmes. In London – a water-scarce region – average water consumption is 162 litres per person per day. Reducing the amount of water used by individuals and by the construction industry will help to alleviate pressure on scarce resources. Improvement of water management in housing estates will also benefit communities and better management of storm water using green infrastructure to tackle runoff can create local green spaces with advantages for residents' health and for biodiversity.

The construction sector generates 35% of all waste in the UK; waste reduction is thus a key priority. Waste management has improved considerably, with 73% of waste from construction and demolition recycled as aggregate. Using recycled aggregate in new construction reduces landfill waste and the environmental impacts of new construction. Additionally, recycling materials at the end of houses' lives may reduce the potential to contribute to global warming by 2-3%. Refurbishing existing buildings is the best way to reduce waste: this avoids demolition waste and reduces the need for new material, avoiding associated costs of landfill, recycling and new materials.

7.4 Social factors

Understanding the impact of demolition or refurbishment on residents is complex, as health and wellbeing are broad and interdependent on many different factors. Because wellbeing is a highly subjective concept, it can be used to support cases for demolition even where strong evidence is lacking. Further research into the impacts of demolition and refurbishment on wellbeing is therefore needed.

There is evidence to show improved physical and mental health as a result of refurbishment, particularly around energy based improvements. At the community level, refurbishment can lead to a reduced sense of isolation and maintenance of social capital. However, these positive impacts are undermined if the neighbourhood and surroundings remain in decline. Housing improvements need to take place alongside other area-based interventions in order to be truly effective and to reach maximum potential. Such an approach requires multidisciplinary collaboration with different departments in local authorities and other stakeholders working together.

Whilst refurbishment has been shown to improve individual mental and physical health, it is also important to bear in mind unintended consequences, such as retrofitting ventilation units leading to poorer indoor air quality which can have a detrimental impact on respiratory health.

There is some evidence that relocation after demolition can improve wellbeing. However, demolition and relocation can also compromise the mental health of residents, with increased reporting in stress, anxiety and depression post demolition. This stress is linked to feelings of powerlessness and the lack of control or opportunity to engage with the housing authority about the move.

The retrofit industry and the decentralisation of energy offer considerable opportunities for local development and community engagement, which in turn can lead to local regeneration, lower energy costs, generation of local income, and improved trust:

- Refurbishment of buildings significantly contributes to job creation
- Small and medium businesses involved in refurbishment and retrofitting in the UK can particularly benefit;
- Employment benefits have been shown to be higher when the refurbishment of the building has higher energy saving specifications.

Involvement of the community in the decision making process, regardless of the outcome, is essential in order to reduce impacts on wellbeing, particularly mental health. This should include actively engaging residents so that they feel a sense of ownership and participation and keeping them fully informed of the process.

8 References

Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T., 2005. A review of intervention studies aimed at household energy conservation. J. Environ. Psychol. 25, 273–291. doi:10.1016/j.jenvp.2005.08.002

AECOM, 2012. Investigation into Overheating in Homes: Literature Review.

Audit Commission, 2002. Learning from Inspection: HOUSING REPAIRS AND MAINTENANCE.

Basbagill, J., Flager, F., Lepech, M. & Fischer, M. 2013. Application of life-cycle a ssessment to early stage building design for reduced embodied environmental impacts. Building and Environment, 60, pp 81-92.

Bates, K., Lane, L., Power, A., 2012. The social implications of energy efficiency retrofit in large multi-storey tower blocks. London.

Boardman, B., Darby, S., Killip, G., Hinnells, M., Jardine, C.N., Palmer, J., Sinden, G., 2005. Chapter 9 Achieving the 40% House scenario, in: 40% House. Environmental Change Institute, Oxford.

Bowie, J., Farfel, M., Moran, H., 2005. Community experiences and perceptions related to demolition and gut rehabilitation of houses for urban redevelopment. J. Urban Health Bull. N. Y. Acad. Med. 82, 532–42. doi:10.1093/jurban/jti075

BRE, Energy Saving Trust, 2012. Refurbishing the Nation: Gathering the Evidence. Watford.

BRE on behalf of DECC, 2011. The Government's Standard Assessment Procedure for Energy Rating of Dwellings: 2009 edition incorporating RdSAP 2009.

Briller, D., 2013. Adapting to a New Reality "Strategies for Building Energy Design in a Changing Climate". Strateg. Plan. Energy Environ. 33, 7–65.

Bryson, J., Higgins, A., Hood, M., 2007. Commission on Housing Renewal and Public Health Final Report.

Buckwell, O., 2012. Wilmcote House Cladding and Refurbishment. Portsmouth City Council.

Bull, J., Kimpian, J., Mumovic, D., 2013. Parametric models for predicting life cycle energy, cost, and carbon implications of refurbishment in schools and offices. Presented at the CIBSE Technical Symposium, CIBSE, Liverpool John Moores University, Liverpool.

CAMCO, 2011. Retrofit South East: Project Summary Report.

CIBSE, 2008. CIBSE Guide M: Maintenance Engineering and Management. CIBSE.

Cole, I., Flint, J., 2007. DEMOLITION , RELOCATION AND AFFORDABLE REHOUSING Lessons from the Housing Market Renewal Pathfinders. Sheffield.

Cooper, H.L.F., Hunter-Jones, J., Kelley, M.E., Karnes, C., Haley, D.F., Ross, Z., Rothenberg, R., Bonney, L.E., 2014. The aftermath of public housing relocations: relationships between changes in local socioeconomic conditions and depressive symptoms in a cohort of adult relocaters. J. Urban Health Bull. N. Y. Acad. Med. 91, 223–41. doi:10.1007/s11524-013-9844-5

Darby, S., 2001. Making it Obvious: Designing Feedback into Energy Consumption, in: Energy Efficiency in Household Appliances and Lighting. pp. 685–696.

Davies, M., Oreszczyn, T., 2012. The unintended consequences of decarbonising the built environment: A UK case study. Energy Build. 46, 80–85. doi:10.1016/j.enbuild.2011.10.043

Davies, P., Osmani, M., 2011. Low carbon housing refurbishment challenges and incentives: Architects' perspectives. Build. Environ. 46, 1691–1698. doi:10.1016/j.buildenv.2011.02.011

Debizet, G., 2012. Public authorities challenge to implement energy renovation of condominium buildings in France, in: COBRA 2012. Presented at the The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors, RICS 2012, Las Vegas, Nevada USA by Arizona State University.

DECC, 2013a. *Detailed analysis from the second phase of the Energy Saving Trust's heat pump field trial*,

DECC, 2013b. The Future of Heating : Meeting the challenge. , (March).

DECC, 2013. The Future of Heating : Meeting the challenge.

DECC, 2014. Implementing the Energy Efficiency Directive as it applies to the metering and billing of heating and cooling.

Department for Communities and Local Government, 2013. Next steps to zero carbon homes - Allowable Solutions (Consultation). London.

Department of Energy & Climate Change, 2014. Standard Assessment Procedure - Detailed guidance [WWW Document]. URL https://www.gov.uk/standard-assessment-procedure (accessed 4.28.14).

Dimitriou, T., Teli, D., James, P.A.B., Bahaj, A., Ellison, L., Waggott, A., 2014. Impact of current occupant behaviour on potential carbon savings in a council owned tower block undergoing retrofit. Presented at the CIBSE ASHRAE Technical Symposium, CIBSE, Dublin, p. 12.

Dixit, M.K., Culp, C. H. & Fernández-Solís, J. L. 2013. System boundary for embodied energy in buildings: A conceptual model for definition. Renewable and Sustainable Energy Reviews, 21, pp 153-164.

Druckman, a., Jackson, T., 2008. Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model. Energy Policy 36, 3177–3192. doi:10.1016/j.enpol.2008.03.021

Egan, M., Lawson, L., 2012. Residents ' perspectives of health and its social contexts Qualitative findings from three of Glasgow ' s Transformational Regeneration Areas February 2012. Glasgow.

Ferreira, J., Manuel|de Pinheiro,Jorge, 2013. Refurbishment decision support tools reviewâ "Energy and life cycle as key aspects to sustainable refurbishment projects. Energy Policy 62, 1453–1460.

Galvin, R., 2014. Making the "rebound effect" more useful for performance evaluation of thermal retrofits of existing homes: Defining the "energy savings deficit" and the "energy performance gap". Energy Build. 69, 515–524. doi:10.1016/j.enbuild.2013.11.004

Garrett, H., Davidson, M., Nicol, S., Roys, M., Summers, C., 2014. The cost of poor housing in London.

Goetz, E.G., 2013. Too Good to be True? The Variable and Contingent Benefits of Displacement and Relocation among Low-Income Public Housing Residents. Hous. Stud. 28, 235–252. doi:10.1080/02673037.2013.767884

Gokce, H.U., Gokce, K.U., 2013. Holistic system architecture for energy efficient building operation. Sustain. Cities Soc. 6, 77–84.

Gram-Hanssen, K., 2014. Existing buildings – Users, renovations and energy policy. Renew. Energy 61, 136–140. doi:10.1016/j.renene.2013.05.004

Halpern, D.S., Reid, J., 1992. Effect of unexpected demolition announcement on health of residents. BMJ 304, 1229–30.

Hamilton, I.G., Shipworth, D., Summerfield, A.J., Steadman, P., Oreszczyn, T., Lowe, R., 2014. Uptake of energy efficiency interventions in English dwellings. Build. Res. Inf. 42, 255–275. doi:10.1080/09613218.2014.867643

Hawkey, D., Webb, J., Winskel, M., 2013. Organisation and governance of urban energy systems: district heating and cooling in the UK. J. Clean. Prod. 50, 22–31. doi:10.1016/j.jclepro.2012.11.018

Hawkey, D.J.C., 2012. District heating in the UK: A Technological Innovation Systems analysis. Environ. Innov. Soc. Transit. 5, 19–32. doi:10.1016/j.eist.2012.10.005

Hong, S.H., Oreszczyn, T., Ridley, I., 2006. The impact of energy efficient refurbishment on the space heating fuel consumption in English dwellings. Energy Build. 38, 1171–1181. doi:10.1016/j.enbuild.2006.01.007

Howden-Chapman, P., Chapman, R., 2012. Health co-benefits from housing-related policies. Curr. Opin. Environ. Sustain. 4, 414–419. doi:10.1016/j.cosust.2012.08.010

Howden-Chapman, P., Crane, J., Matheson, a, Viggers, H., Cunningham, M., Blakely, T., O'Dea, D., Cunningham, C., Woodward, a, Saville-Smith, K., Baker, M., Waipara, N., 2005. Retrofitting houses with insulation to reduce health inequalities: aims and methods of a clustered, randomised community-based trial. Soc. Sci. Med. 1982 61, 2600–10. doi:10.1016/j.socscimed.2005.04.049

Huxley, P., Evans, S., Leese, M., Gately, C., Rogers, A., Thomas, R., Robson, B., 2004. Urban regeneration and mental health. Soc. Psychiatry Psychiatr. Epidemiol. 39, 280–5. doi:10.1007/s00127-004-0739-3

Johnson, E.P., 2011. Air-source heat pump carbon footprints: HFC impacts and comparison to other heat sources. *Energy Policy*, 39(3), pp.1369–1381. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0301421510008906 [Accessed May 28, 2014].

Joseph Rowntree Foundation, 1995. Housing associations, private finance and market rents: Housing Research 154.

Kearns, A., Darling, L., 2013. " Getting a move on ": Tenant experiences of the rehousing process in Transformational Regeneration Areas.

Kearns, A., Lawson, L., 2009. (De)constructing a policy "failure": housing stock transfer in Glasgow. Evid. Policy J. Res. Debate Pract. 5, 449–470. doi:10.1332/174426409X478789

Kearns, A., Whitley, E., Mason, P., Bond, L., 2012. "Living the High Life"? Residential, Social and Psychosocial Outcomes for High-Rise Occupants in a Deprived Context. Hous. Stud. 27, 97–126. doi:10.1080/02673037.2012.632080

Kohler, N., Wei, 2007. Long-term management of building stocks. Build. Res. Inf. 35, 351–362.

Konstantinou, T., Knaack, U., 2011. Refurbishment of Residential Buildings: A Design Approach to Energy-Efficiency Upgrades. Procedia Eng. 21, 666–675. doi:10.1016/j.proeng.2011.11.2063

Lawson, L., Egan, M., 2012. Residents ' lived realities of transformational regeneration February 2012 Phase 1 findings 1–32.

Love, J., 2013. The impact of the CESP scheme on a set of case study households.

Lowe, R., 2007. Technical options and strategies for decarbonizing UK housing. Build. Res. Inf. 35, 412–425. doi:10.1080/09613210701238268

Macintyre, S., Ellaway, A., Hiscock, R., Kearns, A., Der, G., McKay, L., 2003. What features of the home and the area might help to explain observed relationships between housing tenure and health? Evidence from the west of Scotland. Health Place 9, 207–18.

Marmot, 2010. Fair Society , Healthy Lives.

Mason, P., Kearns, A., Coyle, J., Mckee, M., Neary, J., 2012. Sticking with it ? Glasgow.

Milne, G., Boardman, B., 2000. Making cold homes warmer : the e ! ect of energy e $ ciency improvements in low-income homes 28.

Monahan, J. & Powell, J.C. 2011. An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework. Energy and Buildings, 43(1), pp 179-188.

Moncaster, A.M. & Symons, K.E. 2013. A method and tool for 'cradle to grave' embodied carbon and energy impacts of UK buildings in compliance with the new TC350 standards. Energy and Buildings, 66, pp 514-523.

Munton, T., Wright, A., Mallaburn, P., Boait, P., 2014. How heating controls affect domestic energy demand : A Rapid Evidence Assessment. A report to the Department of Energy and Climate Change. London.

Oakley, D., Ruel, E., Reid, L., 2013. Atlanta's Last Demolitions and Relocations: The Relationship Between Neighborhood Characteristics and Resident Satisfaction. Hous. Stud. 28, 205–234. doi:10.1080/02673037.2013.767887

Palmer, J., Cooper, I., 2012. UK housing energy fact file. London.

Patalia, R., Rushton, J., 2007. The Sustainable Refurbishment of High Rise Housing, in: Proc. Int. Conf: Sustainable Construction Materials and Technologies. UW Milwaukee, Coventry, pp. 122–129.

Petticrew, M., Kearns, A., Mason, P., Hoy, C., 2009. The SHARP study: a quantitative and qualitative evaluation of the short-term outcomes of housing and neighbourhood renewal. BMC Public Health 9, 415. doi:10.1186/1471-2458-9-415

Popkin, S.J., Levy, D.K., Harris, L.E., Cunningham, M.K., Buron, L., Associates, A., Woodley, W., 2002. HOPE VI Panel Study : Baseline Report with HOPE VI Panel Study : Baseline Report. Washington.

Power, A., 2008. Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability? Energy Policy 36, 4487–4501. doi:10.1016/j.enpol.2008.09.022

Pyrko, J., Darby, S., 2010. Conditions of energy efficient behaviour—a comparative study between Sweden and the UK. Energy Effic. 4, 393–408. doi:10.1007/s12053-010-9099-x

Ramesh, T., Prakash, R. & Shukla, K.K., 2010. Life cycle energy analysis of buildings: An overview. Energy and Buildings, 42(10), pp 1592-1600.

Rankohi, S., Lloyd, 2013. Review and analysis of augmented reality literature for construction industry. Vis. Eng. 1, 9–18.

RICS. 2012. Methodology to calculate embodied carbon of materials- RICS information paper [online]. 1st ed. Coventry. Available from: http://www.rics.org/Documents/Methodology_embodied_carbon_final.pdf [Accessed 24 May 2014]

Roys, M., Davidson, M., Nicol, S., Ormandy, D., Ambrose, P., 2010. The real cost of poor housing. BRE, IHS BRE Press, Watford.

Shove, E., 2010. Beyond the ABC: climate change policy and theories of social change. Environ. Plan. A 42, 1273–1285. doi:10.1068/a42282

Shove, E., Walker, G., Brown, S., 2014. Material culture, room temperature and the social organisation of thermal energy. J. Mater. Cult. 19, 113–124. doi:10.1177/1359183514525084

Sorrell, S., Dimitropoulos, J., Sommerville, M., 2009. Empirical estimates of the direct rebound effect: A review. Energy Policy 37, 1356–1371. doi:10.1016/j.enpol.2008.11.026

Sustainable Homes. 2014. Embodied Energy in Residential Property Development - A Guide for Registered Social Landlords [online]. Available from: http://www.sustainablehomes.co.uk/Portals/63188/docs/Embodied%20Energy.pdf [Accessed 24 May 20014]

Swan, W., Ruddock, L., Smith, L., 2013. Low carbon retrofit: attitudes and readiness within the social housing sector. Eng. Constr. Archit. Manag. 20, 522–535. doi:10.1108/ECAM-12-2012-0112

Sweetnam, T., Croxford, B., 2011. A carbon, energy and cost assessment of whether to refurbish or rebuild aging UK residential blocks. Presented at the CIBSE Technical Symposium, DeMontfort University, p. 16.

Technology Strategy Board, 2014. Retrofit for the future: Reducing energy use in existing homes. Swindon.

The Future of Heating : A strategic framework for low carbon heat in the UK, 2012.

Thomsen, A., van der Flier, K., 2011. Understanding obsolescence: a conceptual model for buildings. Build. Res. Inf. 39, 352–362.

Thomsen, A., van der Flier, K., 2012. Housing obsolescence in practice; a pilot study. Presented at the ENHR 2012 Conference "Housing: Local Welfare and Local Markets in a Globalised World," Lillehammer, Norway.

Thomson, H., Atkinson, R., Petticrew, M., Kearns, A., 2006. Do urban regeneration programmes improve public health and reduce health inequalities? A synthesis of the evidence from UK policy and practice (1980-2004). J. Epidemiol. Community Health 60, 108–15. doi:10.1136/jech.2005.038885

Thomson, H., Macdonald, C., Higgins, M., Palmer, S., Douglas, M., 2012. Health Impact Assessment of Housing Improvements : A Guide. Glasgow.

Thomson, H., Petticrew, M., 2005. Is housing improvement a potential health improvement strategy ?

Thomson, H., Petticrew, M., Morrison, D., 2001. Health effects of housing improvement: systematic review of intervention studies. BMJ 323, 187–90.

Thomson, H., Thomas, S., Sellstrom, E., Petticrew, M., 2009. The health impacts of housing improvement: a systematic review of intervention studies from 1887 to 2007. Am. J. Public Health 99 Suppl 3, S681–92. doi:10.2105/AJPH.2008.143909

Thomson, H., Thomson, S., Sellstrom, E., Petticrew, M., 2013. Housing improvements for health and associated socio-economic outcomes Cochrane Database of Systematic Reviews, 2. London.

Trim, M.J.B., 1992. High rise housing—A survey of the stock and some methods of refurbishment. Build. Res. Inf. 20, 171–175. doi:10.1080/09613219208727202

Tyler, P., Warnock, C., Provins, a., Lanz, B., 2012. Valuing the Benefits of Urban Regeneration. Urban Stud. 50, 169–190. doi:10.1177/0042098012452321

Utley, J.I., Shorrock, L.D., 2008. Domestic energy fact file 2008.

Uzsilaityte, L., Vytautas, M., 2010. Search for optimal solution of public building renovation in terms of life cycle. J. Environ. Eng. Landsc. Manag. 18, 102–110.

Vadodaria, K., Loveday, D., Haines, V., Mitchell, V., Mallaband, B., Bayer, S., 2010. UK solid-wall dwellings - thermal comfort, energy efficiency refurbishment and the user perspective - some preliminary analysis from the CALEBRE project, in: Adapting to Change: New Thinking on Comfort. Presented at the London: Network for Comfort and Energy Use in Buildings, NCEUB, Cumberland Lodge, Windsor, UK.

Wassenberg, F., 2011. Demolition in the Bijlmermeer: lessons from transforming a large housing estate. Build. Res. Inf. 39, 363–379.

Whitehead, C., Scanlon, K., 2014. Building London's private rented sector.

Whitehead, M., Dalgren, C., 1991. What can we do about inequalities in health? The Lancet 338, 1059–1063.

Wilhite, H., 2008. New thinking on the agentive relationship between end-use technologies and energy-using practices. Energy Effic. 1, 121–130. doi:10.1007/s12053-008-9006-x

WRAP UK, 2012. Refurbishment resource efficiency case study: Daneville Estate, Liverpool.

Yates, T., 2006. Sustainable refurbishment of Victorian housing : guidance, assessment method and case studies. BRE Trust, IHS BRE Press, Bracknell.

Zero Carbon Hub, 2013. Closing the Gap Between Design and As-Built Performance New Homes: Interim Progress Report Executive Summary.

Appendix A: Definitions of Building Life

	(CIBSE 2008)	(Thomsen and van der Flier 2011)	(Kohler 2007)	(Sweetnam and Croxford 2011)	(Lowe 2007)
Economic Life	Estimated number of years until that item no longer represents the least expensive method of performing its function (life expectancy, economic life factors, indicative life factors.		An assumed period of time over which costs and benefits of buildings are assessed - not necessarily related to the likely service lifetime or physical lifetime but to tax regulations, legal requirements or accounting standards.		

Technological Life	Estimated number of years until technology causes an item to become obsolete	Obsolescence as a process described as growing divergence between the declining performance of buildings and the rising expectations of users and proprietors			
Service Life or Estimated Service Life or Useful Life (CIBSE) (single building or its parts)	Estimated number of years during which an item will perform its function according to some established performance standard (at least as long as the design life)	Period of time during which a building or its parts meet or exceed performance requirements (ISO)	Period of time after installation during which a building or its part meet or exceed performance requirements; can be the end of the physical life of a building but also the indication of what a client expects		
Design Life	This is a period of time decided by a building owner/developer and written in to the Client's Brief. It guides engineers and assures investors and insurers about the quality and durability that has been specified for the building and its equipment. Over this time a building or component of a building is expected to function adequately without the need for major repairs or replacement if properly maintained.				

Service Life Replacement Date or Replacement cycles	Time intervals when components or subsystems have to be replaced because their service life is less than design life of the whole building or system					
Effective service life			Time for which a certain probability of survival (effective lifetime) can be guaranteed			
Effective (physical) lifetimes or Implicit Life (whole building stock)		AKA life span, building pathology and mortality of buildings as average period of physical existence, including the usage and end-of-life phase	Estimated from buildings that have been built/ destroyed in whole building/ infrastructure stock over time; lifetime of stocks of building typologies (relates to societal or planning decisions to use the complex resource of the building stock in a sustainable way). AKA Survival Functions			Implicit dwelling life based on the ratio of total household numbers to annual demolition rate
Lifecycle Phases (products or projects)	1. Acquisition 2. Use and maintenance 3. Renewal and adaptation 4. Disposal.	Development phase, including the design and the construction phase, and the usage phase, consisting of the actual use and the reuse or end-of-life phase	New construction, operation, maintenance, refurbishment and disposal	1. Pre-refurbishment 2. Demolition 3. Construction 4. Post-refurbishment 5. Refurbishment or demolition for a refurbishment scenario and a new-build scenario	

Building Components			Patalia and Rushton Tabe 4		CIBSE Guide M	Lowe	
			Replacement Cycle (years)	Cost %	Economic Life Factor (years)	Replacement Cycle	Technological Life
Interior	Decorations		5	2			
	Floor Finishes		10	2.5			
	Kitchen and Bathroom Fittings		15	7.5			
	Sanitation and Drainage	Below ground drainage (plastic)			40		
		Internal waste, foul and rainwater drainage (plastic)			20		
		Sanitary ware			25		
Mechanical and Electrical Systems	General Mechanical and Electrical		30	24.5			
	Space heating	cast iron sectional boilers (MTHW/ LTHW)			25	10	15
		condensing boilers (MTHW/LTHW)			20		
		domestic boilers (combination)			10		
		domestic boilers (condensing)			15		
		pumps			15		
		mild steel flue			15		
		Storage heaters (electric)			10		
	Hot water system	Domestic gas-fired hot water (storage and continuous)			12		
		Electrical water heaters			12		
	Water system	Mains cold water booster			15		
		Shower mixer and head			10		
	Distribution systems	Radiators (steel)			20		
		Heating pipework system (plastic)			35		
		Pipework thermal insulation			30		
	Ventilation	Extract fan (e.g. domestic)			10		
	Cooling	Not considered					
	Electrical	Sub-main distribution (most components)			20		
		External lighting installations			15		
		switched socket outlet (SSO)			15		
		CFL			3		
	Lifts	Electric traction lifts (packaged)			15		

Renewables	PV	PV Panels			25		
		lead–acid batteries (sealed)			5		
		nickel–alkaline batteries (vented)			20		
	Wind Turbines				20		
	Renewable Heat	Solar panels (water heating)			25		
Envelope	Walls	External walls	60	17.5			
		Render and Pointing (masonry walls)				50-100	centuries
	Roof		60			50	
	Windows	Frames	60				many decades
		Sealed Glazing Units	60				20
Structure	Substructure		60+	46			
	Frame		60+				
	Floors		60+				

Appendix B: Buildings codes, targets and regulations

Building Codes

The energy performance standards for buildings in England are covered by the technical documents – Part L (Conservation of Fuel and Power). This separates buildings into four types:

- L1A New dwellings (residential buildings)
- L1B Existing Dwellings
- L2A New Buildings other than Dwellings (non-residential buildings)
- L2B Existing Buildings other than dwellings

New 2013 versions of Approved Document L1A and L2A (ie for new residential and non-residential buildings) come into effect from 6 April 2014. These regulate different energy using aspects of a building including heat loss through walls, roofs, floors, doors and windows, the energy performance of lighting, ventilation and heating systems.

Renovation work and extensions to existing buildings must comply with the approved document L1B. These regulations apply when the work will affect how much energy is being used is and covers:

- An extension
- A change of use (from non residential to residential)
- A change or extension of the windows and lighting, heating or ventilation systems.
- The replacement or renovation of an external wall, floor or roof, or an internal one which separates the conditioned area of a home (the rooms that are heated or cooled) from a non-conditioned area (for example a garage or unheated corridor)

The UK has a 2016 deadline for all new residential buildings to be zero carbon, and a 2020 for all other new buildings. To help the construction sector meet this stretching target, an off-setting system called 'allowable solutions' has been designed, and will come into practice in 2016. This means that developers who cannot make their new buildings 'zero carbon' can contribute to other carbon abatement strategies. Retrofitting existing buildings could be one of these allowable solutions and local authorities "either individually or in multi local authority partnerships, or in partnership with the private sector, [can come] forward with Allowable Solutions' projects or measures" for private sector developers (Department for Communities and Local Government, 2013, p. 41).

Heat polices and Regulation

EU Directive on metering and informative billing

The UK is addressing the need to provide meters and billing information to residents whose homes are connected to district heating systems or shared heating and hot water supplies. For existing buildings, changing from a rated to a metered service is discretionary and depens on the cost and technical feasibility of adding meters and changing the billing system.

For new buildings and renovations it is mandatory to provide meters and charge according to metered supplies.

Details are available on DECC's website:

https://www.gov.uk/government/consultations/implementing-the-energy-efficiency-directive-metering-and-billing-of-heating-and-cooling

Renewable Heat Incentive (RHI) (text from Energy Saving Trust Website)

The domestic RHI provides financial incentives to owners of eligible, renewable heating systems on their homes. It supports air source heat pumps (ASHP), biomass systems, ground source heat pumps (GSHP) and solar thermal technologies with tariffs varying depending on the technology.

The domestic RHI is open to owner occupiers, private landlords, Registered Providers of Social Housing and self-builders who have installed an eligible technology since 15th July 2009, provided they meet the scheme criteria.

Successful applicants will receive quarterly payments for seven years. Any public grants previously received, including the Renewable Heat Premium Payment (RHPP), will be deducted to avoid a double subsidy. The scheme covers England, Wales and Scotland only.

Ofgem is responsible for administering the scheme which opened in Spring 2014. Find out about eligibility criteria and the application process by visiting Ofgem.

Feed in Tariffs

The government is providing support for home owners and community groups who install equipment that generates energy from renewable sources. Once installed, groups receive payments for the electricity generated by any of the following technologies: Groups can be paid for the electricity they generate, even if they use it themselves, and for any surplus electricity they export to the grid. Groups will also save money on electricity bills, because they use their own electricity rather than buy it.

The following technologies can be used:

- Solar photovoltaic (usually called PV) with a total installed capacity (TIC) of 5MW or less
- Wind with a TIC of 5MW or less
- Hydro with a TIC of 5MW or less
- Anaerobic digestion with a TIC of 5MW or less
- Micro combined heat and power (CHP) installations with a TIC of 2kW or less

The tariffs vary, but can be found on Ofgem's website.

Labelling and Certificates (voluntary and compulsory)

The Energy Saving Trust explains the different indicators that landlords can use to measure the energy performance of their buildings:

1) Energy use ratings indicate how much energy a dwelling uses, similar to the way that miles per gallon unit can be used to compare how fuel efficient cars are. It typically includes the energy needed for heating, hot water, lighting and ventilation under set conditions (eg heating the home to 21C for 9 hours a day). It usually does not include things like washing machines, electronic equipment which are not governed by part L.

2) Energy or fuel cost ratings indicate the energy bill a resident could expect from living in a home, and are sometimes used to establish targets by social landlords.

Energy Performance Certificates (EPCs) rate a building on an A to G scale (similar to energy labelling for white goods) to reflect fuel costs under standard occupancy conditions. These are now required for new buildings and existing buildings when they are newly sold, rented or leased.

Social and private landlords must provide new tenants with an EPC for their home.