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European Retrofit Network: Retrofitting Evaluation Methodology Report

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1. Acknowledgements

The research in this report has been supported by interviews with a variety of industry professionals who kindly gave their time and experience. In particular, we would like to thank (in alphabetical order): Carol Bell, Robinson Low Francis; Mark Elton, ECD Architects; Tim Fenn, p3Eco Ltd; Maria Hanrahan, Catalyst Housing; Dan Johncock, United House; Roger Kelly, Energy Solutions (North West London); Andrew Mellor, PRP Architects; Jack Skinner, The Hyde Group.

2. Executive summary

The research programme, funded by the EU Progress Fund, looks at the potential impacts of construction training in the area of „retrofitting" social housing to make it more sustainable, in particular to improve energy efficiency and reduce greenhouse gas emissions.

This report investigates methodologies for measuring and demonstrating carbon emissions reductions resulting from retrofitting measures in the partner countries (UK, Spain, Poland and Montenegro).

The output of this part of the study is a methodology appropriate to measuring the likely carbon reduction impacts through common retrofit measures in the social housing sector, taking into account the likely cost effectiveness of measures, the impact on occupants, the project management challenges and thus the measures that are most likely to be employed in policy and practice.

An appropriate methodology is one that can be applied across the range of different conditions found in the partner countries (representative to some degree of the range of conditions found across Europe as whole).

Low carbon retrofit has been defined as „incremental improvements to the building fabric and systems with primary intention of improving energy efficiency and reducing carbon emissions."[1]

The starting point for considering a common methodology is the methods currently employed across Europe for rating building energy performance. Building energy use is the largest factor in determining carbon emissions from buildings. In general, there is a direct relationship between the two although the particular mix of fuel and energy sources will determine the nature of this relationship. Local climate conditions, patterns of building use and relative costs of energy sources will determine how energy is used in buildings and the measures most appropriate to reduce its use and resulting carbon emissions.

The European Directive on Energy Performance of Buildings (EPBD) requires that Member States certify the energy efficiency of new and existing buildings and develop a methodology for integrated calculation of the overall energy performance of buildings. On the basis of this methodology the EPBD requires that Member States set minimum energy-efficiency requirements for new buildings and existing *large* buildings when they undergo significant renovation. Most the housing stock falls outside this requirement so there are no general or even country-specific requirements for energy efficiency in existing housing beyond that which may (but seldom does) exist in local building regulations.

Nevertheless, there is a requirement for rating of the energy efficiency of existing buildings and for each country to develop a methodology for doing this. A European standard, EN 15603: *Energy performance of buildings: overall energy use and definition of energy ratings*, has been developed to guide Member States in this process. While the long-term aim is the harmonisation of methods across EU countries, it is accepted that „Regional differences in climate, building tradition, legal settings, quality assurance and user behaviour in Europe have impact on the input data, the calculation procedures and consequently on the energy.

[1] Rhoads 2010. *Low carbon retrofit toolkit*. http://www.betterbuildingspartnership.co.uk/download/bbp_low_carbon_retrofit_toolkit.pdf

These differences will also lead to different choices when it comes to finding the optimum balance between accuracy and simplicity."[2]

Our starting point in this study, therefore, is that, at this point in time, across Europe various energy rating methodologies are in use, and that each country will need to employ their own methodology in calculating the carbon emission reduction impacts of retrofit measures. Our methodology provides a common framework for considering appropriate retrofitting measures for social housing across Europe, and their impacts on construction industry skills training. The energy rating methodology of a particular country can then be employed within this framework, along with local conversion factors for translating energy savings into carbon reductions.

In this study we focus on the UK as a case study. The analysis in this report is therefore based on the UK Standard Assessment Procedure (SAP 2009).

The approach we adopt in this report thus relates the standards of carbon reduction in retrofitting social housing to:

1. The nature of the building works required to achieve them through improved energy performance;
2. The associated cost-benefits, and
3. The likely nature of any works to be carried out on the basis of this assessment.

The scale and nature of the works, and hence the likely associated training requirements, the study proposes, is directly related level of disruption that they cause to building occupants. Higher standard of performance are possible with higher levels of disruption. The highest refurbishment standards require a building to be vacated for an extended time and possible adaptive behavioural training programmes and space rationalisation or utilisation.

The specifications of works to achieve these highest standards are sometimes termed „deep retrofitting". Hence the study employs the terms „shallow", „mid-level" and „deep" retrofitting with the associated performance levels related in general to low, medium and high levels of disruption.

In moderate and cool European climates, „deep" retrofitting generally refers to the performance achievable under the European „Passivhaus" standards, with a broad comfort level of 20^{o}C in winter heating conditions.

In the warmer southern European climate, cooling is a more important factor. As people are more generally adaptable to high temperature levels, it is possible to adopt a „free-running" approach in vernacular architecture (adapting clothing and fan assisted air movement) up to a high monthly mean external air temperature (32^{o}C). Outside of these conditions, refrigerated assisted cooling (comfort cooling or air conditioning) is required. This assumption informs the calculations in the report used to illustrate the approach we are proposing.

The economics of retrofitting mean that, in every case we have investigated, there is an evident „tipping point" beyond which diminishing returns set in. Although extremely high levels of carbon reduction are possible through a deep retrofit approach, such an approach is unlikely to be widely adopted for social housing, because of the very high cost-to-benefit ratio and the high level of disruption to occupants involved.

Therefore, any policy to support retrofitting of social housing through targeted public financial incentives or additional regulatory requirements within existing financial constraints, or simply on the basis of individual landlord initiative, is likely to result in the most cost effective, low disruption shallow (or, at most, „mid level") retrofitting measures. Barring the short-term imposition Europe-wide of very stringent carbon reduction regulatory requirements or a

[2] Van Dijk (2009)

carbon tax, resulting reductions in carbon emissions and construction industry training requirements can be assessed on this basis.

Most of the methods of retrofitting existing housing described in this report are already part of standard construction practice in Europe and little additional specialised skills training is required (as likely would be required, for example, in the case of achieving the very high standards required by deep retrofit).

However, quality control and energy assessment expertise is critical and carrying out retrofitting on existing social housing to scale within the reasonable timescale to meet current European carbon reduction targets would clearly required a substantial increase in the capacity of the European construction industry to carry out this work and training programmes to produce the necessary skills.

Economies of scale are obviously achievable but our research indicates that no additional scale benefits accrue from going beyond a batch of twenty houses, so that packages of work accessible for relatively small construction firms are feasible[3].

We have discovered no definitive figures on the quantity of social housing across Europe, except for some countries.[4] However, it is evident that a policy directed towards retrofitting social housing across Europe could have very significant impacts in terms of overall carbon reductions depending on the range of retrofit. Buildings represent some 23% of EU CO_2 emissions (70% for the residential sector and 30% for the tertiary sector), or 46% of final energy consumption, with heating alone represents two thirds of this consumption.[5]

The ETUC summarises the potential for Europe-wide social housing retrofit as follows: „The launch of an initiative on the thermal renovation of social housing and subsidized housing would have a particularly important leverage effect because it would result in action on a lot of housing and a lot of emissions in a brief period of time. What is more, such activities are likely to create additional social benefits: the integration of the long-term jobless or socially-impaired persons, easing of the energy bill and improved living conditions for less favoured households."[6]

The „disruptions" based approach set out in this report provides a starting point for considering the policy challenges in launching such an initiative.

3. Introduction

This report investigates methodologies for measuring and demonstrating carbon emissions reductions resulting from retrofitting social housing (and other parts of the existing built environment) in the partner countries aiming, through the research programme, to establish a European Retrofit Network (UK, Spain, Poland and Montenegro). The research programme, funded by the EU Progress Fund, looks at the potential impacts of construction training in the area of „retrofitting" social housing to make it more sustainable, in particular to improve energy efficiency and reduce greenhouse gas emissions.

The low carbon retrofit has been defined as „incremental improvements to the building fabric and systems with primary intention of improving energy efficiency and reducing carbon emissions."[7]

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[3] http://www.forumforthefuture.org/project/retrofit-at-scale-bristol
[4] Dol K and Haffner M, 2010, *Housing statistics in the European Union* The Hague: The Hague: Ministry of the Interior and Kingdom Relations
http://abonneren.rijksoverheid.nl/media/dirs/436/data/housing_statistics_in_the_european_union_2010.pdf
[5] Source?
[6] ETUC, 2007 *Climate change and employment*
http://www.unizar.es/gobierno/consejo_social/documents/070201ClimateChang-Employment.pdf
[7] Rhoads 2010. *Low carbon retrofit toolkit*.
http://www.betterbuildingspartnership.co.uk/download/bbp_low_carbon_retrofit_toolkit.pdf

In our research, we have employed the following extended definition of retrofitting:

Retrofitting is the refurbishment of buildings to improve their sustainability, in particular their energy efficiency and carbon dioxide emissions. Retrofitting takes place some time after original construction and incorporates or substitutes more up-to-date parts and new elements where appropriate. Retrofitting technologies include those that are 'fit and forget' and those that require attention to control systems, management and maintenance. Retrofitted elements may include those that contribute to wider networked decentralized energy systems such as PV panels (with or without the incentive of feed-in tariffs).

„Retrofitting" in the terminology of this research therefore includes works relating to renewable energy forming part of the refurbishment of exiting social housing, as well as established or innovative refurbishment measures that improve energy performance of buildings and reduce their carbon emissions, also known as sustainable or low carbon refurbishment.

The retrofitting „industry" in the UK and elsewhere in Europe is an emerging one rather than one that is fully formed. Presently it is part of the mainstream reconstruction/refurbishment industry but there are a number of factors driving its emergence as a separate but related market which a huge potential.

4. Performance standards and impacts

Different degrees of performance standards are possible with the highest refurbishment standards requiring the building to be vacated for an extended time and possible adaptive behavioural training programmes and space rationalisation or utilisation.

The approach we have adopted in this report relates closely to these varying standards of carbon reduction and the level of disruption that they cause to building occupants. These, we refer to in general terms as low, medium and high disruption leading to what could be described as „shallow", „mid-level" and „deep" retrofitting. In moderate and cool European climates, „deep" retrofitting generally refers to the performance achievable under the European „Passivhaus" standards, with a broad comfort level of 20°C in winter heating conditions.

In the warmer southern European climate, cooling is a more important factor. As people are more generally adaptable to high temperature levels, it is possible to adopt a „free-running" approach in vernacular architecture (adapting clothing and fan assisted air movement) up to a high monthly mean external air temperature (32°C). Outside of these conditions, refrigerated assisted cooling (comfort cooling or air conditioning) is required. We have made this assumption on the calculations that follow in the report used to illustrate the approach we are proposing.

The economics of retrofitting mean that, in every case we have investigated, there is an evident „tipping point" beyond which diminishing returns set in. Although extremely high levels of carbon reduction are possible through a deep retrofit approach, such an approach is unlikely to be widely adopted for social housing, because of the very high cost-to-benefit ratio and the high level of disruption to occupants involved.

We have no definitive figures on the quantity of social housing across Europe, except for some countries.[8] However, it is evident that a policy directed towards retrofitting social housing across Europe could have very significant impacts in terms of overall carbon reductions depending on the range of retrofit. Buildings represent some 23% of EU CO_2

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[8] Dol K and Haffner M, 2010, *Housing statistics in the European Union* The Hague: The Hague: Ministry of the Interior and Kingdom Relations http://abonneren.rijksoverheid.nl/media/dirs/436/data/housing_statistics_in_the_european_union_2010.pdf

emissions (70% for the residential sector and 30% for the tertiary sector), or 46% of final energy consumption, with heating alone represents two thirds of this consumption.[9]

The ETUC summarises the potential for retrofit as follows: „The job gains compared to the reference scenario are in excess of one million man-years in the case of works corresponding to high energy quality (50 kWh/m2), or 10% of European employment in the sector. The launch of an initiative on the thermal renovation of social housing and subsidized housing would have a particularly important leverage effect because it would result in action on a lot of housing and a lot of emissions in a brief period of time. What is more, such activities are likely to create additional social benefits: the integration of the long-term jobless or socially-impaired persons, easing of the energy bill and improved living conditions for less favoured households."[10]

Economies of scale are obviously achievable but our research indicates that no additional scale benefits accrue from going beyond a batch of twenty houses, so that packages of work accessible for relatively small construction firms are feasible[11].

Most of the methods of retrofitting existing housing described in this report are already part of standard construction practice in Europe and little additional specialised skills training is required, except in the case of achieving the very high standards required by deep retrofit.

However, quality control and energy assessment expertise is critical and carrying out retrofitting on existing social housing to scale within the reasonable timescale to meet current European carbon reduction targets would clearly required a substantial increase in the capacity of the European construction industry to carry out this work and training programmes to produce the necessary skills.

5. Background issues

The IPPC Working Group on Mitigation of Climate Change in 2007 found that there is a potential globally to reduce approximately 29% of the projected baseline emissions by 2020 cost-effectively in the residential and commercial building sectors, the highest among all sectors studied in their report.[12] The IEA report (2010) points out that reducing overall energy demands in buildings and improving energy efficiency could result in possible mitigation of 12.6 giga-tonnes (Gt) of CO_2 emissions and energy savings of 1,509 million tones of oil equivalent by 2050. [13]

There are potentially huge impacts in terms of energy savings to be achieved through robust, accurate and cost effective retrofit activities for the existing buildings.[14] Buildings account for 40% of energy use in the most countries.[15] In the EU, as noted, building stock is responsible for about 46% of Europe"s total final energy consumption.

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[9] Source?
[10] ETUC, 2007 *Climate change and employment* http://www.unizar.es/gobierno/consejo_social/documents/070201ClimateChang-Employment.pdf
[11] http://www.forumforthefuture.org/project/retrofit-at-scale-bristol
[12] Metz B, Davidson O R, Bosch P R, Dave R and Meyer L A (eds), 2007, *Climate Change 2007: Working Group III: Mitigation of Climate Change,* Cambridge: Cambridge U P
[13] IEA, 2010 *Energy performance certification of buildings*. http://www.iea.org/papers/pathways/buildings_certification.pdf
[14] Petersdorff, 2010. *Mitigation of CO2 emissions from the building stock.* http://www.eurima.org/uploads/pdf/puttingHouseInOrder/ecofys_repoft_final_160204.pdf
[15] IEA, 2010. ibid

UK case study
The UK government has committed to international agreement of delivery target to reduce its carbon emissions level by 80% below 1990 levels by 2050.[16] Domestic buildings contribute about 30% of total carbon emissions produced across the UK.

Carbon emissions in existing buildings are largely related to energy consumption. With annual replacement rates of 1 to 1.5 %, it is estimated that in 2050 some 70% of today‟s buildings will still be in use, with 40% having been built prior to 1985.[17] Despite the policy focus hitherto on new buildings, larger part of the challenge in the UK is to upgrade the existing building stock.[18]

Despite the urgency and international commitment in the CO_2 emissions reduction, little work has being undertaken for the primary purpose of improving energy efficiency and reduction carbon emission in the UK existing building stock.[19] When considering the low carbon retrofitting requirements, the decision often is on the basis of either a simple economic pay back or corporate social responsibility (CSR) driven agenda to reduce carbon emission in owner-occupied building or single tenanted premises on long lease term.[20]

6. Policy, legislation and standards

European Union
The European Council‟s 2007 energy and climate change objectives for 2020 are „to reduce greenhouse gas emissions by 20%, rising to 30% if the conditions are right" and „to increase the share of renewable energy to 20% and to make a 20% improvement in energy efficiency." The European Council has also made a long-term commitment to a target for the EU and other industrialised countries of 80 to 95% cuts in emissions by 2050.[21]

On the supply side, „investments should lead to nearly two thirds of the electricity coming from low carbon sources by the early 2020's, the current level being 45%" (mainly nuclear and hydropower). The Council notes that „special attention should be given to the sectors with the largest potential to make energy efficiency gains, namely the existing building stock and transport sector. Member States have agreed to legally binding climate targets for these and other non-ETS sectors but still need to implement appropriate measures".[22]

The current key legislation is Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings[23]

Amongst other points relevant to this project this states:

„(8) Measures to improve further the energy performance of buildings should take into account climatic and local conditions as well as indoor climate environment and cost-effectiveness", and

„(29) Installers and builders are critical for the successful implementation of this Directive. Therefore, an adequate number of installers and builders should, through training and other measures, have the appropriate level of competence for the installation and integration of the energy efficient and renewable energy technology requirements."

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16 Rhoads, 2010. ibid
17 Rhoads, 2010 ibid
18 Carbon Trust, 2008. *Low carbon refurbishment of buildings*. http://www.emcbe.com/Reference-Library/Low%20carbon%20refurbishment%20of%20buildings%20-%20Management%20guide.pdf
19 EST, 2010
20 Rhoads, 2010 ibid
21 *Energy 2020. A strategy for competitive, sustainable and secure energy* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52010DC0639:EN:HTML:NOT
22 Ibid.
23 *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:01:EN:HTML

The European Directive on Energy Performance of Buildings highlights four main elements define the requirements that needs to be integrated into national legislation in the member states[24]:

- „Establishment of a methodology for integrated calculation of the overall energy performance of buildings
- Definition of minimum energy-efficiency requirements per member state based on this methodology. In addition to the aim of improving the overall energy-efficiency of new buildings, large existing buildings will become a target for improvement as soon as they undergo significant renovation
- Energy-efficiency certification of new and existing buildings
- Regular inspection of heating and air conditioning systems.“

Regarding this particular research package, the EPDB states „(9) The energy performance of buildings should be calculated on the basis of a methodology, which may be differentiated at national and regional level. That includes, in addition to thermal characteristics, other factors that play an increasingly important role such as heating and air-conditioning installations, application of energy from renewable sources, passive heating and cooling elements, shading, indoor air-quality, adequate natural light and design of the building. The methodology for calculating energy performance should be based not only on the season in which heating is required, but should cover the annual energy performance of a building. That methodology should take into account existing European standards.“[25]

A set of CEN (European Committee for Standardisation) standards have recently been developed to support this process. These are the outcome of the CENSE project (2007-2010) (CEN Standards on Energy performance of buildings).[26] These European standards aim to increase the accessibility, transparency and objectivity of energy performance assessment in the member states.[27] Of particular interest to this study is EN 15603:2008 *Energy performance of buildings: overall energy use and definition of energy ratings*.[28]

EN 15603 is part of a range of normative European Standards which cover energy assessment for different heating and cooling systems with standards for heating, air conditioning, ventilation, boilers, heat pumps, etc and relates energy demand to national guidance on the resulting CO_2 emissions.

Emissions from fossil fuels are constant provided there is full combustion at any particular appliance thermal efficiency and therefore are the same everywhere. Emissions from electricity are projections since the grid mix is due to change over the coming years, although there is no definitive guidance on that change.

Each member country is still working out what is feasible with a proposed mix of nuclear, coal, wind, etc, along with a trans-European electrical distribution network – a „super-grid“. It is still not known what impact the renewable electricity feed-in tariffs will have or indeed the proposed renewable heat feed-in tariff.

Effectively, we do not yet know what the grid in the UK, or across Europe, is going to look like in 20 years although there are proposals and projections. In addition, there is no agreed methodology for assessing the sum of CO_2 savings based on a changing energy

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[24] IEE, 2008, p3

[25] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52010DC0639:EN:HTML:NOT

[26] Van Dijk, D (2009) *Background, status and future of the CEN standards to support the Energy Performance of Buildings Directive (EPBD),* CENSE_WP6.1_NO3, IEE_CENSE April 29, 2009 <http://www.buildup.eu/publications/5892>

[27] Ibid.

[28] Staudt, A and Erhorn, H (2009) *The different CEN approaches for calculating the energy use for heating and cooling (Dynamic and quasi-steady-state method, holistic and simple approach).* Paper P95, 04-02-2009, EPBD, Buildings Platform http://www.buildup.eu/publications/1210; Issued as a British Standard – BS EN 15603:2008 <http://shop.bsigroup.com/ProductDetail/?pid=000000000030166449>\) (Staudt and Erhorn 2009)

infrastructure.

Building regulation is very much a national concern in European policy in accordance with the principle of subsidiarity. „Regional differences in climate, building tradition, legal settings, quality assurance and user behaviour in Europe have impact on the input data, the calculation procedures and consequently on the energy performance…These differences will also lead to different choices when it comes to finding the optimum balance between accuracy and simplicity."[29] The standards developed under the EPBD therefore need to be flexible enough to accommodate these differences. The EPBD-CEN standards attempt to set a common framework for preparing energy performance certification and energy inspections of buildings. The long-term aim is the harmonisation of methods and development of international CEN-ISO standards.[30]

The Energy Performance of Buildings Directive (EPBD) demands the assessment of energy consumption in buildings based on regulated energy use covering heating, ventilation, cooling and lighting. At this point in time, across Europe various energy-rating methodologies are in use.

The analysis in this report is based on the UK Standard Assessment Procedure (SAP 2009).[31] This was developed by the Building Research Establishment (BRE) based on work done in the 1980s and 90s. In the UK, the EPBD assessment tools are RDSAP (a reduced version of SAP for existing dwellings) and SAP and SBEM (domestic and commercial assessment programs) for new buildings. Once provided with data on „u" values, ventilation rates, heating and cooling systems and fixed lighting, SAP algorithms calculate the annual energy demand of the building, including the electrical energy demand for fans and pumps. The software converts this energy assessment in kWh/year to give an „environmental impact rating" in kgCO2/year. About 75% of social rented housing in the UK has been labelled using this method.

Other examples include Ireland, where the National Irish Centre for Energy Rating created the Energy Rating Bench Mark (ERBM) for existing buildings and the Netherlands, where a rating system EPB was mainly targeted at social housing, with a new method, EPA being introduced in 2000.[32] (Santamouris 2005). In Germany, DIN V 4108 and DIN V 4701 cover the calculation procedures for residential buildings using the simple approach.[33] Each method is based on procedures for collecting energy data, algorithms for normalising energy consumption and for classifying buildings. Various procedures are employed to produce carbon emission calculations. National methodologies are developed in relation to the local characteristics of the building stock and local climate conditions.[34]

Member States are required to set minimum requirements for the energy performance of buildings and building elements „with a view to achieving the cost-optimal balance between the investments involved and the energy costs saved throughout the lifecycle of the building, without prejudice to the right of Member States to set minimum requirements which are more energy efficient than cost-optimal energy efficiency levels. Provision should be made for the possibility for Member States to review regularly their minimum energy performance requirements for buildings in the light of technical progress."

[29] Van Dijk (2009)
[30] Ibid.
[31] BRE 2009. *The Government's Standard Assessment Procedure for Energy Rating of Dwellings* http://www.bre.co.uk/filelibrary/SAP/2009/SAP-2009_9-90.pdf
[32] Santamouris, M, ed. (2005) *Energy Performance of Residential Buildings,* London: James and James/Earthscan
[33] Staudt and Erhorn (2009)
[34] Santamouris (2005)

When setting energy performance requirements for technical building systems, Member States should refer to Directive 2006/32/EC on efficiency of final energy use and energy services, Directive 2005/32/EC on establishing a framework for the setting of eco-design requirements for energy-using products and Directive 92/75/EEC on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances.

EU Energy Efficiency Plan 2011[35] notes that "The greatest energy saving potential lies in buildings. The plan focuses on instruments to trigger the renovation process in public and private buildings and to improve the energy performance of the components and appliances used in them. It promotes the exemplary role of the public sector, proposing to accelerate the refurbishment rate of public buildings through a binding target and to introduce energy efficiency criteria in public spending. It also foresees obligations for utilities to enable their customers to cut their energy consumption."

The Energy Efficiency Plan states that: "A large energy saving potential remains untapped. Techniques exist to cut existing buildings' consumption by half or three quarters and to halve the energy consumption of typical appliances."

These figures are based on examples of refurbishment in the EU Green Building programme which „show cost-effective reductions up to 80%." The Green Building Programme[36] focused on commercial or non-residential buildings. It is therefore assumed that major retrofitting measures occur during a decant of business to alternative office space.

This EPBD will have significant impacts into the existing buildings while carrying out retrofitting and refurbishment in the buildings in terms of reduction of CO2 emission.[37] The Energy Performance Certification (EPC) is key policy instrument that can assist government in reducing consumption in buildings.[38] The focus of this scheme is to provide decision makers in the buildings industry and the property marketplace with objective information on a given building, either in relation to achieving a specified level of energy performance or in comparison to other similar buildings.

Additional to national and local energy efficiency related schemes, the EPC should help governments achieve energy saving targets and enhance environmental, social and economic sustainability.[39] „Energy certification attests to the energy performance of the buildings and provides information that may increase demand for more efficient buildings, thereby helping to improve the energy efficiency with the building stock in the country."[40] By achieving certification of energy performance in existing buildings, it provides prospective buyers and tenants to make decision of purchase and rent and this leads to greater incentive to the owners to improve energy efficiency of buildings, particularly with the pressures of increasing energy prices.

United Kingdom:

UK Carbon Act 2008 and the Green Deal*:* UK Carbon Act 2008 calls for an 80% CO2 reduction by 2050. It was the view of a number of interviewees that residential property would be expected to achieve this reduction in order to offset growth in transport and air traffic sectors. The currently proposed incentive mechanism to achieve the Carbon Act target for buildings is the „Green Deal".[41]

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[35] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0109:FIN:EN:PDF
[36] *Greenbuilding.* http://www.eu-greenbuilding.org/index.php?id=162
[37] Petersdorff, 2010 ibid
[38] IEA, 2010
[39] Ibid.
[40] IEA, 2009
[41] DECC, 2010 *The Green Deal* http://www.decc.gov.uk/assets/decc/legislation/energybill/1010-green-deal-summary-proposals.pdf

There are in excess of 23 million dwellings in the UK, thus the Green Deal may be expressed as needing to achieve „one building per minute to 2050".[42]

„The „core principle" of the Green Deal is the „golden rule" that the instalment payment for the energy saving measures, including the cost of finance, labour and products, should not exceed the projected associated cost savings on an average bill for the duration of the green finance arrangement. The arrangement could be for as long as 25 years for houses. The obligation to make the repayments would then pass to a new occupier or bill payer should the Green Deal applicant move away."[43]

To be implemented, the Green Deal mechanisms require:

- Accredited assessors to develop a suitable energy saving plan for each household
- Accredited providers to finance the project
- Accredited installer quality assurance provisions

Existing Homes Alliance: The Existing Homes Alliance (ExHA) is a collaboration of organisations, campaigning and lobbying for a national retrofitting programme for carbon reduction in the existing domestic housing sector and bases in the UK. The ExHA published its key proposal of minimum standards of home energy efficiency by using an energy efficiency rating system. The principle of the system of minimum standards is based on the current regulations which require all new build sectors to introduce minimum energy efficiency standards on all tenures through the zero carbon homes targets with a clear trajectory and milestone for 2010, 2013 and 2016.[44]

The system of minimum standards focused on energy efficiency ratings aims to act „as a driver creating demand for Green Deal and as a backstop to push those laggards that will not take the offer up even when incentivised, the system of minimum standard can be complementary to the Green Deal Finance by ensuring those taking out the charge will be achieving the required depth of retrofitting to achieve carbon reduction targets and therefore will not be expected to do further deeper retrofits in the future." This system of minimum standards is aimed at existing homes where retrofit is needed to ensure they contribute achieving carbon reduction targets by 2050.[45]

BRE (2008) has attempted to address the issue of standardising requirement for low carbon future for the existing buildings. The development has focused on retrofits required for the non-domestic commercial building and achieving energy performance requirement (see below). Subsequently, the BRE (2009) issued the standards of Environment and Sustainability[46] titled BREEAM in Use. Currently, the standard is aimed at all *non-domestic* commercial, industry retail and institutional buildings and is internationally recognised.

The UK Association for Consultancy and Engineering ACE (2010), suggest a range of measures to encourage retrofitting activity:

- „Local authorities should be encouraged to engage in retrofitting schemes providing service that will allow for lower negotiated price and improved efficiency
- Improving and refining existing regulation regarding efficiency, building and energy consumption standards is an effective way of encouraging investment in social beneficial technologies during a retrofitting work.

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[42] Ibid.
[43] Smith L. 2011. *The Green Deal* http://www.parliament.uk/briefingpapers/commons/lib/research/briefings/snsc-05763.pdf
[44] Existing homes Alliance, 2010 *Key Policies for Accelerating Low Carbon Retrofit in the Existing Domestic Building Stock* http://assets.wwf.org.uk/downloads/summary_report___key_policies_for_accelerating_retrofit___existing_homes_alliance_dec.pdf
[45] BBP, 2010 ibid
[46] BRE 2009 *Breeam in use BES5058: Issue 1.1* http://www.breeam.org/filelibrary/BREEAM%20In%20Use/BREEAM_In-Use_Standard.pdf

- We would urge that such schemes are monitored to ensure that their effectiveness and a continuing effort to ensure alternative methods of funding be considered.
- Technological improvement will have a significant role to play in energy efficiency and in the creation of smarter green homes, it is important that both existing and new installation encourage the purchase of the most efficient products
- Accurate monitoring of energy usage should play a key role in any retrofitting regimes such as installation of smart metering
- The exploration a variety of insurance lead options including the possibility of schemes/policies that cover the gap in funding for newer energy efficient technologies in the event of damage to a property."[47]

The UK government has produced ranges of schemes, regulations, guidance to assist landlord, homeowners and house associations to deliver low carbon emission domestic buildings in the UK by installing energy efficiency devices, systems and products in the existing buildings. Schemes of particular importance to the social housing sector have been the Carbon Emissions Reduction Target (CERT) and the Community Energy Saving Programme (CESP) and which are expected to be retained for the socially vulnerable when the Green Deal comes into operation.

Carbon Emissions Reduction Target (CERT)

CERT requires all domestic energy suppliers with a customer base in excess of 50,000 customers to make savings in the amount of CO_2 emitted by householders. Suppliers meet this target by promoting the uptake of low carbon energy solutions to household energy consumers, thereby assisting them to reduce the carbon footprint of their homes.[48]

Community Energy Saving Programme (CESP)

CESP targets households across Great Britain, in areas of low income, to improve energy efficiency standards, and reduce fuel bills. There are 4,500 areas eligible for CESP. CESP is funded by an obligation on energy suppliers and electricity generators. It is expected to deliver up to £350m of efficiency measures.

CESP promotes a "whole house" approach i.e. a package of energy efficiency measures best suited to the individual property. The programme is delivered through the development of community-based partnerships between Local Authorities, community groups and energy companies, via a house-by-house, street-by-street approach. This partnership working allows CESP to be implemented in a way that is best suited to individual areas and coordinated with other local and national initiatives.[49]

The London Climate Change Partnership[50] (LCCP) reported that the main reasons for the lack of adoption of retrofitting of existing housing stock are:

- „Lack of information on the physical and economic benefits of adaption to climate change that is actively to households and existing related sectors

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[47] ACE *Retrofitting UK's housing stock* http://www.acenet.co.uk/Documents/Files/Policy%20and%20Operations%20Guides/retrofitting%20funding%20FINAL.pdf

[48] DECC *Carbon Emissions Reduction Target (CERT)* http://www.decc.gov.uk/en/content/cms/what_we_do/consumers/saving_energy/cert/cert.aspx

[49] DECC *Community Energy Saving Programme (CESP)* http://www.decc.gov.uk/en/content/cms/what_we_do/consumers/saving_energy/cesp/cesp.aspx

[50] Carbon Trust, 2010 ibid

- Lack of short term or direct benefits from an adaptation retrofit which can act as a barrier to initial investment and refurbishment actions by individual households, despite the existence of wider social benefits
- In some cases lack of access to finance to put in place investment which have positive returns, either individually or socially.'[51]

Building regulations requirements: the existing Building Regulations Approved Document part L1B deals with thermal requirements as applied to refurbishment works. While this does not require particular building elements to be upgraded to meet an overall building energy performance requirement, wherever existing elements are being replaced or worked on substantially, it sets out thermal performance requirements that need to be achieved.

Energy Performance Certificates: Energy Performance Certificates are required on construction, sale or lease of large non-domestic buildings and existing buildings.

Following the EU Energy Performance 'Energy Performance Certificates (EPC) are being introduced to help improve the energy efficiency of buildings. If you are buying or selling a home you now need a certificate by law. From October 2008 EPCs will be required whenever a building is built, sold or rented out. The certificate provides 'A' to 'G' ratings for the building, with 'A' being the most energy efficient and 'G' being the least, with the average up to now being 'D''".[52]

EPC legislation requires that all new and existing buildings have their energy performance assessed before being sold or let out. This is intended to lead to increasing refurbishment or retrofits of existing buildings through market pressures.[53]

Montenegro:

There are no Building Regulations that apply to thermal issues in either new build or retrofit for housing. With regard energy in buildings and in line with accession requirements, Montenegro is currently producing legislation (Law on Energy Efficiency) which will bring it inline with the EU Energy Performance of Buildings Directive (EPBD) 2010.

„The Directive concerns the residential sector and the tertiary sector (offices, public buildings, etc.). The scope of the provisions on certification does not, however, include some buildings, such as historic buildings, industrial sites, etc. It covers all aspects of energy efficiency in buildings in an attempt to establish a truly integrated approach. Energy performance certificates should be made available when buildings are constructed, sold or rented out.'[54]

The Law on Spatial Development and Construction of Buildings covers all „other" issues of building performances and it is expected that this will be adopted shortly. The new version of this law should improve some legal solutions/procedures and it is hoped will harmonize conditions and requirements that deal with energy efficiency.

- Together with the Law on Energy Efficiency there will be codes that support and enable application of this law. These will cover conditions, requirements, criteria, calculation methods and procedures for evaluation of buildings in terms of the quality of their energy performances - aimed at energy certification.

As national (Montenegrin) standards are yet to be established, practitioners still use the old Yugoslav standards (JUS). These have been applied since the second half of the nineties.

[51] LCCP, 2009 *Economic incentive schemes for retrofitting London's existing homes for climate change impacts* http://www.london.gov.uk/lccp/publications/docs/lccp-eco-incentives.pdf
[52] HM, 2008
[53] Carbon Trust, 2008
[54] *Energy efficiency: energy performance of buildings* http://europa.eu/legislation_summaries/other/l27042_en.htm

There is currently no firm obligation in practice to apply the thermal building codes/standards and the application of JUS standards is neither officially proscribed nor approved.

There are four JUS standards that deal directly with thermal performance of buildings:

1. JUS U.J5.600 Requirements for design and manufacturing/construction of buildings
2. JUS U.J5.510 Calculation methods for coefficient of heat transfer in buildings
3. JUS U.J5.520 Calculation methods for diffusion of water vapour in buildings
4. JUS U.J5.530 Calculation methods for damping factor and delay temperature oscillations in the summer period

Poland

Local legislation has been tightened up in line with EU energy directives on some aspects. One of these is the Thermo-modernisation section of the Building Regulations as noted below and a section on the methodology of energy certification active from 1.01.2009 (not enforced for refurbished residential buildings).

Act of 23.11.2008 re Support for Thermo-modernisation and Refurbishment (replacing Acts from 1991 and 1995), regarding financial assistance from the T & R Fund for multi-family dwellings via the BGK Bank (National Economy Bank): This is aimed at specific owner/ user groups and is a complex set of regulations and conditions. The thermo-modernisation grant provides for part payment of credit on reduction of annual primary energy use up to 25% subject to type of improvement and costs for certain types of housing.

In terms of Policy, there are 3 main legislative bases for the above regulation:

- Directive of the Min. of Infrastructure dated 12.03.2009 (programme for guarantees for refurbishment grants)
- Directive of the Min. of Infrastructure dated 17.03.2009 (Scope and form of Energy Audits and Verification by BGK bank)
- Act dated 30.11.1995 (Government assistance in repayment of housing loans)

Spain

In March 2006, the Spanish government adopted a new Technical Building Code (TBC, or in Spanish CTE), which includes an obligation to cover 30-70% of the Domestic Hot Water (DHW) demand with solar thermal energy. Spain is the first European country to make the implementation of solar thermal energy obligatory in new and refurbished buildings.

The code applies to buildings, irrespective of their use, in which there is a demand for domestic hot water and/or the conditioning of a covered swimming pool. The minimum solar contribution determined by virtue of the basic requirement developed in this section, could be justifiably diminished in the following cases:

- When this energy contribution to domestic hot water is covered by the use of renewable sources of energy, co-generation processes, or residual sources of energy from the installation of heat recovery units which are external to the buildings" own heat generation
- When the attainment of this production level entails exceeding the calculation criteria stipulated by the applicable basic legislation;
- When the location of the building does not afford sufficient exposure to the sun, owing to external barriers;
- In the rehabilitation of buildings, when there are irremediable limitations derived from the prior configuration of the existing building or the applicable town planning legislation;

- When stipulated by the competent body that has to give an opinion on historical and artistic protection.
- In buildings where the foregoing cases are encountered in the plan, the inclusion of alternative measures or elements that save thermal energy or reduce carbon dioxide emissions equivalent to the energy saving and emission reduction levels that would be obtained by the corresponding thermal solar system, shall be justified with respect to the basic regulations of the legislation in force, by obtaining improvements in the thermal insulation and energy efficiency of the equipment.

Notably, this requirement only applies to domestic hot water (and swimming pools) and there is no requirement for savings on heating demands, which are substantial in some parts of Spain, or cooling which is important in the south. Spain has not met its carbon reduction targets under the Kyoto Agreement and the massive recent increase in the use of air conditioning is one of the reasons accounting for this."Spain, which was allowed to make a 15 per cent increase in emissions under Kyoto in recognition of its growing economy, had registered a 52.3 per cent cumulative increase by the end of 2005….Large parts of the south of Spain have been installing air conditioning and demand is projected to keep on rising."[55]

Note the last point, however, which suggests that other forms of retrofitting, which may be more applicable in some parts of Spain, could be substituted for solar water heating and give an equivalent energy saving.There are Spanish national and regional government policies regards retrofit, but no legislation apart from the above.

7. Retrofitting of social housing in Europe

Housing and social housing in the EU

Housing Statistics in the European Union 2010 provides an overview of the size of social housing sector, penetration of central heating and hot water and transfers of dwellings from social to private across the EU.[56]

[55] Charter, D, 1997 „*Booming economy makes Spain worst EU offender in fight to cut levels of CO'*, Times Online, June 15, <http://www.timesonline.co.uk/tol/news/world/europe/article1934841.ece>

[56] Dol K and Haffner M, 2010, *Housing statistics in the European Union 2010 The Hague: The Hague: Ministry of the Interior and Kingdom Relations*

	1980 [1]		1990 [2]		2000 [3]		2004 [4]		20	
	% of TS	% of RS	% of TS	% of RS	% of TS	% of RS	% of TS	% of RS	% of TS	% of
Austria [6]	na	40	22	53	23	52	na	na	23	
Belgium	na	18	na	19	7	24	7	24	7	
Bulgaria	na	na	na	na	na	na	na	na		
Cyprus	na	na	na	na	na	na	na	na		
Czech Republic	na	na	na	na	na	na	20	80		
Denmark	14	35	17	40	19	43	19	42	19	
Estonia	na	na	na	na	na	na	4	40	1	
Finland	na	39	na	56	16	49	16	49	16	
France	15	37	17	44	18	44	17	43	17	
Germany [7]	na	na	na	na	na	na	6	12	5	
Greece	0	0	0	0	0	0	0	0	0	
Hungary	na	na	na	na	na	na	3	48	3	
Ireland	12	53	10	44	9	49	8	38		
Italy	5	13	6	23	6	25	5	24	4	
Latvia	na	na	na	na	na	na	1	2	0	
Lithuania	na	na	na	na	na	na	na	na		
Luxembourg	na	na	na	na	na	na	na	na	na	
Malta	na	na	na	na	na	na	6	28	na	
Netherlands	34	58	38	70	36	75	34	77	32	
Poland [8]	na	na	na	na	na	na	12	47	12	
Portugal	na	34	na	26	na	21	na	na		
Romania	na	na	na	na	na	na	na	na		
Slovak Republic [9]	na	na	27	100	4	97	4	80		
Slovenia [10]	na	na	na	na	na	na	6	73		
Spain	na	na	2	21	na	na	na	na	na	
Sweden	20	48	22	50	19	48	18	46	17	
United Kingdom	31	74	25	73	21	69	20	65		

Table 1: EU – Social rented dwellings as percent of total dwelling stock (TS) and present of total ren dwelling stock (RS)

The Netherlands has the largest social rented sector of the countries surveyed (35%), but England shares with France, Sweden, Poland and the Czech Republic a significant social rented sector (15-18%). This contrasts to the very small scale of the sector in the other English-speaking countries and southern Europe (<7%).[57]

[57] CLG 2007. *An international review of homelessness and social housing policy* http://www.york.ac.uk/inst/chp/publications/PDF/internationalreviewsummary%5B1%5D.pdf

	Year	Bath/shower	Year	Hot running water	Year	Central heating
Austria [1]	2009	99.2	-	na	2009	92.0
Belgium	2009	96.8	2009		2009	83.1
Bulgaria						
Cyprus [2]	2001	99.0	-	na	2001	27.3
Czech Republic [2]	2001	95.5	2001	95.1	2001	81.7
Denmark	2009	96.0	-	na	2009	98.0
Estonia	2002	67.1	-	68.0	2002	59.0
Finland	2009	99.1	2009	97.1	2009	93.4
France	2006	98.5	2006	98.5	2006	93.0
Germany	-	na	-	na	2006	92.3 [3]
Greece [2]	2001	97.8	-	na	2001	62.0
Hungary	2005	91.3	2005	91.5	2005	56.7
Ireland	2002	94.0	-	na	2002	59.0
Italy	2008	99.4	2004	99.6	2004	94.7
Latvia	2008	60.3	2008	61.6	2008	61.2
Lithuania	2008	71.1	2008	61.6	2008	73.5
Luxembourg	2008	99.0	2008	99.7	2008	72.8
Malta [2]	2005	98.2	2005	97.1 [4]	2005	1.2 [5]
Netherlands	2009	100.0	2009	100.0	2009	94.0 [3]
Poland [2]	2008	86.9	2002	83.0	2008	78.0
Portugal	2001	65.6	-	na	2001	3.8
Romania	2008	58.9	2008	57.2	2008	51.9
Slovak Republic [2]	2001	92.8	2001	90.5	2001	74.3
Slovenia	2004	92.3	-	na	2004	79.1
Spain	2008	na	2008	99.5	2008	63.8
Sweden	2008	100.0	2008	100.0	2008	100.0
United Kingdom [6]	2001	99.0	2001	100.0	2001	94.0

Table 2: EU – Bath/shower, hot running water and central heating in total dwelling stock (as per ce of dwelling stock)

Whilst there is no data for some EU countries, it is clear from Table 2 that significant numbers of homes have inadequate sanitation and heating.

	Is privatization of social housing allowed? (Y/N)	Who decides? [1]	Criteria of price determination [2]	Average price per dwelling (euro*1000)	Number of privatized public rental dwellings since 1989	Number of privatized co-operative dwellings since 1989	
Austria	Y [3]	a,d [4]	d [5]	na	0	na [6]	na
Belgium		na	na	na	na	na	
Bulgaria							
Cyprus		na	na	na	na	na	
Czech Republic	Y	b	d [7]	na	na	na	na
Denmark	Y	b,c,d	a		9	0	2007
Estonia	N	nap	nap	nap	nap	nap	nap
Finland	Y	a) tenant (not always possible)	d (construction cost)	na	na	nap [8]	2009
		b) The Housing Fund on application					
		(in the cases of whole houses)					
France	Y	a	b		45	0	2004
Germany	nap	c	a,b	na	na	na	na
Greece [9]	nap	nap	nap	nap	nap	nap	nap
Hungary	Y	e (local government)	d (according to regulations of local government)	na	326,365	na	2004
Ireland	Y	a,b	d [10]	69 [11]	30,325	na	2005
Italy	Y	c [12]	b	25	150,000	na	2008
Latvia	Y	a	a,b	20	410,793	na	2005
Lithuania		na	na	na	na	na	na
Luxembourg	Y	c	b	46	6,168 [13]	na	2004
Malta	Y	c			na	na	
Netherlands	Y	c	b	140	286,000	169	2005
Poland	Y	c,d	b	na	600,000 (municipal dwellings) [14]	600,000 [15]	2007
					300,000 (company dwellings)		
Portugal	Y [16]	a,b	a	26	12,000	na	2005
Romania		na	na	na	na	na	na
Slovak Republic	Y/N [17]	c	d [18]	na	343,740	295,589	2008
Slovenia	Y	c	b	na	139,100	na	1994
Spain	Y [19]	e [20]	d [21]	na	na	na	2006
Sweden	Y [22]	c	a		32,841	na	2008
United Kingdom	Y	d	na	na	2,161,200	na	2004

Table 3: EU – Privatisation of housing stock

Table 3 shows that significant numbers of formerly social housing has been and continues to be transferred to the private sector.

Whitehead and Scanlon note the penetration of the private sector into social housing through public private partnerships: “The private sector is becoming increasingly involved (willingly or not) in the provision of social housing. Government subsidies for new provision and regeneration are increasingly targeted and limited. In the Netherlands, for instance, the housing association sector now funds all its own investment; in Sweden the sector actually makes a positive contribution to government; in the transition economies and in Germany there is no longer any appetite for national funding. More generally, EU monetary requirements and other constraints have reduced available funds. In this context, it is hardly surprising that there is growing emphasis on the role of the private sector, not only in undertaking investment but also in funding that investment.‘[58]

It is apparent that the privatization of social housing and its funding mechanisms may require a redefinition of social housing which more closely matches these trends and recognizes that state and EU policy mechanisms no longer apply solely to the public sector.

General EU-wide housing data: The data show in Figures 1, 2 and 3 is taken from the GEODE report: „Strategies in favour of the reduction of CO2 emissions in the housing sector“ and gives an EU-wide profile of key data relevant to this research:[59]

[58] (Whitehead et al, 2007). Scanlon, Kathleen and Whitehead, Christine M. E., (eds.) (2008) *Social housing in Europe II: a review of policies and outcomes*. LSE London, London.

[59] GEODE, 2005. *Strategies in favour of the reduction of CO2 emissions in the housing sector* http://www.ceps.lu/pdf/6/art1143.pdf

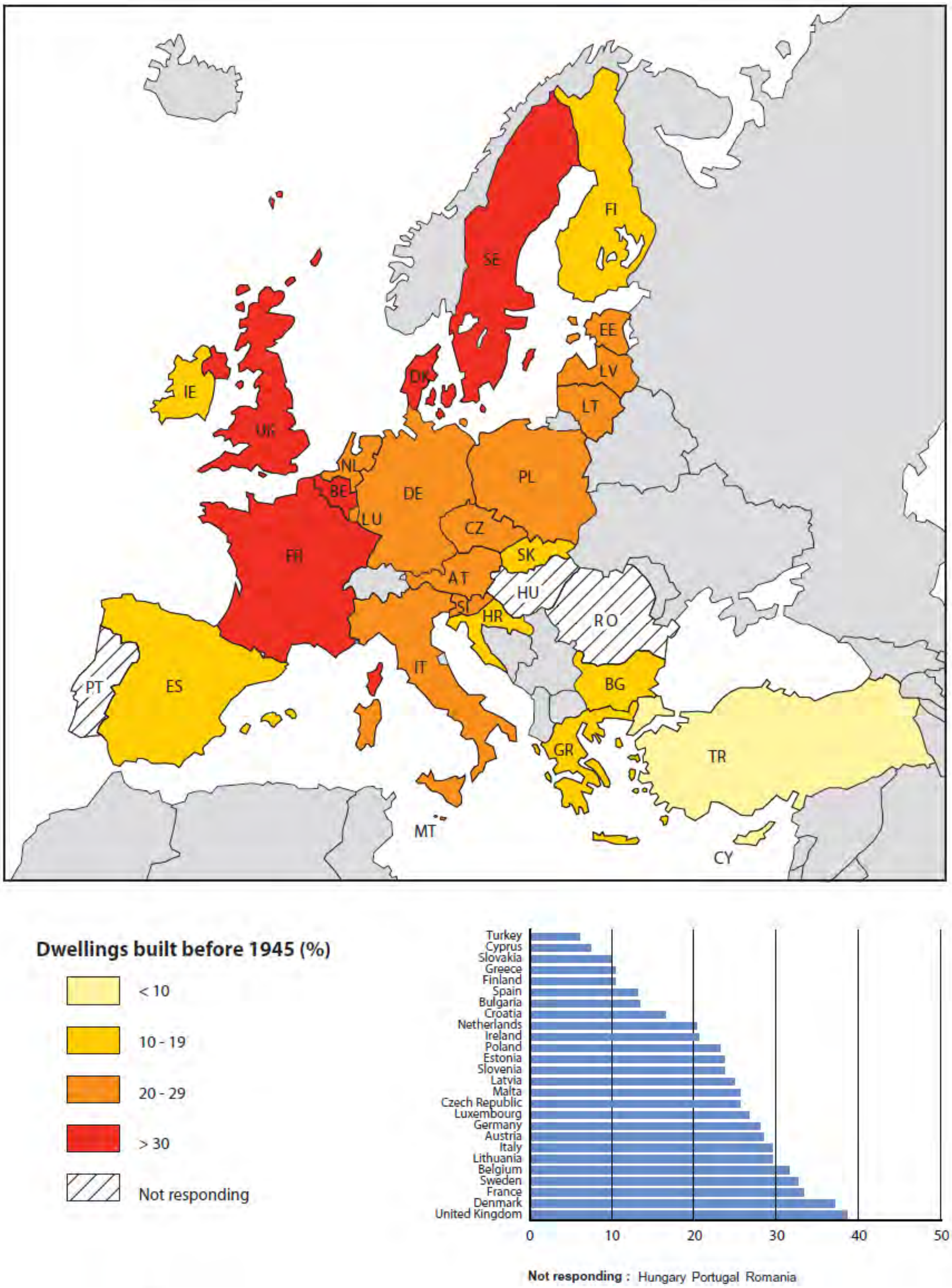

Figure 1: General data on housing – Age of the housing stock
Source: GEODE 2005

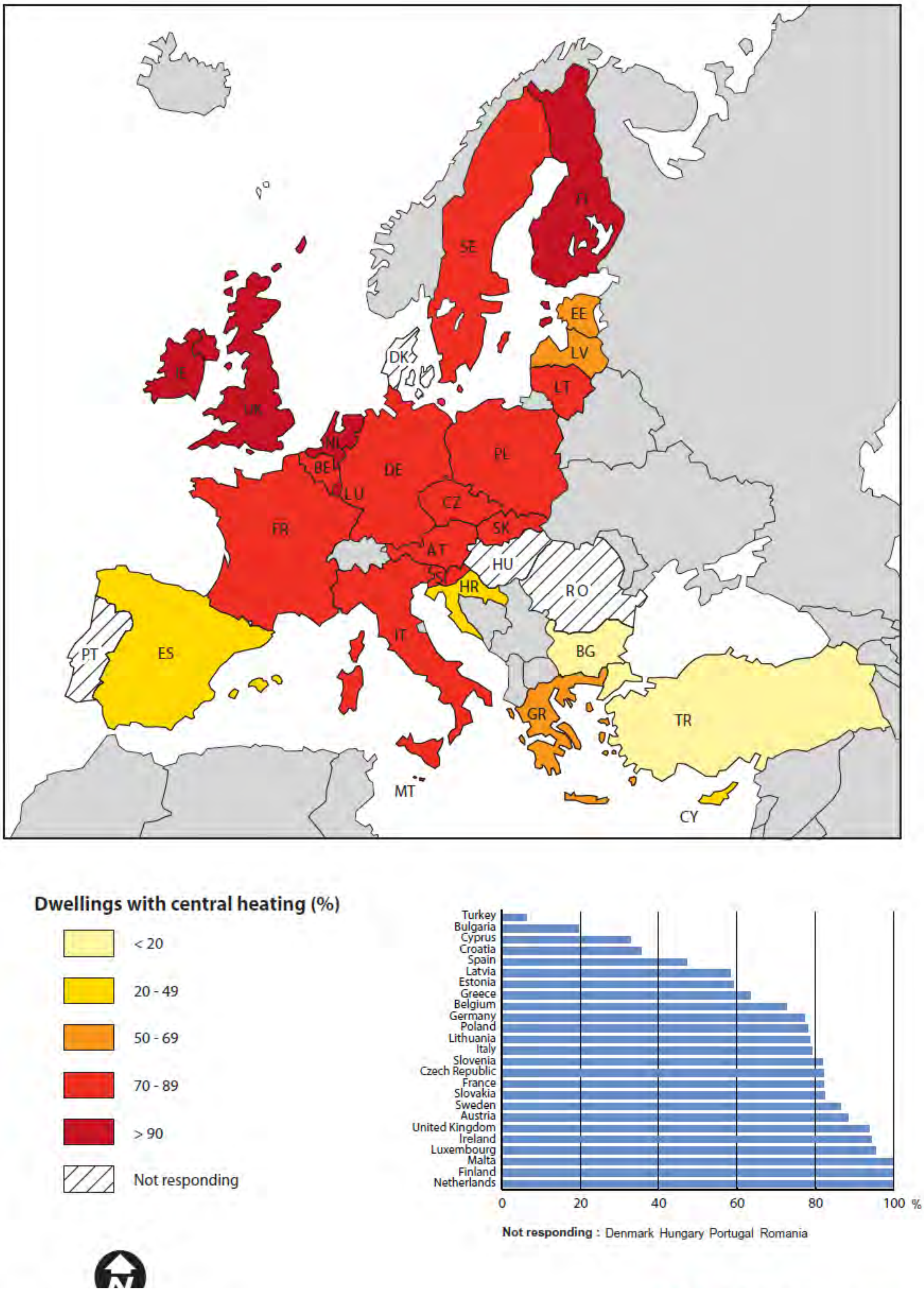

Figure 2: General data on housing – Type of heating
Source: GEODE 2005

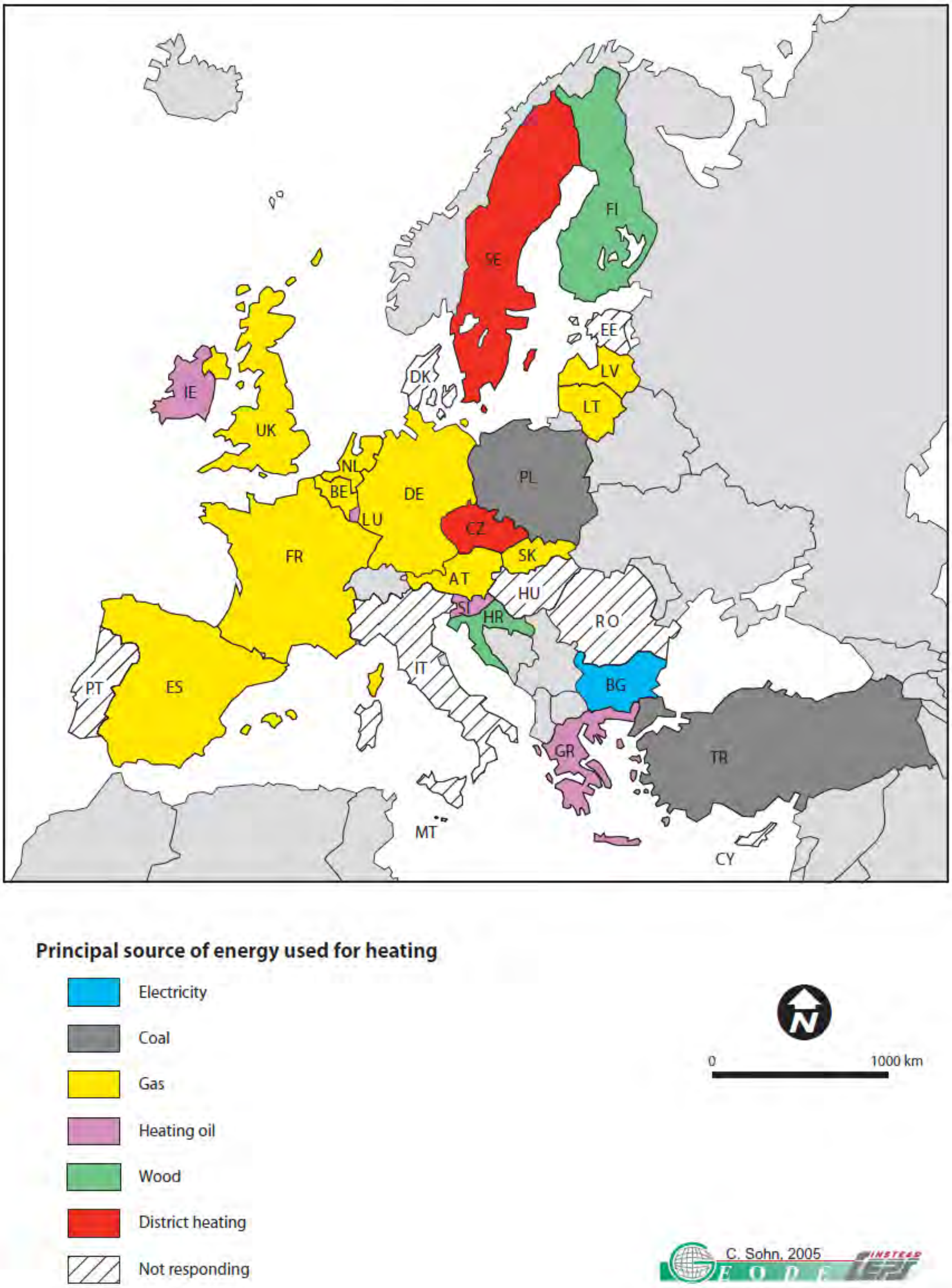

Figure 3: General data on housing – Source of energy for heating
Source: GEODE 2005

United Kingdom housing condition
The UK English Housing Survey is: „a continuous national survey commissioned by The Department for Communities and Local Government (DCLG) that collects information about people's housing circumstances and the condition and energy efficiency of housing in England."[60] The survey provides the data for the following analysis.

Whilst the number of energy inefficient homes is declining, Figure 4, the housing stock is described as: „among the oldest in the world", see Figure 5.[61]

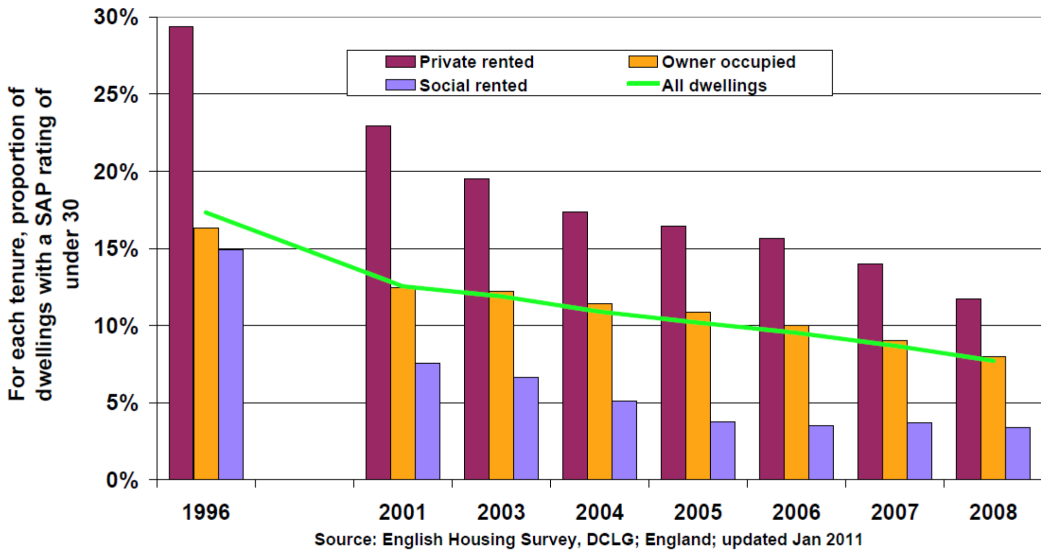

Figure 4: Decline in very energy inefficient dwellings in England

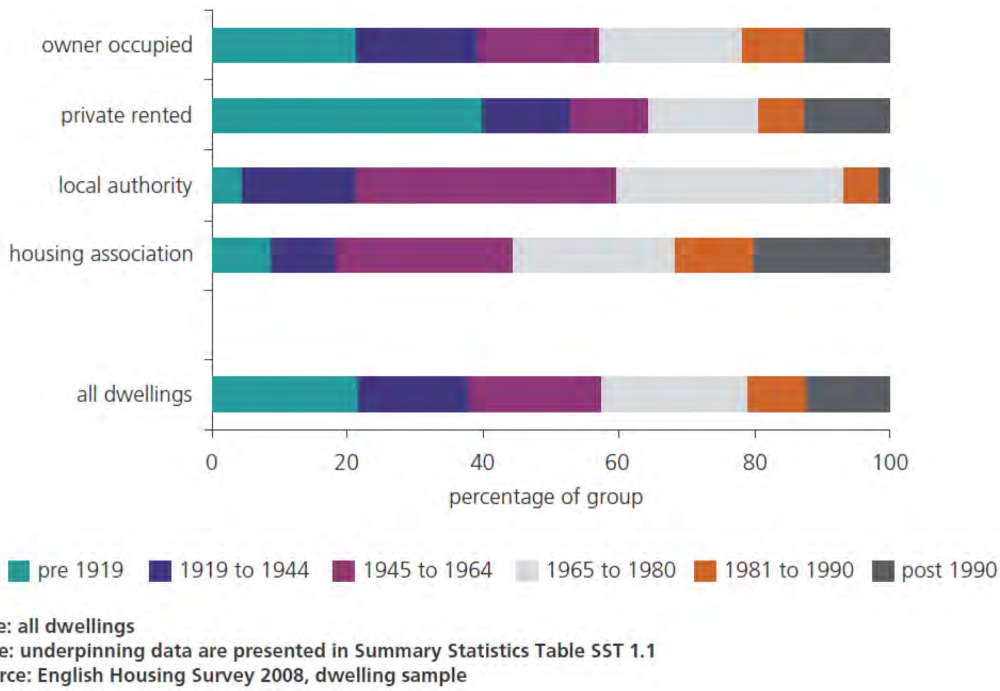

Figure 5: Age of housing in England

[60] CLG http://www.communities.gov.uk/housing/housingresearch/housingsurveys/englishhousingsurvey/
[61] CLG 2008. *English housing survey*. http://www.communities.gov.uk/documents/statistics/pdf/1750754.pdf

Health and safety

In April 2006 the Housing Health and Safety Rating System (HHSRS) replaced the dwelling Fitness Standard as the statutory minimum standard for housing. The HHSRS is a risk-based assessment that identifies hazards in dwellings and evaluates their potential effects on the health and safety of occupants and visitors.

The English Housing Survey notes that approaching half (45%) of dwellings built before 1919 had one or more Category 1 hazards compared with just 5% of those built after 1990 (Figure 4.22). This is mainly due to differences in the size, construction methods and built form of dwellings of different ages rather than higher levels of disrepair in older dwellings. For example, the majority of dwellings built before 1919 have solid 9" brick walls. This makes them more difficult to keep warm and many were built with steep or winding staircases. Standards and Building Regulations have continually set higher levels for these and other aspects of building performance which have improved many aspects of housing over time.

all dwellings

	percentage of dwellings	number of dwellings (000s)
excess cold	8.8	1,966
falls	12.7	2,825
other hazards	5.2	1,165
one or more Category 1 hazards	22.7	5,039

Base: all dwellings
Source: English Housing Survey 2008, dwelling sample

Table 5: Housing hazards in England

It is therefore apparent that older housing stock exhibits poor thermal performance and has a higher frequency of excess cold. This pattern is repeated across the EU, especially in the emerging and recently joined countries.

Healy"s 2003 research[62] used data for 14 EU countries (those which were member states during the years 1994 to 1997) for 1988 to 1997 (data for later years were not available for all countries), and for each expressed the number of „additional" winter deaths as a percentage of the average number of deaths in a four-month „non-winter" period (a statistic which is called the „Increased Winter Mortality index" in Table 4 of GROS's current release).

The results were as follows (listing the countries in order of their index values):

10% - Finland
11% - Germany, Netherlands
12% - Denmark, Luxembourg
13% - Belgium, France
14% - Austria
16% - Italy and overall mean for the 14 countries
18% - Greece, UK
21% - Ireland (Republic), Spain
28% - Portugal

The paper also gave figures for the countries within the UK: England 19%; Wales 17%; Northern Ireland 17% and Scotland 16%.

The Decent Homes Standard

[62] Healy 2003. *Increased Winter Mortality in Scotland* http://www.gro-scotland.gov.uk/files2/stats/increased-winter-mortality/increased-winter-mortality-background-info.pdf

The minimum standard for social housing in the UK is the Decent Homes standard.[63] The broad aims are to raise all homes above SAP 35: „A SAP rating of less than 35 (using the 2001 SAP methodology) has been established as a proxy for the likely presence of a Category 1 hazard from excess cold."

The standard demands programmable heating and: „Because of the differences in efficiency between gas/oil heating systems and the other heating systems listed, the level of insulation that is appropriate also differs:

- For dwellings with gas/oil programmable heating, cavity wall insulation (if there are cavity walls that can be insulated effectively) or at least 50mm loft insulation (if there is loft space) is an effective package of insulation; and
- For dwellings heated by electric storage heaters/LPG/programmable solid fuel central heating a higher specification of insulation is required: at least 200mm of loft insulation (if there is a loft) and cavity wall insulation (if there are cavity walls that can be insulated effectively)."

An overview of UK „Poverty Indicators" and their relation to housing provides adequate evidence that the social housing sector is of a higher thermal quality than the private sector and fuel poverty is highest in the private rented sector.[64]

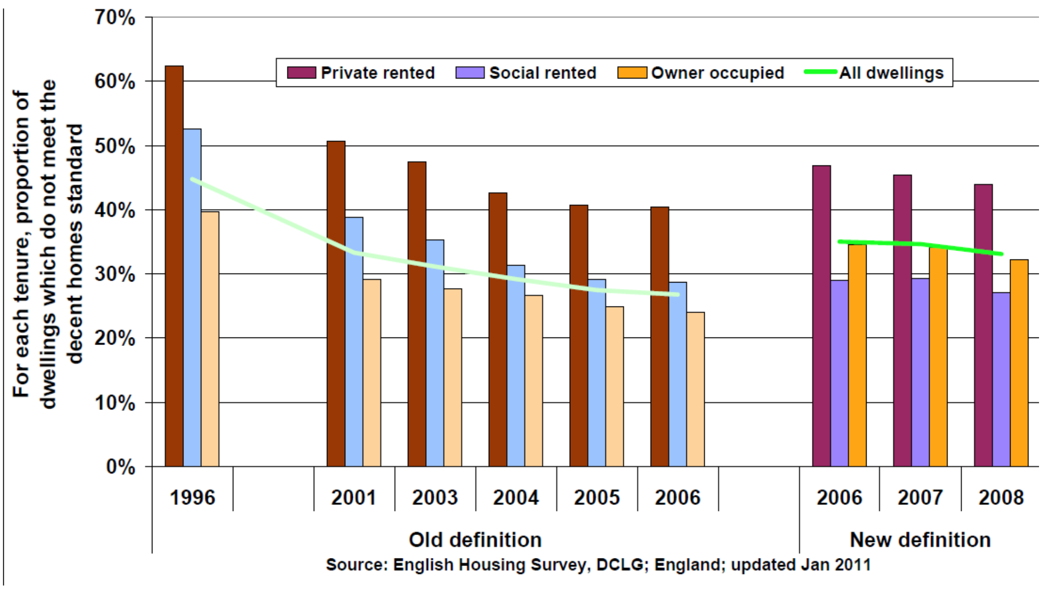

Figure 6: England – number of non-decent homes

[63] CLG (2006). *A decent home: definition and guidance for implementation* http://www.communities.gov.uk/documents/housing/pdf/138355.pdf
[64] The Poverty site. http://www.poverty.org.uk/summary/housing.htm

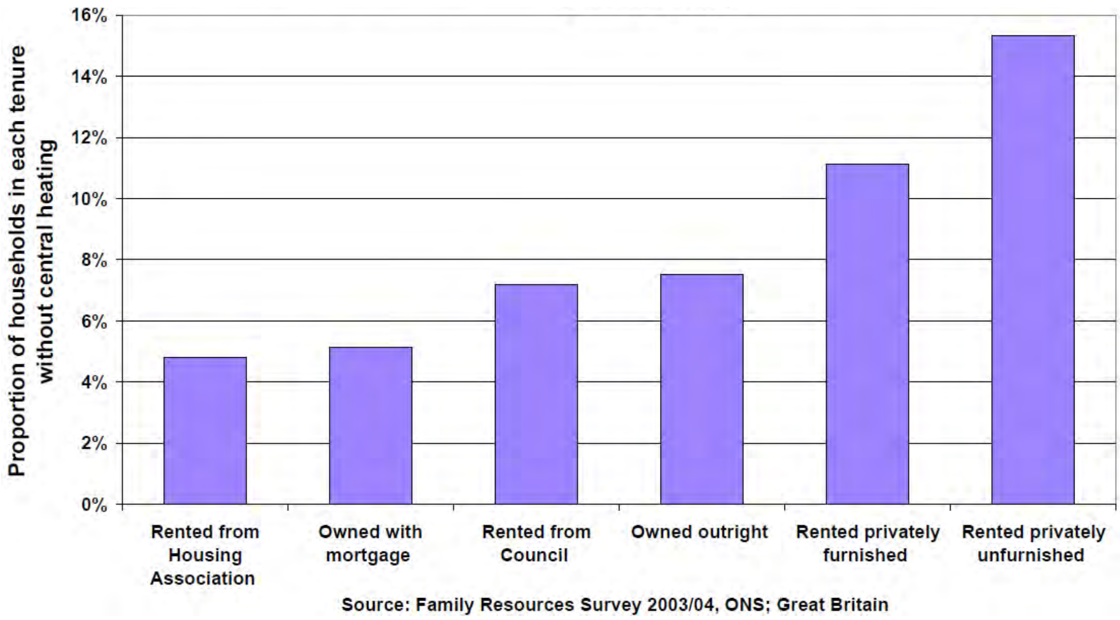

Figure 7: UK – number of dwellings without central heating

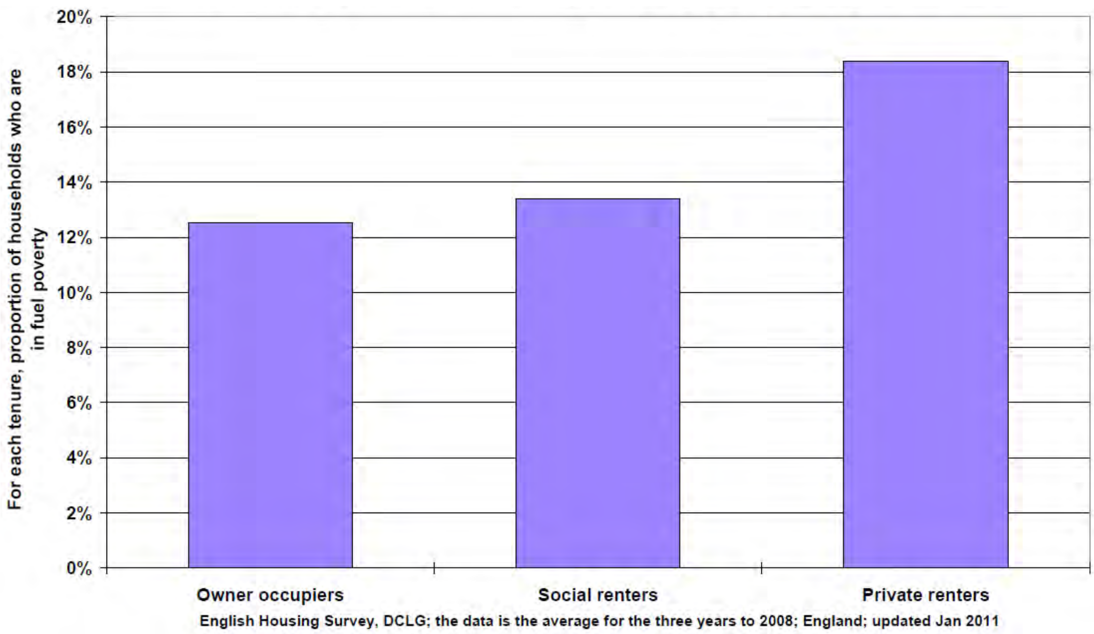

Figure 8: England – fuel poverty by housing sector

The English Housing Survey shows that In comparison to most other housing sectors, social housing has a higher level of thermal efficiency, and central heating, however, there is significant fuel poverty indicating that yet higher thermal efficiencies are socially desirable.

A range of other studies have been conducted to establish the condition of the UK building stock and those buildings which are required to help achieve an 80% reduction in the level of CO2 emission by 2050.[65] David Bott, director of innovation standards at the UK Technology Strategy Board, is quoted as suggesting: „at least 60% percent of the houses we will be

[65] ACE ibid

living by 2050 have already been built, so it is critical that we in the UK look at ways to dramatically improve the performance of our existing housing stock.‟ [66]

According to the Existing Home Alliance (2010), there are approximately 26.65 million homes in the UK, consisting of a mix of housing type and tenures, responsible for 141 million tones of CO2 in 2007. In order to achieve 60% and 80% of CO_2 reduction, the types of homes (detached, semi-detached/terrace, flat/apartment) have been examined to identify potential retrofitting activities. There are total 393,000 homes in Southeast England are required to be upgraded with different retrofits installations to deliver reduced CO_2 emission and energy consumption in next 20 years.[67] In the West Midlands four types of properties (pre-1945 terrace, pre 1945 semi 1945-64 semi and 1965-74 houses) have been targeted for a retrofit programme to help the property owners and landlords achieve energy savings.[68]

According to Retrofit South East (2010), it is estimated that approximately 500,000 existing homes require comprehensive whole house refurbishment every year up to 2050, in order to deliver the targets of 60% to 80% carbon dioxide emission post refurbishment. Therefore cost is highly significant factor affecting the retrofitting of housing in the UK.[69]

Montenegro
There is little social housing in Montenegro. There is some social housing linked to some state sector jobs but virtually all housing previously state owned has been sold to occupants during a process of transfer which began in the 1990s and is now complete.

Poland
In 2008, socially rented housing represented 12% of the total housing stock and 71% of the total rented housing. The City of Warsaw has a municipal „Programme for Social Housing for year 2008-2012‟. In the last 4 years 1300 new units (flats) were completed for use (compared to only 215 between 2003-6). 872 were completed between 2007-9 at a cost of 196m zl. (Current rate 4.6zl to 1 GBP). Warsaw has a population of about 1.72m (June 2010) and alocates10.5% of its budget towards housing.[70]

Spain

Overall housing and social housing statistics for Spain[71] are as follows:

Spain total housing	25,557,237
Andalucia total housing	4,480,787
VPO (Social Housing) Spain	2,776,086
VPO (Social Housing) Andalucia	602, 086

- Between 1991 and 2000 there were 184,759 'retrofits' of VPO stock in Spain
- Between 2001 and 2010 this increased to 501,813
- Between 1991 and 2000 there were 18,818 'retrofits' of VPO stock in Andalucia
- Between 2001 and 2010 this increased to 20,138

What retrofit means in this case mainly is access reforms for disability, but in some cases it involves thermally-related refurbishment. The State Plan for Rehabilitation of Housing 2008-2012 targets various variables aimed at 'improving quality of life' and living conditions, and

[66] TSB, 2010 http://www.innovateuk.org/content/press-release/17m-government-investment-in-retrofitting-to-pave-.ashx
[67] SEEDA *Retrofitting the existing housing stock in the South East* http://www.seeda.co.uk/_publications/346-Retrofitting_exisitng_housing_stock_in_se.pdf
[68] Sustainability West Midlands, 2010 *Scoping study of Good Practice in Finance and Delivery Models for Low Carbon Housing Retrofit* http://www.encraft.co.uk/ws/publications/SWM_housing_retrofit_finance_report-final-22nd_June_2010.pdf
[69] Radian 2010. *The 'Revolving Retrofit Guarantee Fund'* http://www.radian.co.uk/retrofit/files/funding-mechanism-retrofit-overview.pdf
[70] City of Warsaw
[71] Ministry of Economy, 2008, unless otherwise stated

includes energy efficiency. However, the aims of government are not being met in practice, primarily probably because of current financial constraints.

The Public Housing Sector in Spain is similar to the UK, where private companies and organisations collaborate with the local authority to deliver social housing in the form of self-builds; subsidised low-cost housing to buy; low cost accommodation for rent; and partly or fully subsidised housing through state welfare.

Europe-wide research

Ecofys (2005) explored the potentials in reduction of CO_2 emissions in the EU countries by classifying buildings into three different climate zones. Table 6 show the detailed attribution of EU member states to the climate zones.

Cold	Moderate		Warm
Finland Sweden	Austria Belgium Denmark France	Germany Ireland Luxemburg The Netherlands	Greece Italy Portugal Spain

Table 6: EU Members – Climate Zones

Within the different climate zones, the retrofitting demands of housing will be different in terms of house types and sizes based on Ecofys (2005). Table 7 defines the European buildings stock 5 standard building types by the size and use of the buildings.

Type 1	Two-story terrace-end house (120m²)
Type 2	Small apartment house (less 1000m²)
Type 3	Large apartment house (large tan 1000m²)
Small office Building	Less than 1000m²
Large Office Building	large than 1000m²

Table 7: European building types

Figure 9 illustrates the distributions of living areas of the current building stock for different climate zone. The figure shows there are approximate 14bn m^2 of family house in the EU-15 members (Table 4). This gives some idea of the scale of investment needed for the retrofitting and the potential for cost-effective energy savings in the buildings across the EU-15.

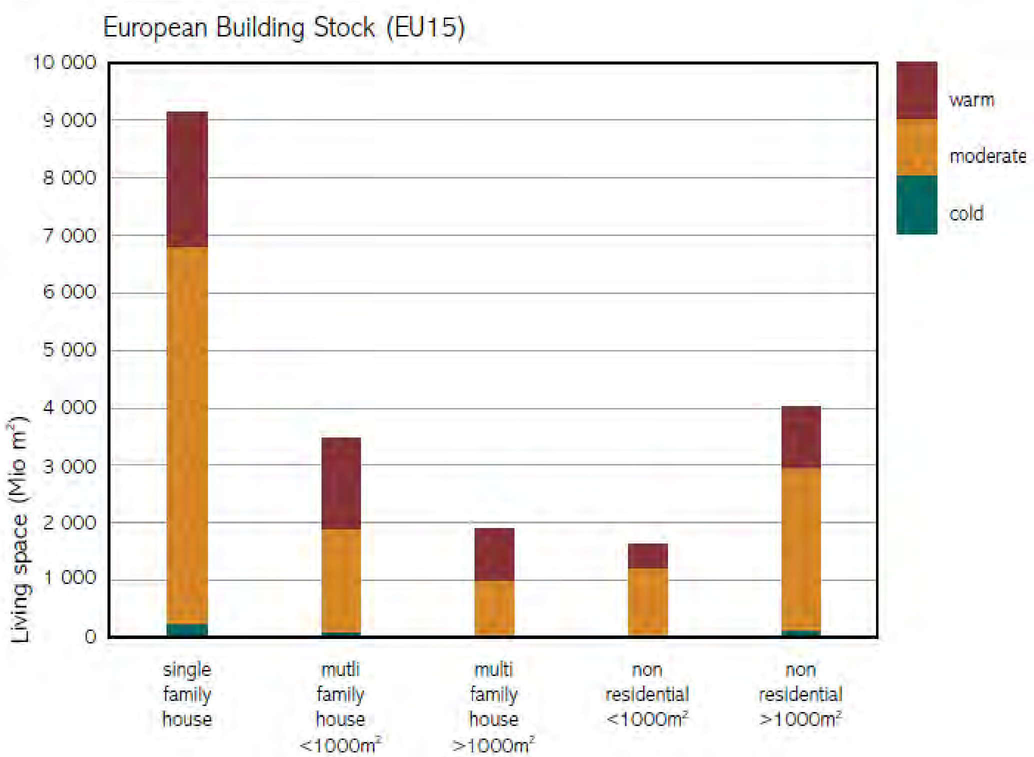

Figure 9: Living areas by housing type and climate zone
Source: EU-15 Building Stock (2002)

In 2006, Intelligent Energy Europe published its research findings in which the focuses on retrofitting of social housing in Europe and which is the main source of recent information on this matter. The research aims to accelerate activities for retrofitting social housing across Europe countries including Denmark, Netherlands, France, Germany, Austria and others.[72]

Projects have been selected to demonstrate the benefits of retrofitting in terms of increased energy performance of (and reduced carbon emissions form) social housing. The aim is to improve knowledge of problems associated with the retrofitting of these houses to provide more appropriate and successful energy-intelligent solutions for the Europe housing sectors.

The main retrofitting activities and schemes covers range of issues in terms of education/training, portfolio management others including tools and systems to deal with financial aspects, communication and strategy development of retrofitting of social housing in the members of EU. Table 8 lists detailed research findings and lessons learnt from the projects.

[72] Intelligent Energy Europe 2006. *Retrofitting of social housing* http://ec.europa.eu/energy/intelligent/library/doc/ka_reports/social_housing.pdf

Projects	Key Findings	Lessons
EI-Education, Denmark (2006)	• An EI-Education programmer for social housing companies • A practical guidebook for social housing companies on energy intelligent retrofitting	• Companies are not interested in training on basic renovation technologies • Web basing guidebook is easy to use
EPI-SoHo, Netherlands (2008)	• Cost effective large scale energy assessment methods • Embedding energy assessment data within policy process (i.e.: portfolio management) • Cost of living to energy saving measure	• A generic implementation technique for cost effective large scale energy assessment needed for policy making process and social housing management • A generic implementation technique on embedding energy performance in policy making arena‟s and social housing management • Barriers for sustainable energy saving strategies
E-Retrofit-KIT, Denmark (2007)	• Tool-kit (Cold bridge, Air-tightness, ventilation with heat-recovery, cooling in southern climate) • Guidance to 30 social housing companies on retrofitting of social housing to Passivhaus standards	• Retrofitting to Passivhaus standards can be implemented in buildings thorough retrofitting • Specific products for retrofitting to Passivhaus to be identified • Concepts for retrofitting of social housing to Passivhaus standards should be developed for Southern Europe climates
ESAM, France (2008)	• Implementation of energy certificates • An energy strategic diagnosis of the housing stock • Definition of energy-retrofitting strategies for housing stock	• Integrated of energy efficiency in global housing stock • Upgrading of energy performance of the social housing stock • Better financing of energy-retrofitting and lower operating cost

Table 8: EU Energy Intelligent projects

The various projects, shown in Table 8, looked at retrofitting activities, schemes, strategic development, training and education and management portfolio (i.e. decision-making processes) to deal with the issues raised in the retrofitting of social housing across EU states.

The EU „Social Housing Action to Reduce Energy Consumption‟ (SHARE) project[73] is a network focused on social housing providers and energy efficiency in order to improve awareness and promote the benefits of low energy retrofitting. The research also developed series of targeted training courses for energy efficiency retrofitting of social housing.

Educational materials aimed specifically at those involved in retrofitting social housing have been developed by the EU under the TREES „Training for renovated energy efficient social housing‟ programme.[74] „The final product is in the form of texts and slides in English. Advanced technologies are described by specialists (e.g. integrating solar hot water systems

[73] SHARE 2008. *Social Housing Action to Reduce Energy Consumption* http://www.managenergy.net/download/nr302.pdf

[74] *Training for Renovated Energy Efficient Social housing* http://www.cenerg.ensmp.fr/trees/

on a roof, preheating ventilation air, insulating and reducing thermal bridges). Tools are proposed (e.g. thermal calculation, life cycle assessment), allowing to assess the interest of these technologies in terms of energy saving and improvement of environmental quality. The presentation of case studies (e.g. European demonstration projects) illustrates the approach and professional good practice. It is hoped that harmonisation of the knowledge at a European level will help to promote good practice, particularly in the new member states."

8. Retrofit employment and labour market

Effects of energy efficiency on employment and the jobs market as a result of the implementation of EU Directive on the energy performance of buildings will depend upon complex macroeconomic feedback mechanisms as is the case with any other policy implementations[75]. Davidson"s 1995 study[76] reported that an increase in jobs by an estimated 71,000 for the Netherlands based on the investment in energy efficiency programme in 1995. The measures cover energy efficiency improvements, lower turnover in the energy sector, reinvestment of saved money and promotion of wind energy. The research examined potential employment effects of the „Toronto Target" for the Netherland, that is a 20% cut in Dutch carbon-dioxide emission from fossil fuel burning by 2005 based on 1988 levels (180 Mton). The total potential net employment effect was record as an increase of approximately 1% of the total employment in the Netherlands.

A study, conducted by the Julich Research Centre (2004) examined "environment protection and job creation by activities of chimney sweeps in Germany".[77] Jobs have been created through service activities, replacement of heating appliances and for energy consulting services. An estimated 45,700 vacancies have been created as a result of these activities whereas the majority of the jobs would result from the replacement programmes.

A ten-year European wide upgrade programme which aims at accelerating the conversion of existing windows in order to reduce energy consumption and CO2 emission by installing high performance glazing in existing dwellings.[78] The study concluded that an estimated 110,000 new jobs could be created for the entire ten-year period. Research[79] examined that direct employment could be effected by additional investment and turnover in construction industry where 11.7 million operatives generate a total turnover of €910 billon/annual. This represents to a turnover of 78,000 EURO/Annual per employee. The study estimated that an additional 150,00-400,000 EURO investment into energy –saving packages would generate one new position.

The study concluded[80] concluded that an ambitious packages with additional investment of 25 billion EURO annually would result at creating approximately 50,000-150,000 additional new jobs in construction and installation industries. The estimated numbers of jobs may be created does not take consideration of the influence on other industries (i.e.: energy or manufacturing) and is clearly not adequate in the numbers. However, the study summarised that moderate positive employment effects in the range of 10,000 to 100,000 jobs across European from the implementation range of energy related schemes and programmes.

A study conducted by Social Development Agency (2007), on the Climate and Employment reported that the Factor 4 has been used to develop the scenarios for the jobs creation across EU-25 and EU-15 states in construction industry. The investment required amount to 25 billion EUROs per year in EU-15 and 4.7 billions per year in EU-25 states will generate approximately 160,000 to 500,00 full time jobs (EU-15) and 135,00 new jobs (EU-25)

[75] Ecofys, 2005 *Cost-Effective Climate Protection in the EU Building Stock.* http://www.rockwool.com/files/rockwool.com/Energy%20Efficiency/Library/CosteffectiveClimateReport.pdf
[76] Davidson, 1995
[77] Kleemann 2004
[78] DG, 1995
[79] Ecofys, 2005
[80] Ecofys, 2005

respectively basing on the different scenarios. SWM estimate that UK retrofitting is already a £20 billion annual market and will need to potentially create108,000 jobs nationally by 2020 in low carbon construction and manufacturing.[81]

With targets of C60 and C80 by 2050, a huge investment will be required to improve and enhance the energy performance of dwellings in the UK. The demand for retrofitting activities presents a golden opportunity for future development and economic growth, in particular, during the current business climate.

9. Economics of retrofitting

Cost and financial impact

Ecofys (2005) suggested that an economic assessment of CO_2 mitigation measures it is not only investment which are relevant but also fuel, maintenance and operational cost-savings that realised. They suggest it is not economic to carry out retrofitting in northern cold regions unless it is combined with other refurbishment measures. However, in moderate and warm climates, stand-alone retrofit measures can be economic.

Total investment of approximately 500 billion EURO would be necessary if all retrofit measures in the scope of the Directive were implemented immediately in the complete residential and non-resident buildings stock. Figure 10 illustrates the required investment to mobilise the technical potential (EU-15). Within an individual climate zone, for example, for the buildings size greater than 1000 m² in the cold condition, 51 billion EURO needed, 394 EURO billion required if the countries are in the moderate climate condition and further 56 billion for the buildings within warm weather condition. For the size of family home (200m²-1000m²), the investment is requested is in total 950 billion EURO. These investments are only based on the estimation of cost for family type of houses which retrofit is required within EU-15 members. Additional investment may also be added if the EPBD takes into consideration of all houses in the members" states and 1750 billion EURO is demanded to fulfil its required implementations.[82]

[81] Sustainability West Midlands, 2010
http://www.encraft.co.uk/ws/publications/SWM_housing_retrofit_finance_report-final-22nd_June_2010.pdf
[82] Ecofys, 2005 ibid

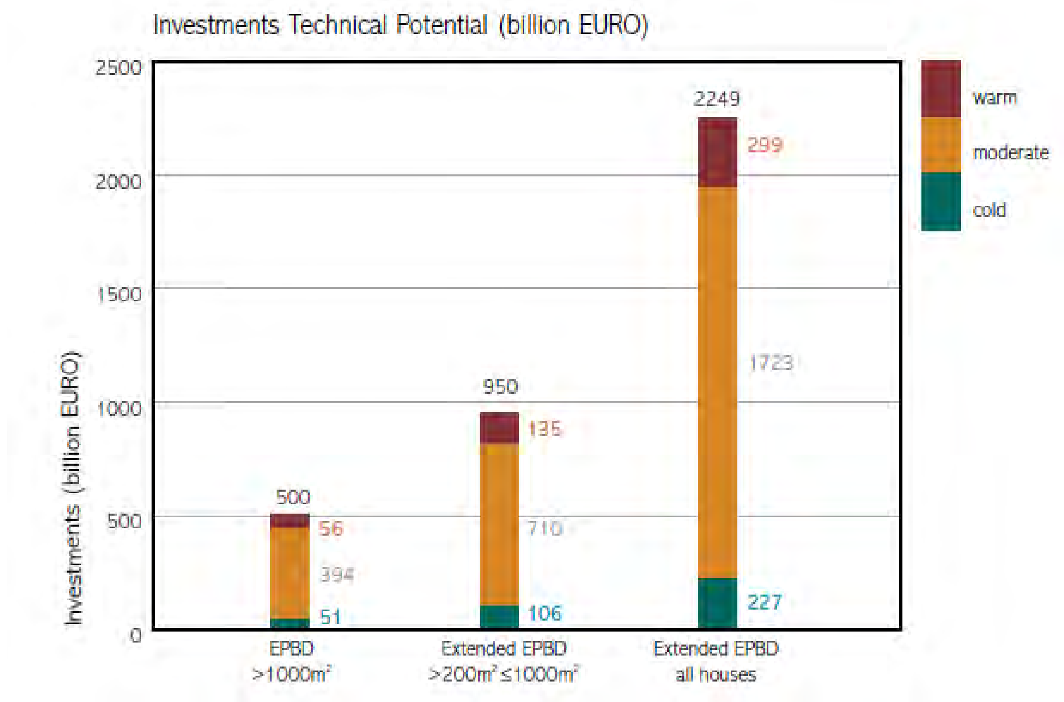

Figure 10: Investment required for family and non-residential buildings (EU15)

Source: Ecofys, 2005

The Existing Homes Alliance represent a picture of investment required for retrofitting housing within the UK.[83] The total requested investment in retrofitting is approximately £500 billion by 2050 estimated at today"s prices. According to SWM (2010), the cost of retrofits will be different basing on the building types and materials used to construct the property. Tables 10 and 11 illustrate the estimated cost for the dwellings.

To retrofit a typical semi-detached house (built 1945-64), the cost is approx £18,581 (lowest) and £32,170 for a pre 1945 semi –detached house constructed with brick/block with render (Table 6). All retrofitting activities are such as over-cladding, double glazing, floor insulation, door replacement and solar thermal collectors and thermal store to reduce the energy performance of the buildings.

A separate cost analysis concluded (Table 7) that the retrofitting of a semi-detached house requires approx £32,236 to carry out the same major improvement work. For the flats, the cost of retrofits is significant lower than a semi-detached home, for example (Table 7), a flat in high rise building block constructed with concrete frame, brick infill, cavity walls can cost approx £16,371 to carry out the retrofitting of over-cladding, triple glazing, communal gas heating with heat recovery and solar thermal collectors. The detailed the cost of retrofitting of a typical flat can been found in the Table 10.

[83] Existing Homes Alliance, 2010 ibid

Archetype	Construction	Major Improvement	Estimated Cost
Pre 1945 Terrace	Solid Wall	• Overcladding • Double Glazing • Floor Insulation • Door Replacement • Communal Biomass Heating	£25,717
Pre 1945 Semi	Brick/Block with Render	• Overcladding • Triple Glazing • Door Replacement • Floor Insulation • Solar Thermal Collectors and Thermal Store	£32,170
1945-64 Semi	Brick/Block External Brick with Cavity	• Double Glazing • Floor Insulation • Solar Thermal Collectors • Upgrading Solid Fuel Boiler	£18,581
1965-74 Houses	Mactrad Timber Frame	• Rebuild of Wall • Wet Space Heating • Communal Solar Thermal collectors	£24,474

Table 10: Cost of retrofitting houses
Source: Sustainability West Midlands, 2009

Archetype	Construction	Major Improvement	Estimated Cost
Semi Detached House	Smiths System	• Overcladding • Triple Glazing • Floor Replacement • Door Replace • Solar Thermal Collectors and Thermal Store	£32,236
Medium Rise Flats	Wimpey No Fines	• Overcladding • Triple Glazing • Communal Solar Thermal collectors	£22,602
Medium Rise Flats	Concrete Frame, Brick in fill, Cavity Walls	• Overcladding • Double Glazing • Communal Solar Thermal collectors	£21,351
High Rise Flats	Concrete Frame, Brick in fill, Cavity Walls	• Overcladding • Triple Glazing • Communal Solar Thermal collectors	£16,371

Table 11: Cost of retrofitting flats

Source: : Sustainability West Midlands, 2009

This study covered only the west midlands region in the England. On average, for all buildings with different construction systems, materials and structures, the cost of retrofitting of a building could reach £24,188 (see Table 12). The estimated annual investment in England basing on the average cost of £24,188 is approx 12 billion. Table 12 shows the cost of a typical residential building with proposed retrofit activities. The proposed retrofit actives are mainly focusing on insulation and the heating system to improve overall energy performance. According to report[84], the key characteristics of a successful retrofit programme that can deliver the highest financial and carbon return are:

- „To deliver the maximum financial and carbon returns, the activities and programme will engage and motivate the occupant
- To optimise investments, bespoke technical solutions need to be specific and delivered to a high quality for each property
- Programme/activities have to be very large scale, successful activities and models must be replicable nationally, across the full diversity of our housing stock."

Building	**Proposed Retrofit Activities**	**Average Cost**	**Annual Investment**
Residential Buildings/Dwelling	• Over-cladding • Communal Biomass Heating • Upgrading Solid Fuel Boiler • Wet Space Heating • Triple Glazing • Floor Insulation • Door Replacement • Solar Thermal Collectors and Thermal Store • Double Glazing • Communal Solar Thermal collectors	£24,188	£12 Billion (Approximately), 500,000 Buildings requested for retrofit

Table 12: Average cost and requested annual investment

Source:

A report on behalf of Radian[85] estimated that average energy bills are likely to quadruple over next 10 years in the UK. The average household is current paying £1243 (compare to 540 in 2004) and could potentially be paying 5000 by 2020, which means that households who posses less than £50,000 yearly disposable income will live in the fuel poverty in 2020. Radian note that the Revolving Retrofit Guarantee Fund (RRGF) has been used in the Hungary where the average family already lives in the fuel poverty, spending 9.7 % or more its disposable in come on the energy bills.[86] In Hungary 300,000 homes have already been refurbished and further 100,000 per annum will be refurbished according to the government plan.[87] This requires huge investment of the refurbishment of homes which have to achieve an energy efficiency upgrade. Higher energy prices encourage households to invest into energy efficient retrofits or lobby their landlord for the same, however, by the time that they will be ready to make the investment decisions, they may not be able to afford the cost of the retrofit project.

Financial Mechanism and Models

Low interest loans for energy (German Model, 2008-2020) are available to assist older properties reach new-build standard through refurbishment (only pre-1984 dwellings are eligible for the loans scheme). Upon reaching this standard the government will repay 10% of the loan to the household. The essential features of the scheme are:

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[84] Sustainability West Midlands 2010 ibid

[85] Radian, 2010. *The Revolving Retrofit Guarantee Fund Mechanism* http://www.radian.co.uk/retrofit/files/funding-mechanism-retrofit-indepth.pdf

[86] CEU, 2010

[87] Bencsik, 2010

- „Fixed (and heavily subsidised) interest rate for 10 years - the rate varies depending on loan amount and duration and revised annually
- Repayment over 4 - 30 years
- Up to €50,000 per dwelling, regardless of which package is chosen
- Loan can cover 100% of the investment as well as labour cost and secondary cost such as scaffolding
- Flexible repayment
- Can be used in combination with other refurbishment loans
- ESCOs carrying out refurbishment are eligible for the loan."[88]

A low cost capital programme funded by Green Bond (Green Infrastructure Bank, GIB) has provided: i) Upfront capital to householders to be repaid as loans; ii) Subsidies to householders to complement these loans-on bases of ability to pay; iii) The administrative process-including the „portfolio manager" who would oversee delivery of the scheme.[89] The scheme has raised a subsidy stream which is used to:

- 'Provide a loan guarantee facility (to underwrite loans taken out under the Pay-As-You-Save system
- Subsidise loans to say 3% (disbursed through the retail banks) and provide additional grants to incentivise „deep" refurbishment with many measures (allocated by portfolio manager according ability to pay)
- Fund the delivery agent (portfolio manager) overseeing the delivery of energy efficient retrofit „[90]

For loan based schemes, the repayment could be secured through a long-term location-specific Pay As You Save approach as proposed by the UK government, which attaches the loans to the home not the occupant, enabling the loans to be spread over 25 years and pass from householder to householder.[91] A report by Conservative Party, „The low carbon economy: security, stability and green growth" (2009) highlighted that a variety of measures, including pay as you save (PAYS), could encourage the development of a low carbon economy, including the retrofitting and improvement of the UK"s current housing stock by:

> „Introducing a new entitlement for very home to be fitted immediately with up to £6,500 of approved energy efficiency improvement, the cost to be repaid through fuel bills over a period up to 25 years but delivering immediately reductions in the gas and electricity bills of participating householders"[92]

Some other funding schemes and approaches have been introduced to support retrofitting of housing in the UK. ACE (2010) suggest that interest free loans and PAYS have helped householders and business to carry out retrofitting of housing. Table 13 outlines the key features of their proposed schemes. The schemes have made positive impact in the retrofit/refurbishment and receive a good response from the sector.[93] The report (ACE, 2010) pointed out these schemes should be monitored to ensure that alternative methods of funding be considered, for instance it may turn out to be beneficial to redirect funds from schemes such as the fuel allowance which aid current consumption towards efforts of energy efficiency that improve longer term performance and ultimately lower the burden of energy bills.

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[88] Seeda, 2010, ibid p.82
[89] E3G and Ingrid Holmes, 2010, *Financing energy efficiency: Bringing together the Green Infrastructure Bank,green bonds and policy* http://www.transformuk.org/attachments/products/17/e3gfinancingenergyefficiencybringingtogetherthegreeninfrastructurebankgreenbondsandpolicy.pdf
[90] E3G and Ingrid Holmes, ibid
[91] E3G and Ingrid Holmes, ibid
[92] House of Commons library research paper, 2009 *Fuel Poverty Bill*, p.26 www.parliament.uk/briefing-papers/RP09-**25**.pdf
[93] ACE, 2010 ibid

Funding Scheme	Key Features/Assessment Criteria
Interest Free Loans	• Between £3000 and £500000 borrowed interest free • Anticipated energy savings offset the loan repayment • The loans • Are government funded and unsecured • The application process is straight forward and fast, with no arrangement fees • A conditional offer will be made within 24 hours of an application processed • Loan can be repaid over a period of up to 4 year
Pay As you Save (PAYS)	• Loans to be provided to owner to make retrofitting/improvement on their property • Increased energy efficiency • Energy bill reduced • Repayment to be added to the fuel bill ever a period of years

Table 13: Summary of retrofit scheme

Relish™, „residents for low impact sustainable homes", is a funding mechanism which focuses on the retrofitting of the existing housing in southeast England. The funding programme is to explore ways in which it could contribute towards the 80% target reduction in CO2 emission through serial of exemplar and demonstration projects for social landlords and the existing homes.[94] The purpose of the Relish™ scheme is to reduce the energy in existing occupied home through low cost, „sensible" refurbishment-giving maximum return, in term of energy savings, per pound spend. The key features of Relish™ are:

- „Formulating a sensible approach and specification for low carbon refurbishment within an affordable budget
- Implementing the programme whilst the property remains occupied for a target sum of £6,500 above decent homes costs
- Developing bespoke and tailored residents" advice and education which is accessible, easy to use and involves every member of the household
- Helping to lift households out of fuel poverty
- Sharing best practice on low carbon retrofit works to occupied homes
- Developing an updateable database of the most cost effective, best in class, energy improvement
- Documenting the benefits of energy monitoring and targeted energy advice
- Developing the Relish™ rating system (household energy rating system)."

Four pilot homes have been selected to improve insulations of loft/roof, walls, floors and air tightness, heating, lighting and electrics appliances in order to achieve energy saving. The initial finding is that households with these retrofits could save up to £367.72 (18%) on their annual energy bills when supported with energy advice. Households without energy advice saved as little as £38 (4%).[95]

[94] Relish, 2010 *Residents 4 Low Impact Sustainable Homes* http://www.relish.org/downloads/RELISH_9_MONTH_REPORT.pdf
[95] Relish *Lessons learned and outcomes of phase 1* http://www.relish.org/downloads/RELISH_12_MONTH_REPORT.pdf

Under The Green Deal[96] householders and business will be able to improve their homes at no up-front cost; they will be offered loans which will be repaid directly from their energy bills. The table 14 illustrates a typical example the loan for the retrofitting activities.

Cost of Installation	Interest Rate	Annual Repayments	Annual Energy Bill (Price as today)	Actual Savings Per Year
Cavity Wall, Door and Loft Insulation £1,000	7% for 10 years	£137	Reduced by £267	£130

Table 14: An example of loan repayment and savings

This example shows that actual savings can be achieved through the loan system where the loan will be used to install cavity, door and loft insulation at a cost of £1,000. The money the owners/business has to pay back is £1370, the energy bill will be reduced by £2670, and in the total the business/owner can save £1300 cash. However, to get access to the loan, there is „golden rule,“ which is: the energy bill should go down by more than the loan repayment.[97]

There are various funding mechanism, models and programmes such as Pay-As-You Save (PAYS) and interest free loans which aim to help householders, owners, landlords to undertake retrofitting activities in existing building to deliver CO_2 emission targets and to reduce energy consumption. To achieve these aims and objectives, there are a range of retrofit techniques and methods which have been developed and applied to different types of dwellings to address energy related issues.

10. Understanding retrofitting

CO_2 emissions from homes amount to some 30% of UK emissions. Typical household emissions are 10 tonnes per year and their distribution is shown in Figure 11.

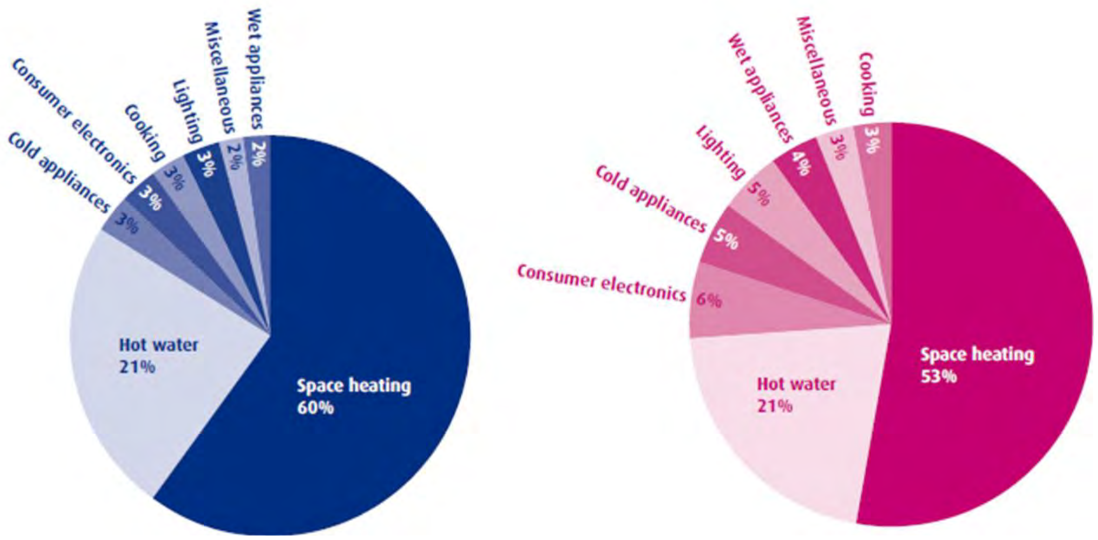

Figure 11: Average household energy use and CO2 emissions

Source UK DTI Energy consumption tables 2004

[96] DECC, 2010
[97] DECC, 2010

Retrofitting in social housing has been concerned with reducing heat losses and thus energy bills. Early retrofit projects concentrated on the building envelope and central heating boiler. Social housing providers indicate that, through grants or their in-house budgets, loft insulation has been installed across their property portfolio and where applicable, cavity wall insulation. Annual boiler servicing provides the opportunity to assess boiler efficiency and generally at the end of the working life, old boilers have been replaced with new condensing boilers operating at higher efficiencies. These three measures, loft, cavity wall and boiler replacement, have been rolled out across the social housing stock by most social landlords in order to meet and exceed Decent Homes standards and to improve thermal comfort whilst reducing fuel poverty. Older housing stock with open coal fires with back boilers, or gas-fired room heaters with gas multipoint hot water heaters have mostly been replaced with full house central heating. Many Local Authorities and Housing Associations have also replaced single glazed windows with double glazed units as part of their long term upgrading of stock in line with maintenance requirements and occupant expectation.

Modelling emissions

To calculate emissions, it is necessary to model the existing building to evaluate annual fuel costs and CO2 emissions as a benchmark to compare retrofit measures against. In England the most commonly used tool for this is The Government‟s Standard Assessment Procedure for Energy Rating of Dwellings (DECC 2010).[98]

SAP has been developed from the Building Research Establishment‟s Building Research Establishment Domestic Energy Model (BREDEM) software. SAP calculates the energy demand for heating, ventilation, hot water and fixed lighting under standard occupation developed from long term stock analysis. A reduced form of SAP, RDSAP, has been used to implement the EPBD with emissions from dwellings in the form of Energy Performance Certificates. SAP will calculate, inter alia, the annual kWh loads and CO2 emissions under normal occupation for a single UK location.

Approaches to retrofit

Consultation with social landlords, architects and builders have provided a number of metrics applicable to retrofit. These include initial cost, annual monetary savings, annual CO2 savings, simple payback, cost per kgCO2 saved. More complex measures involving life cycle costs are less common but include carbon cost effectiveness.

Retrofit analysis also requires a supply and fit cost database and current fuel costs. For life cycle analysis, projections of grid carbon intensity and fuel costs are necessary.

Typical units provided are: Installation costs, annual monetary savings, annual CO2 savings, payback period, cost per kgCO2 saved, cost per kWh saved. A life cycle approach such as carbon cost effectiveness (CCE) considers {(initial cost – fuel saved)/ lifetime CO2 savings}. These metrics may be expressed as Prime Cost, Payback, Value Utility, Value Carbon and Carbon Cost Effectiveness.

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

Metric	Units	Comments
Prime cost	£ or €	Generally the principle concern of residents
Payback (Cost/Annual savings)	Years	Does not take into account time value of money. Needs Net Present Value level of complexity for more complete analysis
Value Utility	£/kWh	Recognises that energy savings are related to specific fuel costs. One kWh of electricity is worth more than one kWh of gas.
Value Carbon	£/kgCO2	Model based cost of intervention and resultantchange in annual emissions
Carbon Cost Effectiveness {(initial cost – fuel saved)/ lifetime CO2 savings}	£/kgCO2	Requires assessment of future fuel costs and lifetime energy efficiencies

Table 15: Retrofit metrics

Example application based on SAP and current UK costs
Assume a detached house with insulated cavity walls, 150mm loft insulation, double glazed windows, existing free standing cast iron boiler and hot water cylinder at 60% efficiency. Replacing the heating system with condensing combi gas boiler at 90% efficiency and weather compensation controls produces the results in Table 16.

Retrofit measure	Cost	Fuel saved	payback	kgCO2/yr saved	£/kgCO2	Life years	CCE
Condensing Combi & New controls	£3,000.00	£282.00	11	1095	£2.74	12	-0.03

Table 16: Example retrofit evaluation

Retrofit Hierarchies
A series of retrofit measures of increasing cost form a hierarchy of intervention packages. A number of hierarchies are given below.

Forum for the Future – Retrofit West: The Retrofit West programme, a consortium of environmental groups, green architects and eco builders, led by Forum for the Future[99] proposed a series of retrofit packages for a range of building typologies including detached, semi and flats with: "each designed to combine measures that are efficient to complete together and designed to become progressively more expensive."

Package 1

- Energy saving lighting
- Draught proofing
- Roof insulation
- Cavity wall insulation

Package 2

- New windows
- New boiler and controls

[99] *Forum for the Future – Retrofit West* http://www.forumforthefuture.org/projects/refit-west

Package 3

- Internal wall insulation
- Floor insulation

Package 4

- External wall insulation
- Floor insulation

Package 5

- Renewables
- Solar thermal
- Solar PV

"Each package should be applied in order (you cannot install package 2 until you have installed package 1), but packages 3 and 4 are mutually exclusive, a choice must be made between internal and external insulation." The renewable options are available with all packages.

Generation Homes initiative: "Generation Homes is an initiative that aims to establish a systematic approach to reducing carbon emissions from existing houses by more than 60% through deploying integrated low-carbon technical solutions as part of major refurbishment work. As a result, individual houses will emit no more than 2 tCO_2/year, which is the Generation Homes standard."[100]

Basic improvement measures – fabric

- Cavity wall insulation
- Top-up loft insulation
- Full double glazing
- Floor insulation
- Draught stripping and extract fans

Improvement measures - heating

- Condensing boilers
- Heating controls – thermostatic radiators
- Heating insulation – hot water cylinder

Lights and appliances

- Low energy light bulbs
- Rated appliances

Advanced improvement measures - package

- Cavity wall insulation
- High performance windows all round
- Insulated doors
- Better controls
- Air tightness measures
- Heat recovery ventilation

New and renewable technologies

- Solar hot water (solar thermal)
- Photovoltaics
- Biomass (wood) heating
- Ground source heat pumps

[100] Camco *Generation Homes* http://www.camcoglobal.com/en/casestudyview.obyx?cs=generationhomes.html
The general specification is again based on a hierarchy of interventions:

- Domestic combined heat and power
- Wind turbines

This study recognises that: "Solar thermal and PV are well established and demonstrate good performance. Others, including biomass heating and GSHP are common in some European countries, but not in the UK. Yet others, namely DCHP and wind, are not well tested and monitored in practice at a small, individual property scale."

A similar approach is taken by the UK Housing Forum[101] who provide an extensive review of retrofit in "Sustainable Refurbishment of Existing Housing Stock" (Housing Forum, 2009): "The 2008 Climate Change Act requires the UK to reduce its carbon emissions by 80% by 2050 against a 1990 baseline. Table 1 from the Department of Communities and Local Government shows the contribution the residential sector will be expected to make in achieving this reduction. The average household in the UK produces over ten tons of carbon dioxide per year from energy use in the home, consumption of food and products and transport. Under the new target this will need to be 8 tons by 2020 and 2 tons by 2050."

Whilst commenting on the physical demands of this programme, the Housing Forum add that:

"Although the reduction of carbon emissions in the existing housing stock will entail a huge programme of physical renovation of its building fabric, this will not be enough on its own. The profile of the occupants of a particular dwelling and their behaviour has a critical impact on the levels of carbon emissions from their homes. As the modelling ….. indicates, improvements to the building fabric become uneconomical at a certain point, after which it becomes sensible to concentrate on behavioural change and management of occupancy."

Thus the challenge is two-fold – reduce the need for fossil-based fuels and change occupant behaviour. SAP can however provide a useful benchmark for assessing structural heat losses and attendant heating and hot water efficiencies.

The Housing Forum: The Housing Forum propose a methodology for retrofit based on the assumption that modelled properties have not had significant refurbishment works. The model is based on four types of intervention with cost and disruption as the benchmark factors.

Low cost and or non disruptive measures i.e.

- Low energy light-bulbs
- Hot water tank insulation
- Heating controls i.e. TRV"s, programmers and thermostats

Medium cost and or moderately disruptive measures i.e.

- New gas condensing boilers
- Loft insulation
- Cavity wall insulation

High cost and or Significantly disruptive measures i.e.

- External wall insulation
- Internal wall insulation
- Floor insulation
- Double glazing

Low carbon technology and Renewable energy technology i.e.

- Communal biomass systems

[101] Housing Forum *Sustainable Refurbishment of Existing Housing Stock* http://housingforum.org.uk/sites/default/files/sustainable-refurbishment-010409.pdf

- Photovoltaic panels
- Solar thermal evacuated tube

These options are then modelled against four different building typologies and the results graphed to show cost against carbon reduction. All exhibit a similar pattern of gentle gradient followed by a "tipping point" where costs accelerate against CO2 reductions. These impacts are shown in the graphs below.

Emission reduction curves – 'Tipping Point'

Assessing retrofit interventions by cost per kgCO2 saved, clearly shows that high cost and often disruptive options produce an emissions reduction curve which displays a tipping point indicating that, at about 50 to 60% savings, a cost increase disproportionate to the emissions saved. This has been described as the tipping point. Any interventions beyond the tipping point are considered by some industry sources to be unduly expensive at the current time.

Results from the Housing Forum methodology are shown in Figures 12, 13, 14 and 15. These suggest four levels of intervention and disruption which can be linked to the following housing typologies: period terrace, tenement/low rise block, high rise block and 1950"s semi-detached. The English Housing Survey shows that these typologies make up about 80% of English housing stock with high rise blocks making up the smallest fraction.

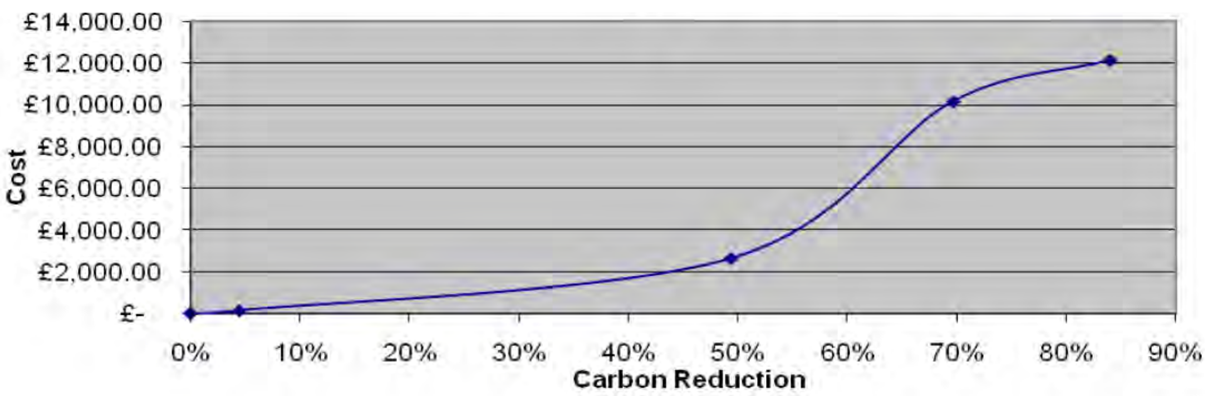

Figure 12: Housing Forum: Cumulative const of reduction in high-rise mid floor flat

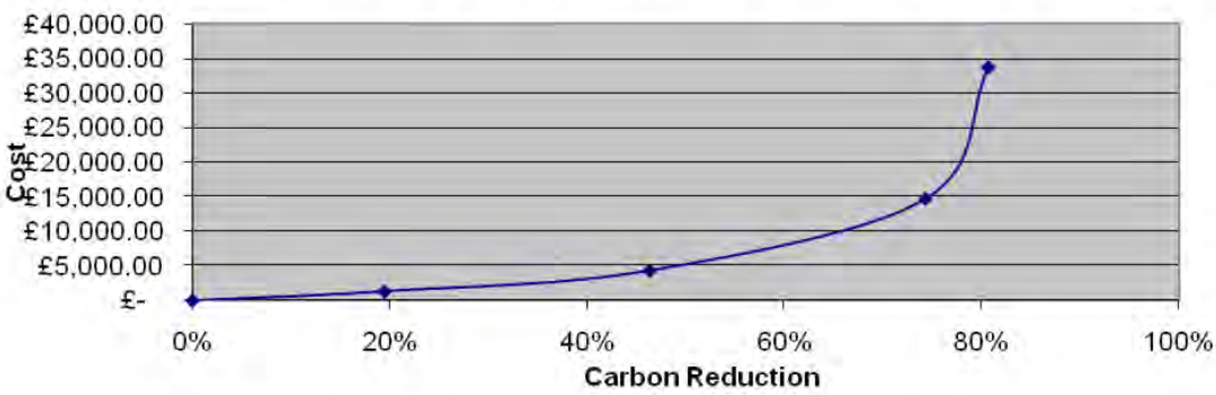

Figure 13: Housing Forum: Cumulative const of reduction in period terrace dwelling

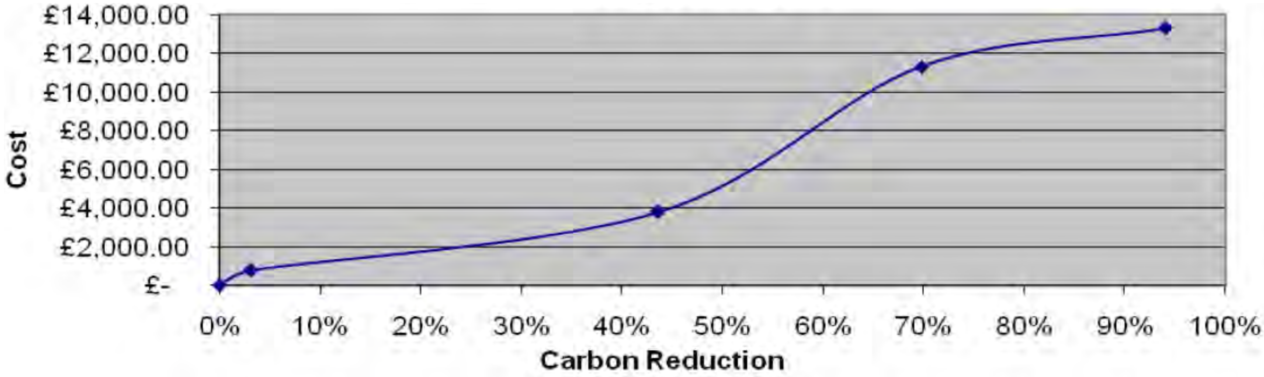

Figure 14: Housing Forum: Cumulative const of reduction in tenement/low rise top floor flat

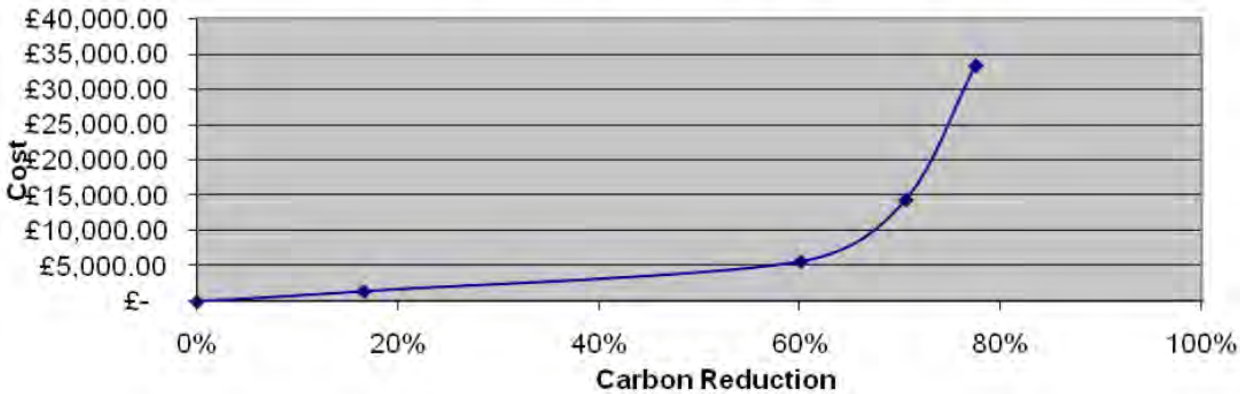

Figure 15: Housing Forum: Cumulative const of reduction in 1950s semi-detached house

Verification of this pattern is provided from other sources representing commercial organisations, construction contractors and sector forums. Each retrofit measure is evaluated and the results tabulated by the most important criteria for the client. The literature review and the interviews provided various ways of viewing these outputs but what is common is that all show the same type of cost per emissions savings curve which rises steadily until it reaches a "tipping point".

Generally, the tipping point occurs at approximately 60% emissions reduction and indicates the beginning of the "deep" retrofit process with its related high cost and high disturbance. The Housing Forum provide a further acceleration to the curve with renewable energy, whilst Passivhaus-type retrofit would aim to reduce emissions through the envelope and thus impact by further reducing heating and ventilation demands.

11. Disruption

In the UK there are clear correlations between high emissions and year of construction/typology. Provided that occupants are willing to cooperate, low and medium cost/disruption measures are possible although interviews provide evidence of the refusal to insulate lofts because of the need to empty the space with the added burden of permanently losing this storage area. The potential carbon reduction for these low and medium measures range from 45 to 60% "assuming the properties have not received any significant refurbishment works" (Housing Forum, 2009).

Each retrofit measure has been assessed for the disruption it causes to normal lifestyles. All building works cause disruption, clearly some more than others. Measuring disruption requires both a quantitative and qualitative approach since interviewees note the dependency on occupant cooperation and the need to spend far longer thinking about the specific details for installation, supply chain management and site skills. Interviews suggest that what may appear as simple or straightforward interventions are usually far more complicated than assumed with a quoted example being the comparison between external and internal wall insulation.

The literature and interviews provides a list of typical interventions. An analysis of disruptive tendency is provided in Table 17 with, where appropriate, comments from stakeholders.

Intervention	Comments	Level of Disruption
Low energy lighting	CFL becoming more common. GLS lamps to be phased out in UK by 2011	Low
Hot water tank insulation	Uncontrolled heat loss to the house leading to summer overheating.	Low
Insulated primaries	Potentially difficult to insulate in cylinder cupboards, behind boilers and where pipes go through walls	Medium
Heating controls	User interface leads to difficulty in programming heating and hot water. Default to manual over-ride	Medium
Reduced upstairs temperature	Assumes all house heating at a common temperature. Living room and bedroom temperatures for low income families indicate 19.1 and 17.1oC respectively102 Dependent on TRV103 installation in all rooms and on occupant behaviour	Medium
Cavity wall insulation	Many RSLs have already installed CWI. QA issues where thermal imaging shows poor application or entirely missing	Low
Loft insulation	Many RSLs have already installed LI. Potentially disruptive where loft used as storage space. Reticence to allow access104	Low to Medium
Draught proofing	Reduced ventilation can lead to condensation problems especially where envelope u values are low and insulation is internal105. Sash windows in particular require skilled labour	Medium
Condensing boilers	Replacement generally at end of working life due to cost and lenth of payback106	Medium
External insulation	Requires extensive external works to roof soffits, rainwater pipes, soil stacks, gulleys and drainage connections. For blocks of flats can create access issues requiring widening of balconies. Conservation issues.	Potentially High
New windows & Doors	Wide experience of window replacement market. Potential challenges where new windows interface with deep insulation and effective air tightness sealing.	Medium
Internal wall	“Dry lining” requires furniture removal and loss of space	Very High

[102] Oreszczyn, et al. 2006. *Determinants of winter indoor temperatures in low income households in England*. Energy in Buildings 38 (3), 245 - 252
[103] Thermostatic radiator valves
[104] Project partner Marie Monaghan
[105] Surface and interstitial condensation. See BS 5250: 2002. *Code of practice for control of condensation in buildings.*
[106] Registered Social Landlord interviews

insulation	during retrofit. Loss of space as insulation effectiveness increases and extensive making good to doors, skirtings, electrical outlets, etc. High cost for single room. New methods proposed for laser measuring and off-site prefabrication to lower disruption. Potential for interstitial condensation	
Ground floor insulation	Requires removal of existing floor or the use of expensive "super insulation" products such as vacuum sealed insulation with extensive making good to doors, skirtings, electrical outlets, etc.	Very High
MVHR	Very low air permeability from draught proofing requires whole house mechanical ventilation. MVHR is the most energy efficient but requires whole house ductwork installation and is thus high cost. Skills shortage in design, installation and commissioning and maintenance.	Very High
Solar thermal	Generally requires dual coil hot water cylinder, and interventions in internal central heating system plus external roof work with scaffolding	Medium
Photovoltaics	Scaffolding, roof work, external and internal electrical wiring. High cost currently offset by Feed in Tariff.	Medium
Heat Pumps	Highest efficiencies only achieved with underfloor heating. Poor understanding of the technology and controls107. Ground source more disruptive than air source	Medium to High
Micro wind turbines	Poor efficiencies in built-up areas108. Difficulties with fixing to roof or chimney. Scaffolding, external and internal electrical wiring	Medium
Community Biomass systems	Scope ranges from district heating to communal block heating. "Replacing a community gas boiler may not require tenant removal but replacing a block of flats on electrical storage heaters may result in significant disruption"109	None to High

Table 17: Disruption metric

Whilst recognising the subjectivity of the concept of disruption, an attempt to quantify the intervention impacts in shown in Figure 16.

[107] Energy Savings Trust, 2010. *Getting warmer: a field trial of heat pumps*
[108] Energy Savngs Trust, 2009. *Location, location, location. Domestic small-scale wind field trial report*
[109] Housing Forum, 2009. Ibid.

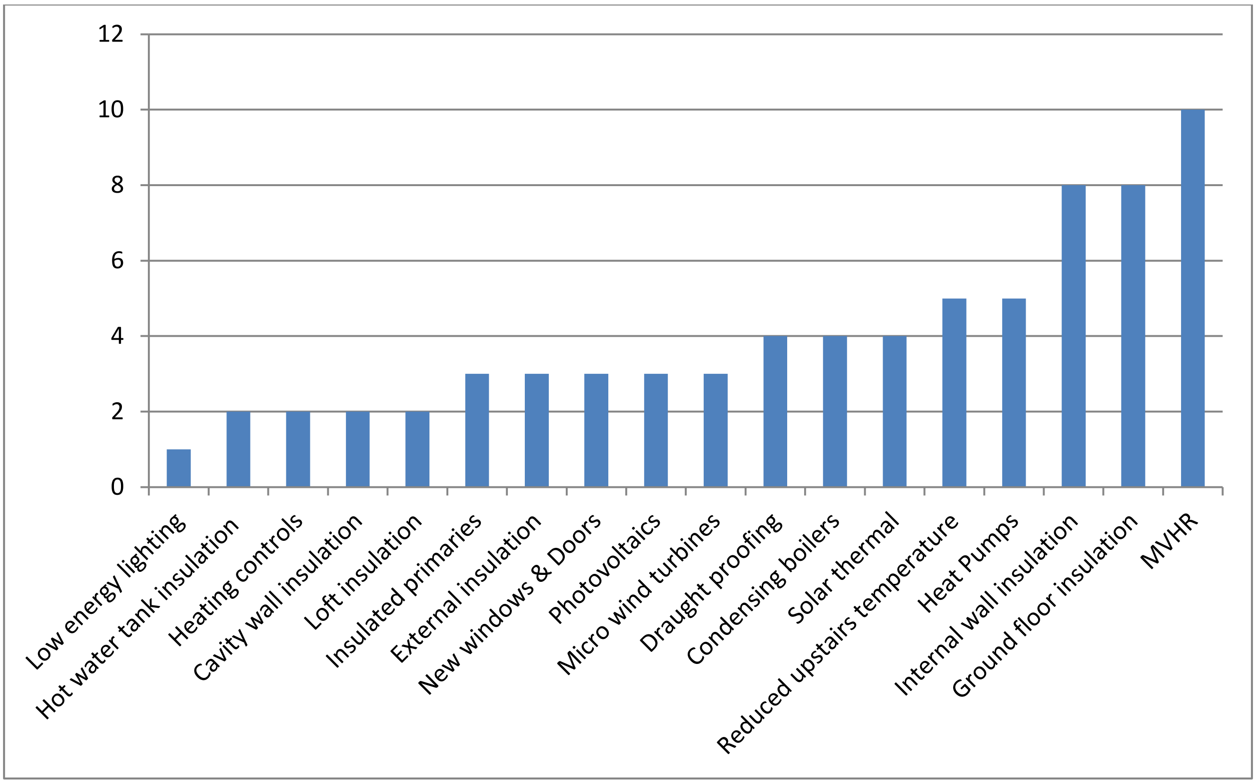

Figure 16: Disruption

Potential scale of retrofit: to decant or not to decant

Within the UK, meeting Government targets for an 80% carbon dioxide reduction increases pressure to reduce emissions from the housing stock. With in excess of 20,000,000 dwellings, the scale of the challenge can be represented as "1 house per minute till 2050." An 80% reduction requires the combination of retrofit to the tipping point plus renewable energy.

Retrofitting requires consideration of the disruption to normal life for tenants. Decanting allows major works to be done in a shorter time with better cost effectiveness. Health and safety issues are easier to resolve with the work occuring "on-site" rather than in the "home" and thus reducing potential contflict between occupier and builder. Special consideration needs to be taken for elderly and disabled occupants. Deep retrofitting will impact on the finishes within the dwelling. The impact on furnishing, carpets and decoration will need to be taken into consideration.

Decanting allows for scaling up the works and thus the reduction of costs. The Forum for the Future, Bristol Retrofit report (http://www.refitwest.com/wp-content/uploads/2010/08/E21C-Final-Report.pdf) shows that increasing a deep retrofit from 1 to 20 houses reduces costs by apporoximately 40% but that an increase to 50 houses reduces costs by only a further 5% per house. "This illustrates that with a contract for 20 homes, a large contractor is able to command large orders and offer savings. Above this however, savings are minimal."

Examples of Deep Retrofit

Across the EU there are still relatively few examples of deep retrofit models available. In the UK, the Technology Strategy Board programme of Retrofit for the Future (RfF)[110] retrofitted 86 projects between 2009 – 2010, in a £17m programme, to start the retrofitting of the UK's social housing stock. The AECB – The Sustainable Building Association[111] was among those

[110] http://www.retrofitforthefuture.org/
[111] The Sustainable Building Association http://www.aecb.net

who developed appropriate energy performance targets for the competition and provide ongoing support and guidance. The AECB and the TSB have developed this database as an education and dissemination tool, incorporating both the RfF projects as well as new and refurbished domestic and non-domestic low energy buildings which are typical of the Passivhaus approach. Energy performance targets were based on an 80% reduction in CO_2 from an average 1990 baseline for a typical 80m² semi-detached house of 97 kg CO_2 /m².yr. The targets were:

- CO_2 target: 17 kg/m².yr (if modelled in SAP) and 20 kg/m².yr (if modelled in PHPP112)
- Primary energy target: 115 kWh/m².yr

Space heating: No specific target but if the above targets are met, space heating requirements should necessarily be low (i.e. around 40kWh/m².yr)"

The Passivhaus approach requires such measures as "super-insulated" envelope, very low or thermal bridge-free construction, triple glazed windows, very low air permeability and whole house mechanical ventilation with heat recovery. These interventions raise the initial costs including consultants" fees, detailing for „buildability" and thermal bridge treatment, building services kit, commissioning), workforce skills requirements. Disruption to the occupant is so great that the process can only be achieved by decanting. Whilst no costings are available on the web-based database, interviews with participants indicate costs ranging from £50,000 to £150,000. It is not possible to distinguish structural refurbishment from thermal upgrades and the small scale of the works does not provide an indication of how much work would be involved taking the housing market as a whole.

Passivhaus EnePHit standard

The Passivhaus Institute provide the EnePHit standard for retrofit[113]. The standard has five criteria which must be met to achieve certification and is assessed by Passivhaus Planning Package (PHPP) software. The standard states the following:

- Heating demand: QH ≤ 25 kWh/(m²a)

Certification can be issued alternatively if the criteria for individual building components as given in Section 2 are met. In this case the requirement for the heating demand does not apply.

- Primary energy demand: QP ≤ 120 kWh/m²a + ((QH - 15 kWh/(m²a)) * 1.2)

The requirements apply to the total sum of the heating, hot water, cooling, auxiliary and household electricity.

- Summertime comfort: Excessive temperature frequency (> 25 °C) ≤ 10 %

If calculating the excessive temperature frequency is not possible due to very high daily temperature fluctuations, a warning appears in the PHPP "Summer" sheet. In case of doubt, other suitable evidence of summertime comfort should be provided.

- Moisture protection: All standard sections and connection details must be invariably planned and implemented so that there is no excessive moisture on the interior surfaces or in the building component build-ups. The water activity1 of the interior surfaces must be kept at aw ≤ 80 %. In case of doubt, evidence for moisture protection based on established techniques must be provided.
- Airtightness: Limit value: n50 ≤ 1.0 h-1; Target value: n50 ≤ 0.6 h-1[114]

Passivhaus retrofit standard would be described, in the UK, as a deep retrofit.

[112] Passivhaus Planning Package software
[113] Passivhaus 2011 *EnePHit standard for retrofit*
http://www.passiv.de/01_dph/Bestand/EnerPHit/EnerPHit_Criteria_Residential_EN.pdf
[114] ibid

12. Cost estimates

The Housing Forum (Housing Forum, 2009) present costs based on four levels of emissions reduction: low, medium, high and low zero carbon (LZC) technologies. The cumulative costs of these interventions range from around £12,000 to £34,000 to achieve between 78 and 94% CO2 emissions reductions. “At an average upgrade cost of £20,000/dwelling the total cost is likely to be £500 billion or closer to £15 Billion/annum [over 33 years].”

The Existing Homes Alliance: EHA, (2010) provides the following: “Analysis by Camco illustrates the accumulating costs of applying individual energy reduction refurbishment measures to different property types. The example shown here shows the impact on energy related CO2 emissions and costs for a typical house (a three bedroom, 91m2, semi-detached home, built between 1965 - 1972 with a gas central heating system). Installing all the measures up to and including solar photovoltaics is expected to deliver a 68% in regulated CO2 emissions (excluding appliances) at a cost of £22,300 [our italics].

The cost of delivering the whole-house package of measures in the solid wall house is estimated to be £29,500 and in the off-gas house is £27,400.”

The range of property types and ages is clearly much greater than the three examples modelled in the study but they serve to illustrate the diversity of the stock and give an indication of the variability of refurbishment costs.

United House Ltd: A ground floor flat modelled by United House suggests that a C60 can be achieved for £9000 whereas a C70 would cost £22000. They comment that it makes sense to retrofit 3 houses to C50, saving 150% than to retrofit one to C70 to save 70%.

Dumfries and Galloway Housing Partnership: DGHP is a registered social landlord, registered Scottish Charity. DGHP provide the following information on their retrofit project, Municipal Terrace & Millburn Avenue, Dumfries which claims to achieve an 80% emissions reduction[115]. Our “eco” works cover the following areas:

- Significantly higher levels of insulation including use of sheep"s wool loft insulation, passive standard doors, windows and living Sedum first floor flat roofs.
- Solar Photovoltaic (electric production) and Light Emitting Diodes (LEDs) lighting & Cat 5 wiring.
- Underfloor gas heating & “A” rated gas boilers or air source heat pump and Mechanical Heat Recovery Ventilation (MHRV).
- Smart Metering and monitoring Equipment.

Although full costings are not provide, the description claims that: “The added cost at tender stage has been calculated at around £25,000 per eco flat”.

Radian: Radian are a social housing provider. Their Highfield Road project claims to achieved a 70 to 85% emissions reduction:[116] “All homes are compliant with the Decent Homes Standard and include new kitchens and bathrooms. The core package of energy efficiency measures applied to each home costs approximately £24,000. This figure increases to approximately £36,000 for the homes which benefit from the solar package.”

Table 18 provides cost and emissions reductions based on the literature and interviews where average costs and emissions savings are approximately £26,000 for 80%.

Source	Typology	Low	Med	High	LZC	£Total	%CO2

[115] http://www.24dash.com/news/Campaign/2010-03-19-Dumfries-and-Galloway-Housing-Partnership-DGHP
[116] http://www.24dash.com/news/Campaign/2010-03-19-Radian

							reduction
Housing Forum	HR Flat	150	2500	7500	2000	12150	84
	Terrace	1350	3000	10450	19000	33800	81
	LR Flat	800	3000	7500	2000	13300	94
	Semi	1450	4200	8750	19000	33400	78
Existing Homes Alliance	Semi cavity wall					22300	68
	Semi solid wall					29500	71
	Semi off gas					27400	78
United House	Precast semi					22000	70
DGHP	Terrace					25000	80
Radian	House					36000	85
MEAN						25485	79

Table 18: Mean costs and CO_2 saving

Gross Value Added modelling
The World Wildlife Fund report[117] provides an in-depth analysis of costs from four retrofit scenarios based on net present value assessment and gross added value: "The sophisticated computer model draws together geographically specific data from the English House Condition Survey (EHCS) and data on sustainable energy improvements from ACE"s Fuel Prophet Model (which includes fuel type and savings data). This is integrated with data from the devolved administrations to build the nationwide picture." The model provides a detailed cost breakdown based on retrofitting properties, the uptake of Low Zero Carbon technologies (ranging from installing renewables to combined heat and power heat), occupant behavioural change118 and decarbonisation of the energy grid.

13. Skills implications

There are clearly different levels of skills required for low, medium and high impact retrofit.

Discussion of low skills in construction occupations is fraught with danger. The Australian experience of its nationwide insulation programme is assessed in the „Review of the administration of the home insulation programme."[119] At its peak (in November 2009), the program registered over 10,000 installers employing thousands of low-skilled workers. It was reported that there were four deaths of young Australians and over 100 house fires linked to the installation of insulation. There were also concerns regarding poor quality workmanship and materials and alleged claims of high levels of fraud by unscrupulous operators. A classic example of the need to regulate markets to ensure their proper functioning.

Constructionskills Report: Constructionskills, the UK body responsible for construction training, consider that low emissions construction will require of the construction team, a greater depth of knowledge not new skills. Training will be required in new technologies but these are considered to be within the scope of qualified construction workers.

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[117] WWF 2008 *How Low, achieving optimal carbon savings from the UK's existing housing stock* http://assets.wwf.org.uk/downloads/how_low_report.pdf
[118] Research in occupant behaviour change from the University of Oxford"s Environmental Change Institute suggests: "The norm is for savings from *direct feedback* (immediate, from the meter or an associated display monitor) to range from 5-15%" (Darby, 2006).
[119] http://www.climatechange.gov.au/~/media/publications/energy-efficiency/Home-Insulation-Hawke-Report.ashx

United House Ltd: United House Ltd, a construction company recognised as a leader in low energy construction and retrofit, aim to achieve emissions savings targets with their current sub-contractors. These sub-contractors are skilled building workers with a long term contracting relationship and not especially trained for low emissions retrofitting. Detailed drawings, site "toolbox talks" and a commitment to long term business relationship are the only „new skills" that are identified. Retrofits are based on a value carbon scenario where savings of 50-60% require the standard skills associated with experience tradespersons and where the only significant new target is an air permeability of half the current UK maximum which is, in terms of air tightness standards, a moderate increased in comparison to Passivhaus requirements.

P3Eco Ltd ; P3Eco Ltd specialise in high-end refurbishment to Passivhaus standards. Tim Fenn has responded to lack of skills indentified in his workforce and has developed in-house training for his construction team. In addition, he has been a prime mover in establishing new national training standards for low emissions construction through a "Sustainable Construction" NVQ level 3 qualification validated by Accredited Skills for Industry (ASFI) UK. With regard to emissions, the qualification mandates modules in "Energy and building construction trades and site roles" and "Airtight technologies in sustainable construction".

The RfF experience: RfF demands are essentially Passivhaus standards. In order to meet a maximum heating demand of 25 kWh/2 per year, the standard demands a highly trained team focused on envelope heat loss. The Sustainable Building Association, AECB, has set up "CarbonLite" training to provide courses in a range of skills covering: Passivhaus Planning Package (PHPP, the design tool for Passivhaus assessment), construction of Passivhaus, building services for Passivhaus and thermal bridge assessment. AECB memebers have been to the fore in the Retrofit for the Future programme both as standard setters and as architects and builders.

Number of Jobs

The Low carbon existing homes report from the UK Green Building Council[120] suggests some 40 – 80,000 jobs for an 80% emissions reduction target: "This is based on a rough calculation that the construction sector is worth around £107bn per year and employs approximately 1.2 million people which equals one job for every £89,000 spent. If the low-carbon refurbishment agenda represents growth of £3.5 - £6.5 bn per year.[121]

The European Trade Union Confederation Climate Change and Employment report (ETUC, 2007[122] suggests that estimates may be based on two measurement approaches, buisness as usual and a "factor 4" energy reduction from 200 to 50 kWh/m2.yr. These result in a wide range of possible new jobs dependent of emissions reduction target and the implimentation timescale. Numbers range from as few as 20,000 up to 1,377,000 full time equivalent jobs.

Heating and Cooling Requirements

This chapter begins with the analysis of energy needs in dwellings and discusses the energy flow routes through the envelope. The discussion includes fabric and ventilation losses, heating fuel emissions, summer overheating and hot climate conditions.

Carbon dioxide emissions from energy use may be offset by renewables, particularly photovoltaics.

There is a discussion of the common nomenclature for energy and a review of heating and cooling load equations.

Energy loss from a building is a function of the temperature difference between inside and outside. The occupant decides the comfort temperatures in the building. The discussion of comfort temperature is supported by analysis based on DIN EN 15251: 2007-8. Indoor

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[120] Green Building Council, 2008 www.ukgbc.org/site/document/download/?document_id=370

[121] Killip, 2008, http://www.fmb.org.uk/ea/pdf_ea/FMBBuildingAGreenerBritain.pdf) , it could provide between 39,000 - 73,000 jobs."

[122] http://www.tradeunionpress.eu/Web/EN/Activities/Environment/Studyclimatechange/rapport)

environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. Appropriate temperatures are selected for heating and cooling across the partner countries.

Finally a heat loss retrofit example is given and degree day calculation used to provide annual kWh and CO2 emissions for heating.

Dwellings: Heat losses and gains

Space heating and cooling demand is dependent on occupant perception of comfort. Adaptive thermal comfort theory proposes that the comfort temperature is not fixed but dependent on the running mean monthly outdoor air temperature and that people adapt their comfort demands as the weather warms and cools in its annual cycle and in their expectations of winter and summer extremes.

Vernacular architecture has traditionally responded to the local climate with appropriate design which minimizes the demand for heating and cooling energy with the expectation that occupants adapt to seasonal changes. In cold climates, low expectations for artificially produced thermal comfort resulted in the use of a „living room" for comfort with lower temperatures in the rest of the house and an increase in clothing in winter. In hot countries, the use of heavyweight construction (thermal mass), natural ventilation, inner courtyards and window shading has been subordinated to the requirement for mass housing typically of the concrete high-rise design requiring energy intensive mechanical cooling.

Energy is required for space heating, space cooling, domestic hot water, cooking, lighting and appliances. This energy demand is dependent on the climate zone which may be simplified into three dominant typologies: cold winters and warm summers (continental climates), mild winters and moderate summers (temperate climates) and mild winters with hot summers (Mediterranean climates). Cold climates are distinguished by the demand for winter space heating systems and Mediterranean climates for summer space cooling systems.

Thus there are varying demands in terms of space comfort temperature as well as varying artificial lighting demands which are dependent on hours of daylight and internal daylight levels. To simplify the analysis, one could assume similar energy demands for cooking, domestic hot water and appliances although the actual levels of energy consumption for all requirements are socio-economically dependent and vary across the EU.

14. Understanding heat flow

„Heat flows from hot to cold". An unoccupied building will eventually achieve the same temperature as the outside as heat flows either into or out of the building envelope. For a winter occupant comfort temperature to be maintained, there needs to be heat energy flowing into the building at the same rate as heat is transferred. Reducing the rate of heat transfer to a minimum will therefore lead to lower demands for fuel and lower carbon dioxide emissions.

Heat is transferred by the combination of thermal conductivity, known as fabric heat loss, and by the infiltration of outside air in the form of draught or as purpose designed ventilation. A unit of energy is defined as a Joule (J) which can be visualised as a lump of energy. One Joule per second is a Watt (W) and it is clear that there is a difference between the flow rate of one joule per second and 10 joules per second, 1 Watt and 10 Watts. The actual rate of heat transfer by thermal conductivity is defined by the u value of each element of the envelope, the rate of heat loss per square metre for a one degree temperature difference between inside and outside (W/m2K).

For opaque elements, the most effective way to reduce heat loss is through insulation. Any gaps in the insulation, either from structural elements or poor installation practices, will act as „thermal bridges". The rate of heat transfer through thermal bridges is defined as the ψ(psi) value measured linearly (W/mK) or as an average value for the dwelling based on the sum of the individual ψ values and the envelope area and known as the y value (W/m2K). Since thermal bridges are weaknesses in the insulation, their remedy is to redesign to effectively eliminate them for „thermal bridge-free" construction.

For windows, double and triple glazed units with low draught, low thermal radiation emissivity coatings and the addition of gas fill such as argon or krypton, will reduce single glazing losses by a factor of about five.

All buildings require ventilation since occupants produce smells and water vapour. Water vapour will condense if it comes in contact with surfaces below the dew point temperature leading to surface and interstitial condensation and, typically mould growth. Traditional construction which relied on open fires was designed to provide excess air to promote the flow of smoke and fumes up chimneys and to prevent incomplete combustion which would lead to carbon monoxide build-up. Little attention was paid to reducing ventilation to the minimum required to maintain a fresh internal air quality.

As open fires are replaced by central heating and open flued boilers by room-sealed (balanced) flued boilers, air infiltration or draught has become the focus of low energy design. For optimum low energy design, the air permeability of the envelope, or the air leakage rate, is minimised and the ventilation regime is based on providing adequate fresh air to achieve freshness and reduce condensation risk.

The air permeability of the envelope is measured by pressure testing at 50 Pascals either above or below atmospheric pressure, in units of either air changes per hour (ac/h@50Pa), common EU practice, or in cubic metres of air per hour for each square metre of the envelope (m3/hm2@50Pa), UK practice. These units are often simplified to N50 and Q50 respectively. To convert Q50 to air changes per hour at normal pressure differences, use the rule of thumb conversion of Q50/20. Thus the maximum air permeability for new build in the UK of 10 m3/hm2@50Pa is roughly equivalent to 0.5 air changes per hour (ac/h).

Offsetting the heat losses are heat gains from either the sun through the windows, known as solar gains, and heat gains from cooking, electrical lighting, electrical appliances, hot water cylinder and the occupants, see Figure 17. Thus a winter heat balance occurs in an occupied building where under steady state conditions:

Fabric losses + Ventilation losses = Heat gains + Space Heating output

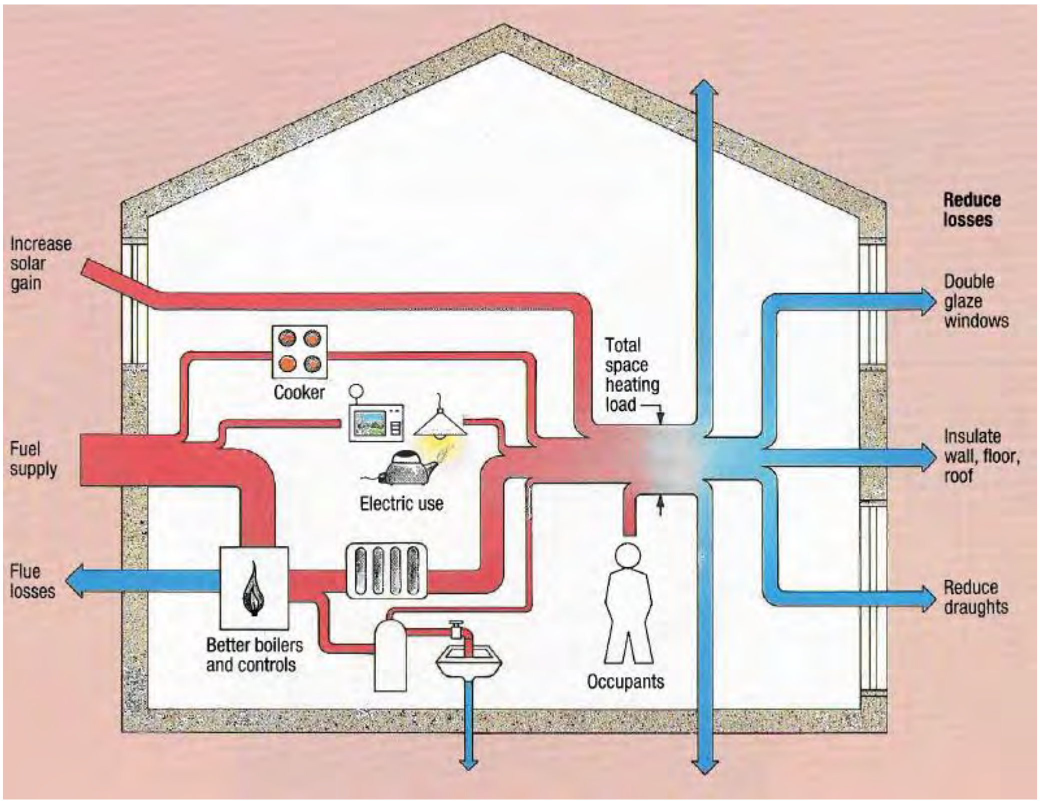

Figure 17: Energy flows

Source: UK Dept of Energy 1988 Heating Fuel

The wet central heating market is dominated by fossil fuel gas and oil boilers. Hydro-carbon fuels combust to produce carbon dioxide and water vapour. By replacing conventional boilers with condensing models, the water vapour may be condensed to release latent heat in the steam and thus increase the thermal efficiency by up to 14%.

Summer overheating

In order to reduce summer overheating, the building needs to be designed to reduce solar gains through window shading and to provide sufficient outdoor air to purge internal gains. Heavyweight envelopes provide thermal mass which will „soak up" internal gains during the day and will require night time ventilation to cool the surfaces and flush out the day time heat gains. This thermal mass effect is known as Admittance and defined as the flow of heat into the structure (W/m2K). In addition, efficient electrical appliances and fully insulating any hot water storage system and connecting pipework (the primary flow and return) will reduce unwanted heat gains to the building.

Hot Climates

In hot climates there is an increase in heat gains from solar radiation on the envelope and through windows. In addition, outside air is hot and ventilation may add to internal heat gains. Thus Figure 17 would show an increase in solar gains and a decrease in heat losses through the envelope leading to a summer heat balance where:

Solar gains + Fabric gains + Vent gains + Internal gains = Thermal mass effect + Space Cooling output

In Mediterranean climate zones, where non-vernacular architecture and inadequate cross ventilation fail to purge internal heat gains, high summer temperatures may lead to demands to cool the building using refrigeration. The simplest and cheapest form of cooling is provided by „comfort cooling" where the vapour compression cycle (refrigeration cycle) extracts heat from inside the building and dumps it outside into the atmosphere. The cycle is driven by an electrical compressor and utilises fans to promote heat transfer from the room air to the evaporator and from the condenser to the atmosphere. Units may be packaged through the wall systems or „splits" with room cassettes and remote condenser, see Figure 18.

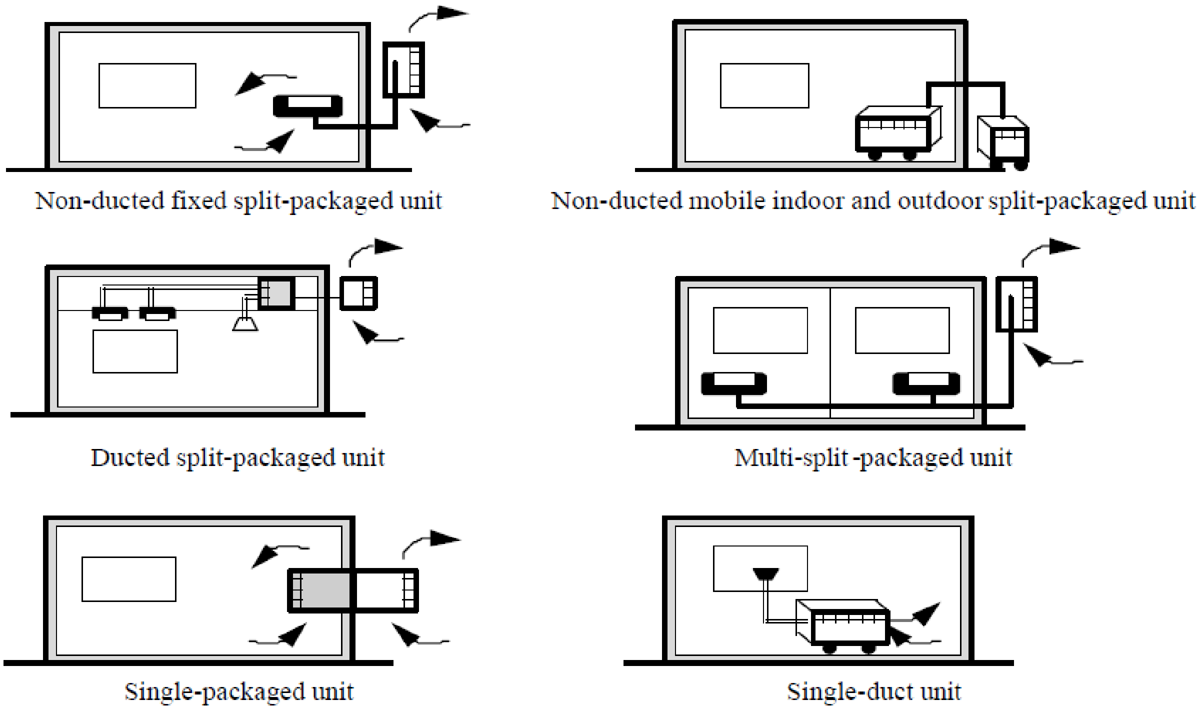

Figure 18: Diagrammatic representation of different RAC types

Source: Adnot J, et al. 2005.[123]

For optimised energy use, the dwelling needs to operate in a „mixed mode" manner. Where outside air temperatures allow, natural ventilation may be utilised to promote free cooling by opening windows and by utilising fans. Where temperatures rise about comfort levels, doors and windows need to be shut, air infiltration reduced to the design minimum and comfort cooling operated.

In addition to high summer temperatures, some EU countries have cold damp winters. Poor levels of insulation and low ventilation rates promote condensation in cold and damp conditions. Where these conditions pertain, a well insulated envelope supported by a reversible heat pump may be the optimum solution. Using the vapour compression cycle, heat may be extracted from the building in summer or extracted from outside air and dumped into the building in winter.

All European climate zones should utilise solar hot water or „solar thermal" for zero emissions hot water. In hot countries, this is likely to be supported by electrical resistance heating and in cold countries by an existing central heating boiler system.

Low zero carbon technologies

Low zero carbon technologies (LZC) may be classed into low carbon technologies such as heat pumps and micro-combined heat and power, and zero carbon such as photovoltaics, wind and micro-hydro. The literature refers to the potential impact of low zero carbon technologies but field trials indicate that real efficiencies tend to be somewhat below

[123] Adnot, J. et al. *Limiting the Impact of Increasing Cooling Demand in the European Union: Results from a Study on Room Air-Conditioner Energy Efficiency*
http://www.cenerg.ensmp.fr/english/themes/mde/pdf/223.pdf

manufacturers" predictions[124]. Roof mounted micro-wind turbines, for example, have been found to have low efficiencies, especially in urban environments. Biomass is considered to be low carbon but there continue to be issues with its procurement in urban areas and its impact on air pollution.

Domestic Renewables
Photovoltaics is the dominant form of domestic renewable electricity production across Europe. Supported, or with a history of support, in a number of member states by „feed-in tariffs", photovoltaics „offset" building CO2 emissions and can provide „zero emissions dwellings". Photovoltaics are sold by kilowatt peak output (kWp) but are more usefully described by their annual output in kWh.

For optimal orientation and angle of inclination, the output across Europe varies such that in Aberdeen it is some 800 kWh/kWp and in Seville some 1450 kWh/kWp (source: http://sunbird.jrc.it/pvgis/apps/pvest.php).

Measuring energy and emissions.
Whilst energy is measured in Joules, the kilowatt hour (kWh) is the standard unit for measuring energy demand at the household level. One kilowatt hour is equivalent to 3,600,000 Joules. Energy comparisons may be given in kWh/year or more specifically in kWh/m2 (of floor area) per year.

Carbon dioxide emissions from fuel are dependent on the fuel chemical composition and the efficiency of the appliance in converting the fuel to useful energy whether for heating, cooling or hot water demand. Carbon dioxide emissions from electricity are dependent on the electrical generation fuel mix, transmission losses and lighting/appliance efficiency. At the household level, emissions are commonly measured in kgCO2/yr or kgCO2/m2yr.

The energy efficiency of cooling units, the refrigeration load, is given by the Energy Efficiency Ratio (EER) where EER = Cooling Power output/Electrical power input. Heating output from reversible units and heat pumps is defined as Coefficient of Performance (COP) where COP = Heating Power output/ Electrical power input.

Typical efficiencies for comfort cooling vary (Adnot J, et al. 2005) with the EER of the most common domestic units varying between 1.54 and 3.74, see Table 19. Thus the electrical demand for a 5kW cooling unit could vary between 3.25 kW and 1.34 kW respectively. http://www.cenerg.ensmp.fr/english/themes/mde/pdf/223.pdf

RAC category	Cycle type and cooling mode	Heat-transfer fluid	EER		
			Minimum	Average	Maximum
Multi-split-packaged	Cooling only	Air	1.91	2.70	3.74
	Reverse	Air	2.08	2.53	2.94
Split-packaged	Cooling only	Air	1.54	2.53	3.56
		Water	2.70	2.75	2.88
	Reverse	Air	1.45	2.48	3.45
Single-packaged	Cooling only	Air	1.88	2.38	2.77
		Water	2.11	3.32	5.42
	Reverse	Air	1.93	2.32	2.84
		Water	2.26	3.20	5.31

Table 19: Energy efficiency performance of RACs on the EU market 1997-8
Source Adnot J, et al. 2005

[124] See for example: Carbon Trust, 2007. Micro-CHP accelerator. EST, 2009. Domestic small scale wind field trial report. EST, 2010. Getting warmer: a field trial of heat pumps report.

Summary

Heat Loss = (Sum of the u values + thermal bridges + ventilation rate) x (Comfort temperature inside – Design temperature outside)

Heating load (Watts) = $(\sum U + \sum \psi + NV/3)\ \Delta T$

Where $\sum U$ is the sum of the u values, $\sum \psi$ is the sum of the thermal bridges, N is the number of air changes per hour, V is the volume of the dwelling and ΔT is the temperature difference between inside and outside.

Heat Gains = Solar + Fabric + Infiltration + Lighting + Occupants + Cooking + Appliances.

These gains may be expressed as Watts. The cooling load is then dependent on the volume of supply air, its temperature and the design room temperature where:

Cooling load (Watts) = vt (tr – ts)

Where vt is the volume of cooled air at the supply temperature (litres/second), tr is the room temperature and ts is the supply air temperature.

Once heating and cooling loads are reduced to a minimum, the energy demand for heating and cooling is ultimately dependent on the difference between the inside design indoor comfort or operative temperature, and external air temperature.

Consider winter: Figure 19 (based on Figure A1 from DIN EN 15251: 2007-8) shows the minimum comfort temperature against the running mean outdoor temperature. All partner countries demand January comfort temperatures of about 19 or 20oC since their mean winter temperature range from about (-4) Krakow, to 11oC (Seville) and thus will all require heating for at least some of the winter.

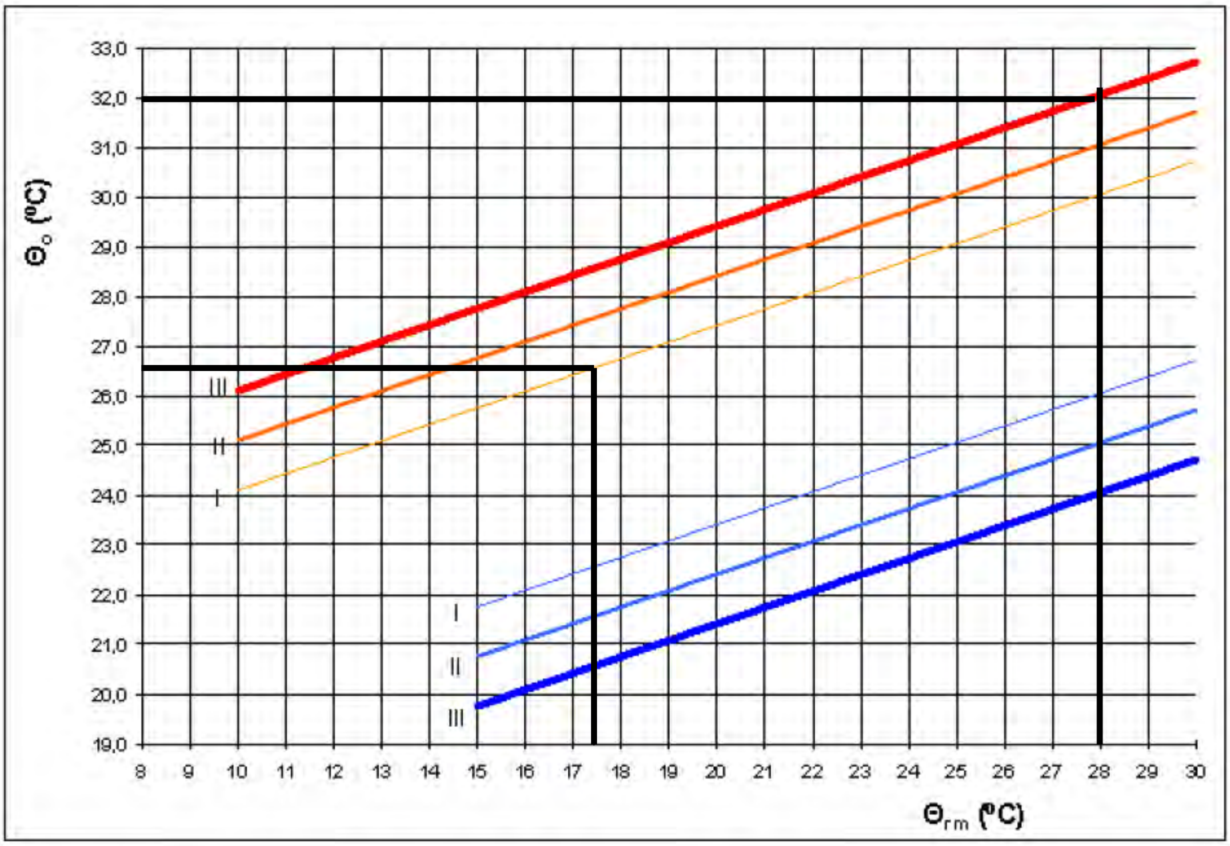

Figure 19: Summer comfort temperatures range across the partner countries (based on DIN EN 15251: 2007-8)

Consider summer: Figure 19 shows the mean monthly summer outdoor and comfort temperature band across the partner countries. For Seville and Podgorica, in modern high rise flats with little cross ventilation and poor insulation, there is a perceived requirement for cooling in summer. In Seville, with a summer mean of 28°C, the maximum comfort temperature would be 32°C. This is 5K warmer than mechanically cooled buildings (max temp 27°C). DIN EN 15251 suggests that if a fan were driving air at 1m/s the adaptive comfort temperature rises to 35°C.

The Energy Saving"s Trust provides guidance on reducing overheating in dwellings (EST, 2005)[125]. EST suggest thermal mass and cross ventilation with night cooling, combined with solar shading, high reflectance of building surfaces, minimising internal gains through efficient electrical appliances, low energy lighting and insulated hot water cylinder and pipework.

Where comfort cooling is installed, it can generally be expected to be turned on before dwellings reach temperatures in or near 30°C.

Comfort temperature
It is clear from observation that if occupants cannot turn on space heating then they adapt with extra clothing. Across Europe, it would appear that the winter minimum comfort temperature for both free running and heated buildings is approximately 20°C. Thermally efficient building envelopes allow this to be achieved at low energy loads.

For Northern countries, summer should be free running and therefore design should comply with Figure 19 (Figure A1 DIN EN 15251: 2007-8). For Southern Europe, DIN EN 15251 indicates that the summer control objective should be to extend the free-running period before turning on any cooling by changing occupant behaviour to make the most of the free-running period with the support of fans. Where the full range of adaptations are not available and temperatures become oppressively hot, comfort cooling is demanded. Comfort temperature in mechanically cooled buildings is perhaps 5 to 8K below free running and thus requires electrical power to drive the cooling refrigeration cycle. Reducing emissions from cooling will require a change in electrical generation to increase renewables in the grid.

Cooling energy is required to drive down the internal air temperature by "soaking up" heat gains. The lower the inside design temperature, the greater the cooling energy requirement. Heat gains can be limited by solar shading, thermal mass, reducing internal gains through efficient appliances and by limiting the infiltration of hot outside air. Clearly free running summer operation requires no energy but does require the option for occupants to adapt local conditions through a range of adaptive methods such as opening windows, cross ventilation and access to fans.

Annual energy demand and CO2 emissions
Heating Examples 1 and 2:

Typical UK size two storey, solid wall and single glazed detached house. The design rate of heat loss at a 21K (20 – (-1)) temperature difference is about 13 kW, Table 21. A deep retrofit reduction of fabric and ventilation losses reduces the heat loss to about 2 kW, Table 22. The initial Heat Loss Coefficient (W/K) is about 648 W/K or 0.648 kW/K, reducing to 76 W/K or 0.076 kW/K after retrofitting.

Envelope type	Mean u value	Thermal bridge y value	Air changes/hour
Solid wall with single glazing	2.26	>0.15	1
Deep retrorofit to Passivhaus standards	0.2	<0.04	≈ 0.25

Table 20: Base thermal conditions

125 EST, 2005. *Reducing overheating – a designer's guide* http://www.energysavingtrust.org.uk/Publication-Download/?p=1&pid=260

Heat loss routes	Area	Volume	Mean u or y	ac-h/3	W/K	ΔT	W	%
Fabric	236		2.26		533	21	11201	82
Thermal bridges			0.15		34	21	743	5
Ventilation		240		0.33	79	21	1663	12
TOTAL					648		13607	100

Table 21: Example 1

Heat loss routes	Area	Volume	Mean u or y	ac-h/3	W/K	ΔT	W	%
Fabric	236		0.2		47	21	991	62
Thermal bridges			0.04		9	21	198	12
Ventilation		240		0.083	20	21	416	26
TOTAL					76		1605	100

Table 22: Example 2, Deep Retrofit

The examples show that with deep retrofitting techniques such as super insulation, triple glazing and air tightness, heating power can result in over 80% heating power reduction.

Annual energy demand in kWh/yr can be estimated using heating and cooling degree days:

Degree days are essentially a simplified representation of outside air-temperature data. They are widely used in the energy industry for calculations relating to the effect of outside air temperature on building energy consumption.

"Heating degree days", or "HDD", are a measure of how much (in degrees), and for how long (in days), outside air temperature was lower than a specific "base temperature" (or "balance point"). They are used for calculations relating to the energy consumption required to heat buildings.

For winter, the building heating load is calculated as:

kWh = (kW/K x degree days x 24)/η

"Cooling degree days", or "CDD", are a measure of how much (in degrees), and for how long (in days), outside air temperature was higher than a specific base temperature. They are used for calculations relating to the energy consumption required to cool buildings. http://www.degreedays.net/

Cooling loads may be assessed by:

kWh = (kg/s x kJ/kgK X degree days x 24)/η

Where W/K is the heat loss coefficient, η is the system efficiency, kg/s is the mass flow rate of supply air, kJ/kgK is the specific heat capacity of air (kg/s x kJ/kgK = W/K) and where degree days refers to the total below or above the heating or cooling base temperatures.

Research on behalf of Eurima[126] divides the EU 15 countries into climatic regions: cold, moderate and warm based on their average number of heating degree days, see Table 23.

Cold 4500	Moderate 3000	Warm 1800
Finland Sweden	Austria, Germany, Belgium, Ireland,	Greece Italy

[126] Ecofys, ibid

	Denmark, Luxemburg, France, The Netherlands, United Kingdom	Portugal Spain

Table 23: Degree day regions for EU 15 (source Ecofys)

Table 24 shows a UK heating degree day analysis for Example 1 compared with retrofit Example 2 which includes a new gas condensing boiler (efficiency raised from 70% to 85%).

	HLC	DD		η	kWh/m2yr	kgCO2/kWh	kgCO2/m2yr
Existing	0.648	2686	24	0.70	622	0.185	115
Retrofit	0.076	2686	24	0.85	60	0.185	11

Table 24: Calculating emissions from heating

The results in Table 24 show the potential for carbon dioxide emissions reduction is dependent on the rate of heat loss and number of degree days and thus the climatic zone.

Conclusion

Irrespective of climate zone, DIN EN 15251 indicates that comfort temperature in winter will be approximately 20^{o}C. Where heating is installed, emissions are reduced by retrofitting the building envelope to reduce fabric and ventilation heat losses and to supply the necessary heating energy by replacing inefficient heating systems with low carbon technologies such as condensing boilers, biomass boilers and solar thermal hot water systems. The actual winter indoor temperature, and thus the overall heating demand and its carbon dioxide emissions, will be dependent on occupant preference and extent of fuel poverty.

Acceptance of high summer temperatures is dependent on adaptive opportunities. DIN EN 15251 indicates that where occupants can adapt their clothing and behaviour, supported by sufficient air movement, temperatures above 30^{o}C can be acceptable. Vernacular building design to achieve high thermal mass and cross ventilation will reduce internal temperatures but where these are not present occupants will demand mechanical cooling. DIN EN 15251 indicates that in the presence of mechanical cooling, occupants demand lower comfort temperatures of approximately 28^{o}C maximum which therefore leads to increased emissions from electricity consumption.

Zero carbon technologies such as wind and photovoltaics offset emissions form grid electricity. The emissions reduction effectiveness of each kWh generated is dependent on the local grid generation fuel mix which varies, not only in each country and also during the year. The emissions reduction impact in the coming years will be dependent on changes to the grid fuel mix. It has been shown that in hot countries, photovoltaics and solar thermal systems offer greater emissions reductions due to the increase in solar radiation in Southern Europe.

15. Methodology

The methodological approach is based on interviews with stakeholders and computer analysis of interventions. Semi-structured interviews were held with social housing providers, architects, construction companies and project managers and their advice considered regarding retrofit interventions, skills requirements and the challenges of occupant liaison and skills demands, see Appendix. Many of their comments have been included in the selection of interventions, potential challenges and skills analysis previously identified in the text. As a result of these investigations, a computer model for interventions has been developed.

To explore the impact of retrofit interventions a SAP[127] model is created for three dwelling typologies: detached, mid-terrace and mid-floor flat based on Figure 20.

Each dwelling is based on a two storey model with a total floor area of 96m^2 and window openings of 17m^2 .

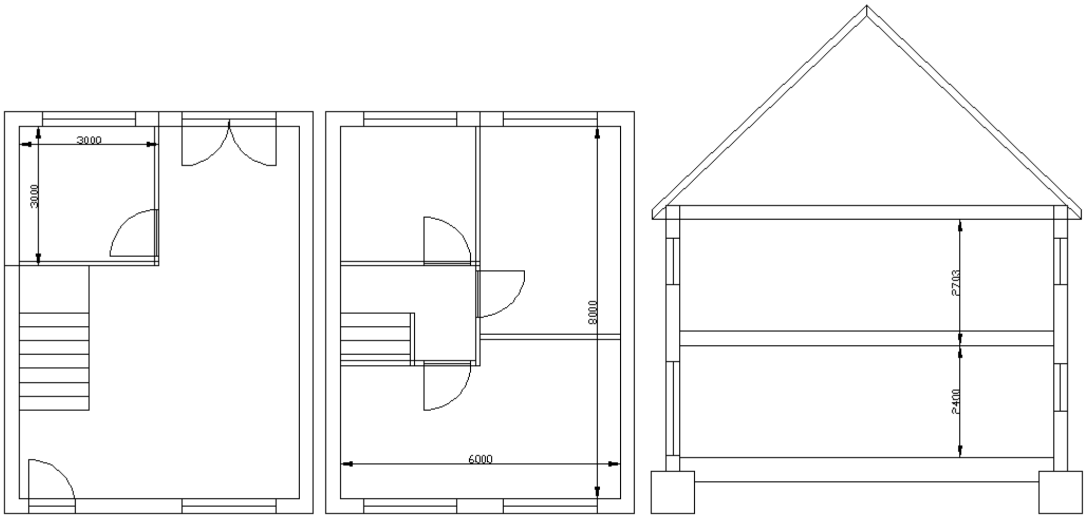

Figure 20: Dwelling model

	TFA	Openings	Walls	Floor	Roof
Detached	96	17	143	48	48
Mid-Terrace	96	17	63	48	48
Mid-floor Flat	96	17	63	0	0

Table 25: Dwelling dimensions

Thermal Elements

Each type is modelled as solid wall and cavity wall based on typical UK construction techniques of 215mm (9 inch brick) and 270mm (2 inch cavity). The solid wall u value is taken as 2.3 W/m^{2}K and the cavity wall u value is 1.0 W/m^{2}K.

Base conditions

Solid floor	0.76 W/m2K
Roof	2.76 W/m2K
Single glazing (sash windows)	5.7 W/m2K
Door	3.0 W/m2K
Air Permeability	15 m2/h@50Pa
2 open chimneys No extract fans	
Existing gas boiler with programmer & room thermostat	70% efficiency

[127] NHER SAP ASSESSOR v5.2

Hot water cylinder 136 litres 50mm DIY jacket	
Thermal bridges	0.15 W/m2K
GLS lamps	16

Table 26: Initial building elements

Disruption to occupants

On the assumption that any retrofit programme must lead to minimum disruption to occupants, each scenario is modelled as low, medium and high disruption based on access inside the dwelling. Each level of disruption assumes 2 days, 5 days and 10 days of disruption respectively. Each scenario is based in building elements, ventilation and services typical of UK housing conditions and retrofit opportunities.

Only two interventions are assumed to be "do it yourself" (DIY), changing GLS lamps to compact fluorescent and replacing existing appliance with low energy, A rated appliances. Appliance emissions are based on Energy Savings Trust data and assume a maximum saving of 200 kgCO2/yr: (http://www.energysavingtrust.org.uk/calculator/checklist)

LOW DISRUPTION

Low disruption is designed to achieve maximum emissions reductions with minimum interference to daily life in the dwelling. Internal access is assessed at 2 days. It is assumed that access to the property is available as are the relevant plant, labour and materials. Scaffolding is assumed for external works. For solid wall dwellings, low disruption interventions include the following:

Change existing lighting to CFL.

Draught strip to achieve an air permeability of 10 m2/h@50Pa. In order to combat condensation, combined with extract fans for kitchen and bathroom.

Loft insulation to 300mm

Install 2 kWp of photovoltaics (PV)

Note disruption to electrical supply form fan and PV installation.

For cavity wall construction, cavity fill is included as a low disruption process.

MEDIUM DISRUPTION

Medium disruption assumes up to 5 days disruption within the dwelling due to additional works to electrical supplies, boiler, space heating controls and hot water. Typical interventions include:

New condensing boiler and insulated dual coil hot water cylinder with insulated primaries

Solar thermal hot water

Low emissivity double glazing (u = 1.4 W/m2K).

Note disruption to electricity supply, heat and hot water and need for access to all rooms.

HIGH DISRUPTION

High disruption is effectively deep retrofit without the decanting occupants. It is assumed that up to 10 days access is required. Options include those for low and medium as well as internal and external wall insulation. Analysis of the disruptive effects of low air permeability (5 and 3m2/h@50Pa), whole house mechanical ventilation with heat recovery (MVHR) and floor insulation mean show that whilst they save on emissions they cannot be considered as viable options since they require the complete removal of all furniture for access to the entire façade for draught proofing and duct installation.   An occupant decant would have to be assumed.

Results
The analysis of retrofit disruption is shown in Tables 27. Low, medium and high disruption activities and savings are shown in Tables 28, 29 and 30. A skills analysis based on these interventions is shown in Table 31.

	Low	Medium	High	Comments
CFL	*			None
Appliances	*			None
Draught exclusion Q15 to Q10	*			Access to all windows and doors. Remove curtains/blinds, prepare windows and frames
Cavity wall insulation	*			Requires scaffolded access to façade. Dwelling located within building site. Health & Safety issues
Extract fans	*			Power disruption, running of cables, builder‟s work
Loft insulation	*			Access to loft, clearance, loss of storage space
PV	*			Scaffolding, access to house for running cables and meter connections ,
Boiler & controls		**		Interruption to heating & hot water. Access to all radiators for TRVs. Power connections for boiler/controls. Builders work for flue
Cylinder		**		Interruption to heating & hot water.
Solar Thermal		**		Scaffolding, power disruption, run cables, builder‟s work, Interruption to heating & hot water.
Windows/doors		**		Access to all rooms, temporary security. Scaffolding
External Wall Insulation			***	Requires scaffold access to façade. Dwelling located within building site. Health & Safety issues . Potentially disruption to all services supplies and drain connections. May impact on width of access and egress leading to extensive construction works, increase in building footprint.
Internal Wall Insulation			***	Total room disruption. May be programmed room by room. Will require removal/replacement of skirting, architrave, electrical outlets and switches.
Q10 to Q5			***	Total dwelling disruption. Access to all rooms
Q5 to ≤Q3			***	Total dwelling disruption. Requires mechanical ventilation for IAQ
MVHR			***	Total dwelling disruption. Access to all rooms for ductwork installation, testing and commissioning.
Floor insulation			***	Total dwelling disruption

Table 27: 1 Disruption analysis

Disruption analysis-related savings

		Initial emissions	Low disruption savings %	Comments
Detached	Solid wall	9717 kgCO2/yr	31 22	With PV Without PV
Detached	Cavity wall	7910 kgCO2/yr	53 43	With PV Without PV
Mid-terrace	Solid wall	7481 kgCO2/yr	34 45	With PV Without PV
Mid-terrace	Cavity wall	6741 kgCO2/yr	45 57	With PV Without PV
Mid-floor flat	Solid wall	5187 kgCO2/yr	17	No PV
Mid-floor flat	Cavity wall	4301 kgCO2/yr	30	No PV

Table 28: Low Disruption potential emissions reductions

		Initial emissions	Low disruption Savings %	Comments
Detached	Solid wall	9717 kgCO2/yr	55	
Detached	Cavity wall	7910 kgCO2/yr	78	
Mid-terrace	Solid wall	7481 kgCO2/yr	72	
Mid-terrace	Cavity wall	6741 kgCO2/yr	84	
Mid-floor flat	Solid wall	5187 kgCO2/yr	50 95	Boiler Biomass
Mid-floor flat	Cavity wall	4301 kgCO2/yr	80 98	Boiler Biomass

Table 29: Medium Disruption potential emissions reductions

		Initial emissions	Low disruption Savings %	Comments
Detached	Solid wall	9717 kgCO2/yr	81 88	50mm IWI 100mm EWI
Detached	Cavity wall	7910 kgCO2/yr	81 87	50mm IWI 100mm EWI
Mid-terrace	Solid wall	7481 kgCO2/yr	86 90	50mm IWI 100mm EWI
Mid-terrace	Cavity wall	6741 kgCO2/yr	88 91	50mm IWI 100mm EWI
Mid-floor flat	Solid wall	5187 kgCO2/yr	71 98	Boiler + 50mm IWI Biomass + 200mm EWI
Mid-floor flat	Cavity wall	4301 kgCO2/yr	84 99	Boiler + 50mm IWI Biomass + 200mm EWI

Table 30: High Disruption potential emissions reductions

Skills Analysis

	Low	Medium	High	Skills	Comment
CFL	*			DIY	
Appliances	*			DIY	White goods energy advisors
Draught exclusion Q15 to Q10		*		Joiner/specialist contractor	Specialist contractors identified in interviews
Cavity wall insulation		*		Specialist contractor, Builder	Cavity wall Insulation contractor
Extract fans			*	Electrician Builder	
Loft insulation	*			Insulation contractor	May be DIY, otherwise builder or specialist contractor
PV			*	Electrician, Roofer	Specialist contractor under Microgeneration scheme
Boiler & controls			*	Plumber, Electrician, Builder	Future maintenance works
Cylinder & controls			*	Plumber, Electrician	
Solar Thermal			*	Plumber, Electrician, Roofer, Builder	Specialist contractor under Microgeneration scheme
Openings		*		Builder, Joiner, specialist contractor	Builder or window contractor
External Wall		*		Specialist	Specialist EWI contractor, all

Insulation				contractor, Builder, Plumber, Electrician	trades attending.
Q10 to Q5		*		All trades	Requires specialist tapes and mastics, knowledge & commitment from all trades. Supported with Tool Box talks
Q5 to ≤Q3			*	All trades	Requires specialist tapes and mastics, knowledge & commitment from all trades. Supported with Tool Box talks and in-depth planning & supervision.
MVHR			*	Specialist contractor, builder, electrician	Specialist design, installation, commissioning and maintenance. Requires access to hidden ductwork and MVHR unit.
Internal Wall Insulation		*		Builder, Plasterer, Decorator	Builder or specialist contractor, all trades attending
Floor insulation		*		Builder	Builder, all trades attending
Making good		*		Builder, plaster, decorator	All building works require "making good" and redecorating

Table 31: Skills analysis

Maximising Potential Savings
Figures 21and 22 show graphically the maximum interventions for solid and cavity wall detached houses. For fully tabulated and graphical output see Appendix.

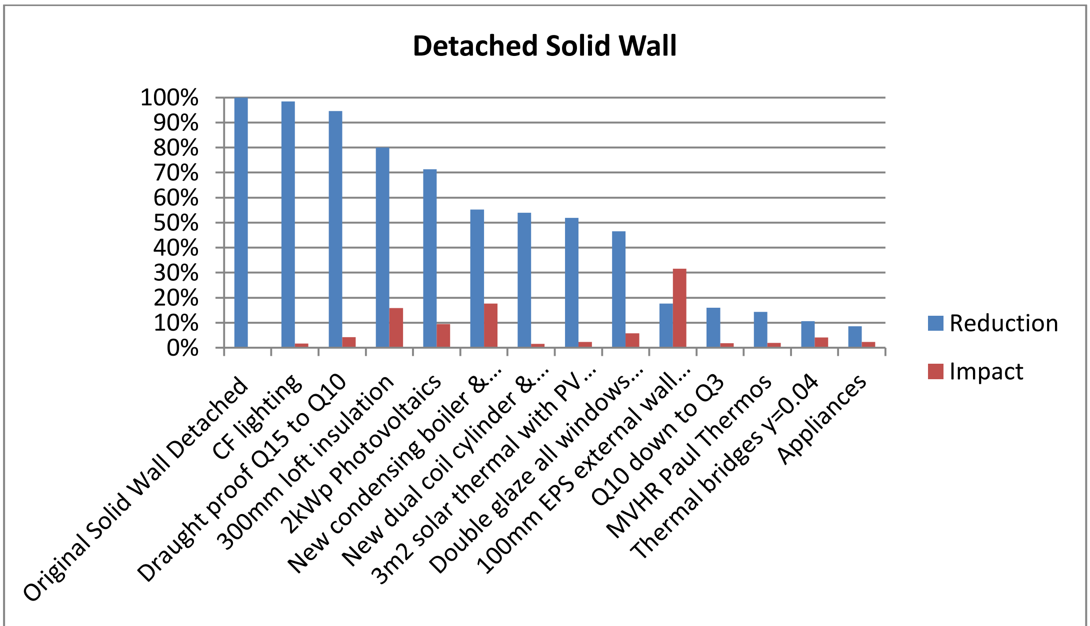

Figure 21: Solid wall analysis (maximum impact)

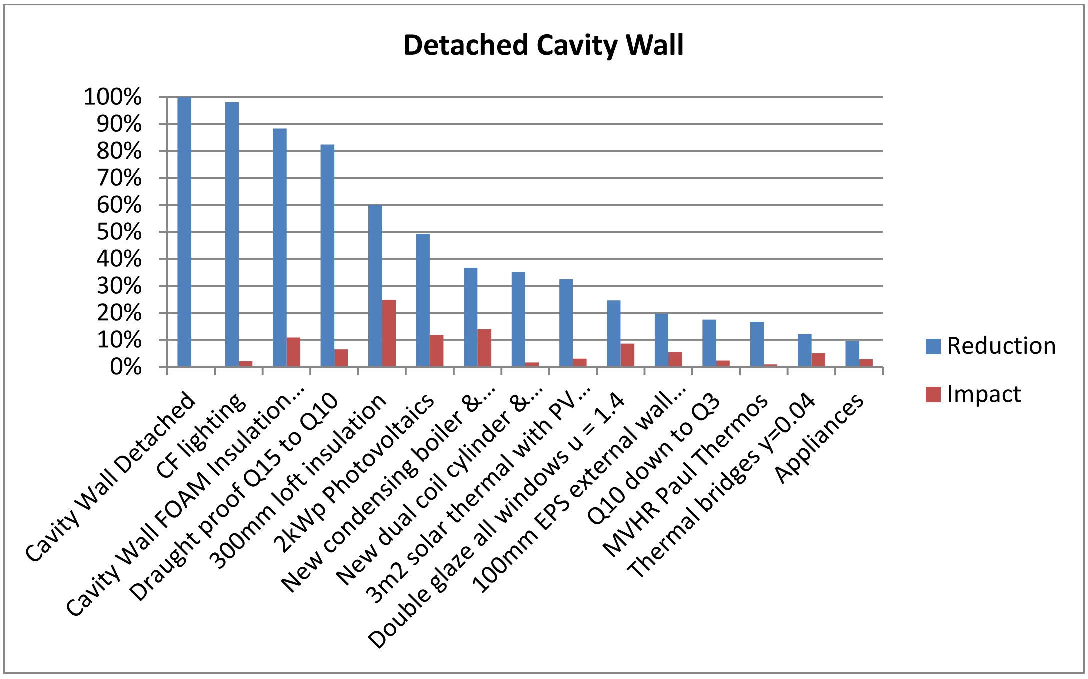

Figure 22: Cavity wall analysis (maximum impact)

The analysis shows that it is possible to meet 90% reductions in housing but only at maximum disruption. The impact of individual interventions is shown in Table 32 as percentage savings.

Cavity Wall Detached	
300mm loft insulation	23.6%
New condensing boiler & controls	13.2%
2kWp Photovoltaics	11.2%
Cavity Wall FOAM Insulation u= 0.5	10.3%
Double glaze all windows u = 1.4	8.2%
Draught proof Q15 to Q10	6.1%
Floor insulation	5.3%
100mm EPS external wall insulation (EWI)	5.3%
Thermal bridges y=0.04	4.8%
3m2 solar thermal with PV pump	2.9%
Appliances	2.6%
Q10 down to Q3	2.2%
CF lighting	2.0%
New dual coil cylinder & insulated primaries	1.6%
MVHR Paul Thermos	0.9%

Table 32: Typical hierarchy of emission savings

Hierarchy of Retrofit

Building heat loss is a function of external surface area to volume ratio. Significant winter emissions savings may be achieved by reducing heat losses from the building envelope, principally by retrofitting insulation. Roof and cavity wall insulation provide the maximum benefit for the least internal disruption with the UK detached model saving up to 34% depending on building geometry. Two options exist for solid walls; internal and external insulation. The installation of internal wall insulation causes maximum disruption as well as loss of floor area which can be significant in smaller properties. Internal wall insulation is potentially an "all trades attending" intervention, requiring plasters, joiners, electricians and decorators. External wall insulation provides a solution to thermal bridges such a external corners and lintels and may provide an additional 4 or 5% saving. External wall insulation has less disruption within the dwelling but places the occupants within a building site surrounded by potential hazards. External wall insulation may have multiple knock-on effects due to service penetrations, soil and rainwater pipes, roof soffit reduction and the increase in building footprint. Interviews indicate multiple hidden costs, often not foreseen until the installation process begins. The insulation effect is subject to the law of diminishing returns increasing cost and thickness. UK retrofitting schemes such as CERT and the proposed Green Deal require that only accredited contractors fit insulation.

Efficient space heating and controls can save about 13% of emissions by replacing existing boilers with condensing gas and oil models, combined with a minimum of time programmer, room and cylinder thermostats interlocked to control the boiler and thermostatic radiator valves (TRVs). TRVs allow for zoning within the dwelling, where zones of limited occupation can be held at lower temperatures. However, TRVs require informed occupant behaviour in order to maximise savings.

South facing, optimally inclined roofs receive on average some 3000 Wh/m^{2}yr of solar radiation in London and 5330 Wh/m^{2}yr in Seville. The UK model shows a 2kWp PV installation emissions savings of 11%. Local emissions savings by off-setting grid emissions will vary from country to country depending on generator fuel mix.

Poorly insulated hot water cylinders provide unregulated heat to the building in winter and can lead to overheating in summer. Replacement with a factory insulated cylinder will save little in emissions unless combined with solar thermal hot water where the UK total emissions savings are about 4 or 5% for gas heated water whereas Southern Europe would show a greater reduction, increasing with oil and electricity depending on which fuel was replaced. Where boiler replacement interrupts household heating and hot water production consider replacing an inefficient cylinder with a new insulated dual coil model which may at some later time be connected to a solar thermal panel.

Replacing single glazing and poor quality doors with a quality low-e double glazed unit (u value 1.4 W/m^{2}K) and new solid door (u value 1.7 W/m^{2}K) will further reduce emissions by about 8%. Window and door replacement will also increase air tightness and attenuate external noise. Additional savings are offered by triple glazing where whole window u values are quoted as low as 0.76 W/m^{2}K, potentially doubling window emissions savings. Window replacement is a mature industry where the occupants perceive the benefits of new draught-free windows to outweigh any disruption.

Draught proofing will improve the quality of life for occupants by reducing asymmetric discomfort within a room. Draught proofing to 10m/h@50Pa (Q10), the UK maximum for new build, is possible with professional draught stripping of windows, doors and services penetrations and can potentially save up to 6% of emissions. Draught proofing is again subject to diminishing returns where reducing air permeability to Q5 requires a whole room approach and is applicable to refurbishment where property is empty. Interviewees describe a target of Q3 or less requiring a complete building strip out, advanced skills covering detailed design and installation of tapes and mastics. Architects who target such low air permeability in retrofit, describe "living on site" to supervise and builders talk of air tightness champions and the need to fail in order to see just how exacting such a low target is in practice. An air tight building will demand whole house mechanical ventilation in order to provide sufficient fresh air for indoor air quality. The SAP model shows MVHR to save as little as 1% for a quality unit with a quoted efficiency of 91% and specific fan power of 0.56 W/ls.

Whilst floor insulation may save 5% of emissions, installation requires total disruption to household living. Suspended timber floors may be lifted, the insulation inserted and the floor re-laid. Solid floors require either the replacement of the entire floor, or a rigid insulation fitted over the existing finish and attendant works such as re-fitting doors.

Year round savings may be achieved with energy efficient lighting and appliances. Do it yourself replacement of incandescent light bulbs with compact fluorescent lamps saves between 2 and 3%. Replacement of white goods with A, A+ and A++ models will save some 200 $kgCO^2$/yr and represents about 2.5% emissions reductions.

16. Conclusion

The methodology results from the literature review and interviews with stakeholders. The methodology has identified three levels of intervention, shallow, medium and deep based on low, medium and high disruption to occupants. We cannot over-emphasise the importance of disruption and the need for complete transparency between occupants, advisors and contractors.

In order to assess retrofitting opportunities, a qualified emission"s assessor is required who will need to discuss and agree the level of intervention with occupants who will generally have little understanding of the impact of retrofitting their homes. The literature points to the potential difficulties of procurement with the construction standard requirement for three quotations from quality assured builder companies. Pricing retrofit works is often complicated by unforeseen additional works uncovered during the retrofit, the logistics of moving and replacing furniture and carpets and the extent of redecoration.

New build studies have identified the gap between low energy design and actual performance[128] SAP analysis is based on a particular occupation pattern at a particular winter temperature and may not match the occupants" life style, particularly in areas of low income, where energy savings are offset by higher internal temperatures for better comfort.[129] Advice on emissions reductions must be supported by evidence from previous metered field trials so that pay back programmes can be achieved. Similarly, field trial results provide feedback to contractors in order to increase their quality of output. On-going energy saving advice to occupants has been shown to have a significant impact.[130]

Low intervention will entail some disruption inside the dwelling with access for works to roof spaces for insulation, draught stripping of windows and doors, builder"s work to install extract fans and electrical works for fan and photovoltaic connections to the mains. Cavity wall insulation will generally require scaffolding to the exterior placing the occupant within a building site environment and may require additional hazard analysis and risk assessment as well as impacting on nearby plants and gardens. Some of works will require temporary loss of electrical power and surface preparation, „making good" and redecoration. It is assumed that a competent construction team require only 2 days access within the dwelling.

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[128] Zero Carbon Hub 2010 *Closing the gap between designed and built performance* http://www.zerocarbonhub.org/resourcefiles/TOPIC4_PINK_5August.pdf
[129] Gentoo 2010 *Retrofit reality* http://assets.gentoogroup.com/assets/Downloads/Retrofit%20Reality%203%20final.pdf
[130] *Relish 12 month report* http://www.relish.org/downloads/RELISH_12_MONTH_REPORT.pdf

Medium disruption requires disruption hot and cold water and heating. Works include boiler, cylinder and controls replacement, access to all rooms to fit TRVs, plus access to primary flow and return pipes for insulation. Where photovoltaics are to be fitted, solar thermal will entail minimal additional cost but will require project management to prevent clashes within the roof space between electrical, plumbing and insulation requirements.

High disruption requires access to walls for insulation. External wall insulation provides the least disruption provided there is adequate clearance for scaffolding. External wall insulation is potentially complex where services and pipe work are fixed to the façade. Internal wall insulation requires the removal and replacement of furniture, wall mounted electrical and lighting fittings, skirting boards and architraves with furnished rooms requiring redecoration. Extensive internal works are potentially challenging where the home becomes a building site and construction workers need to socialise with occupants. Interviews reveal that deep retrofitting with low air permeability and whole house mechanical ventilation requires a complete strip-out of the building for air tightness interventions and extensive builder"s work for ductwork installation. These operations can only proceed after occupant decant. Because of the extent of the intervention and the possibility of additional works, it would be inadvisable to plan for these interventions except where a full refurbishment was undertaken.

The skills analysis has identified the need for all traditional construction trades such as electricians, plumbers, plasters and decorators if targets of 60 – 80% emissions reductions are to be met. Electricians and plumbers will need to develop competencies in renewable energy installations, photovoltaics in particular. There will be an increasing demand for insulation and draught proofing contractors especially with the expansion of wall insulation opportunities. Construction teams will need to develop a whole-house appreciation of energy losses with a focus on envelope air tightness and continuity of insulation.

A wide scale retrofitting programme will demand competent emissions assessors, project managers and a supply chain capable of delivering for mass retrofitting. Such a programme will require specific in-house training programmes for industry stakeholders and the development of low emissions education across all sectors of the education system from schools to post graduate.

Proposed methodology

Our starting point in this study has been that, at this point in time, across Europe various energy rating methodologies are in use, and that each country will need to employ their own methodology in calculating the carbon emission reduction impacts of retrofit measures. Our methodology provides a common framework for considering appropriate retrofitting measures for social housing across Europe, and their impacts on construction industry skills training. The energy rating methodology of a particular country can then be employed within this framework, along with local conversion factors for translating energy savings into carbon reductions. The basic steps in the methodology can be summarised simply as follows:

1. Consider lights and appliances
2. Consider occupant behaviour
3. Assess the emissions using SAP or local country equivalent which requires an estimation of envelope u values and ventilation rates
4. Carry out an options appraisal based on levels of disruption inside and outside including furniture and carpet removal/replacement, redecoration, scaffolding, etc.
5. Decide the acceptable level of disruption
6. Carry out project management appraisal – costs, decanting, supply chain, skilled labour availability, etc.
7. Specify the retrofitting measures and their potential savings
8. Monitor and report on final fuel and emissions

17. Appendices

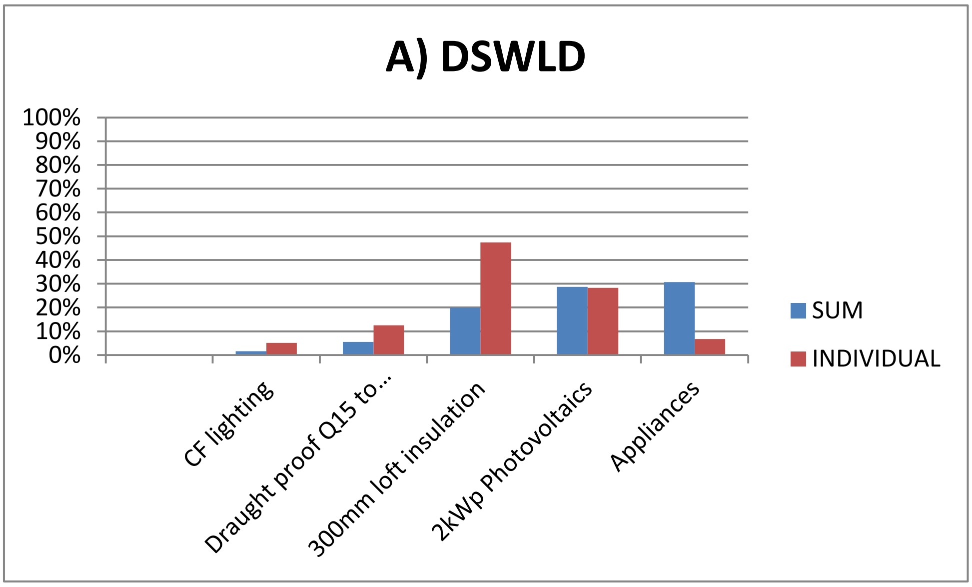
Appendix with some retrofit options for detached, mid-terrace and mid-floor flat

DETACHED SOLID WALL SOME OPTIONS

A

SOLID DETACHED

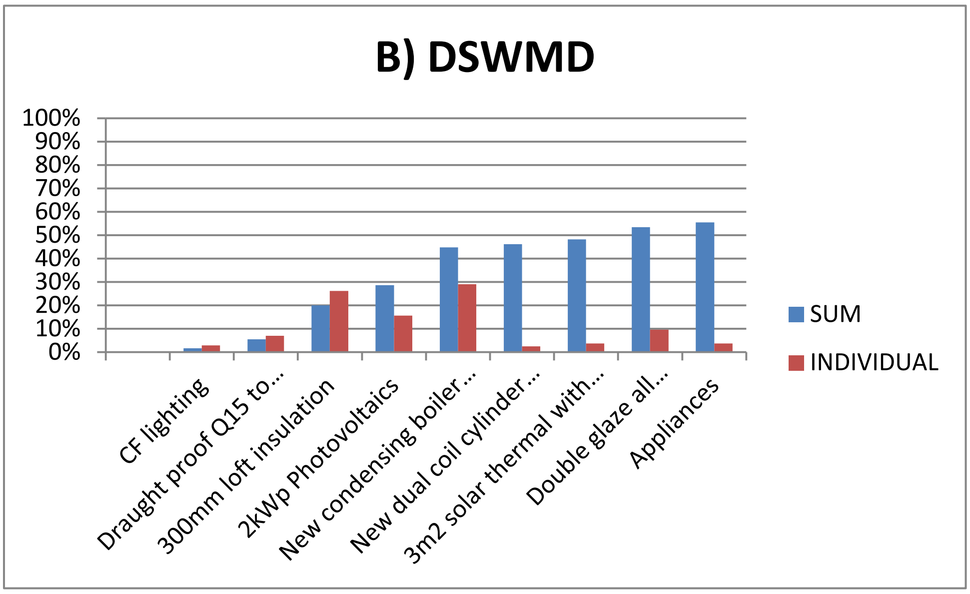
2 days in house,				
LOW DISRUPTION	REUCTION	SAVED	REDUCTION	IMPACT
Original Solid Wall Detached	9717	0	0%	0%
CF lighting	9564	153	2%	5%
Draught proof Q15 to Q10	9190	374	5%	13%
300mm loft insulation	7778	1412	20%	47%
2kWp Photovoltaics	6934	844	29%	28%
Appliances	6734	200	31%	7%
	TOTAL	2983		100%
Heating, hot water and drainage available				
Internal access required for draught proofing and roof insulation				
Disruption to electrical services				



2 days in house,				
LOW DISRUPTION	REUCTION	SAVED	REDUCTION	IMPACT
Original Solid Wall Detached	9717	0	0%	0%
CF lighting	9564	153	2%	7%
Draught proof Q15 to Q10	9190	374	5%	17%
300mm loft insulation	7778	1412	20%	66%
Appliances	7578	200	22%	9%
		2139		100%
WITHOUT PV	7578		22%	

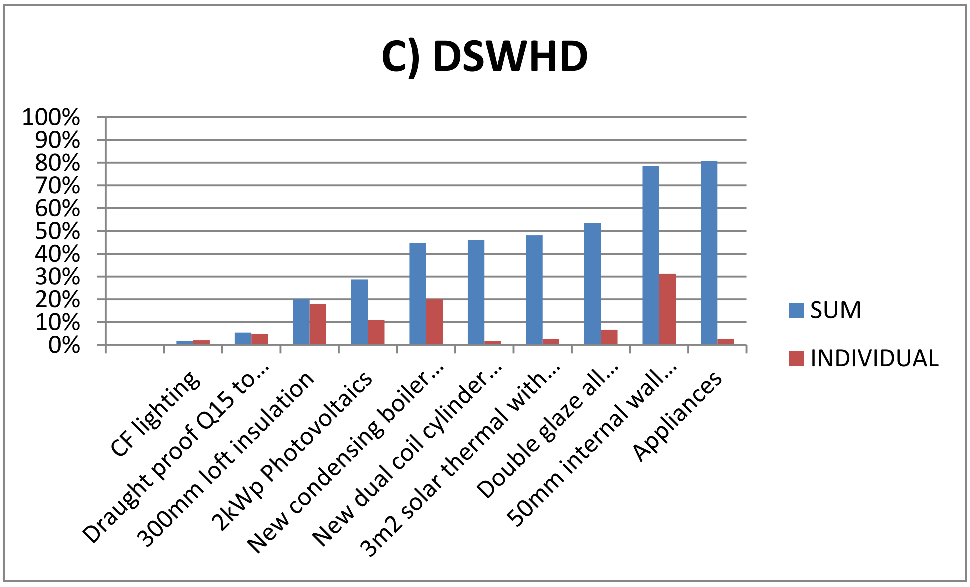
B

5 days in house				
MEDIUM DISRUPTION	REUCTION	SAVED	REDUCTION	IMPACT
Original Solid Wall Detached	9717	0	0%	0%
CF lighting	9564	153	2%	3%
Draught proof Q15 to Q10	9190	374	5%	7%
300mm loft insulation	7778	1412	20%	26%
2kWp Photovoltaics	6934	844	29%	16%
New condensing boiler & controls	5371	1563	45%	29%
New dual coil cylinder & insulated primaries	5240	131	46%	2%
3m2 solar thermal with PV pump	5039	201	48%	4%
Double glaze all windows u = 1.4	4525	514	53%	10%
Appliances	4325	200	55%	4%
	TOTAL	5392		100%
Disruption to heating and hot water	TOTAL	55%		
Internal disruption from window replacement				



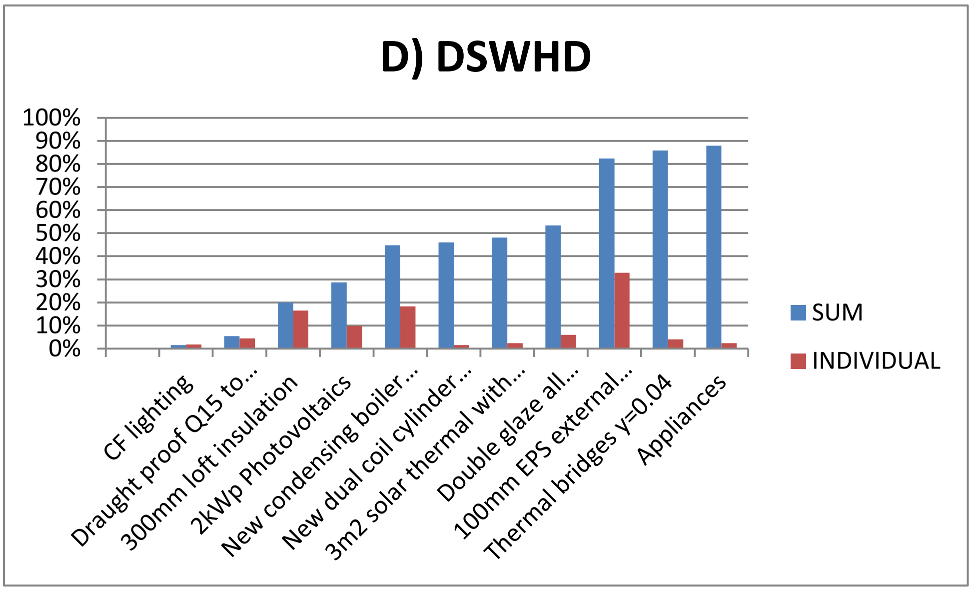
C

10 days in house				
HIGH DISRUPTION	REUCTION	SAVED	REDUCTION	IMPACT
Original Solid Wall Detached	9717	0	0%	0%
CF lighting	9564	153	2%	2%
Draught proof Q15 to Q10	9190	374	5%	5%
300mm loft insulation	7778	1412	20%	18%
2kWp Photovoltaics	6934	844	29%	11%
New condensing boiler & controls	5371	1563	45%	20%
New dual coil cylinder & insulated primaries	5240	131	46%	2%
3m2 solar thermal with PV pump	5039	201	48%	3%
Double glaze all windows u = 1.4	4525	514	53%	7%
50mm internal wall insulation (IWI)	2080	2445	79%	31%
Appliances	1880	200	81%	3%
		7837		100%
Disruption to heating and hot water		81%		
Internal disrution from window replacement				
Individual rooms need clearing for IWI				
OPTION FOR Q5 + fans or Q3 + MVHR				



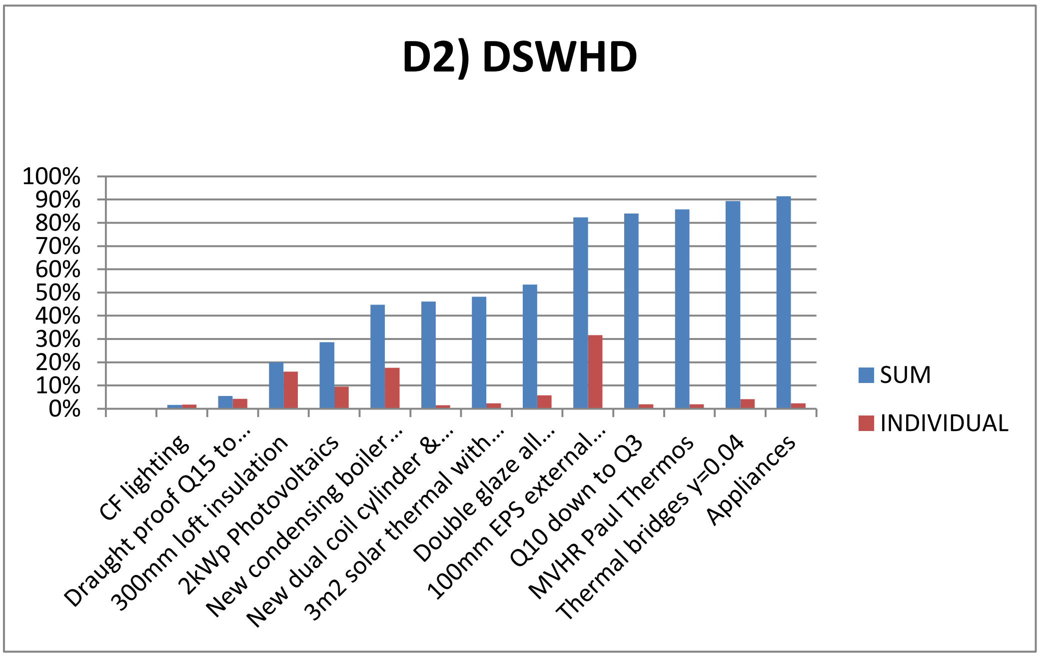
D

10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Original Solid Wall Detached	9717	0	0%	0%
CF lighting	9564	153	2%	2%
Draught proof Q15 to Q10	9190	374	5%	4%
300mm loft insulation	7778	1412	20%	17%
2kWp Photovoltaics	6934	844	29%	10%
New condensing boiler & controls	5371	1563	45%	18%
New dual coil cylinder & insulated primaries	5240	131	46%	2%
3m2 solar thermal with PV pump	5039	201	48%	2%
Double glaze all windows u=2.0	4525	514	53%	6%
100mm EPS external wall insulation (EWI)	1718	2807	82%	33%
Thermal bridges y=0.04	1373	345	86%	4%
Appliances	1173	200	88%	2%
		8544		100%
Disruption to heating and hot water				
Internal disrution from window replacement				
External facades require preparation				
EWI: re-routing of services & RWPs, SVP & drains?				
EWI: Roof soffits may need extending?				
OPTION FOR Q5 + fans or Q3 + MVHR				



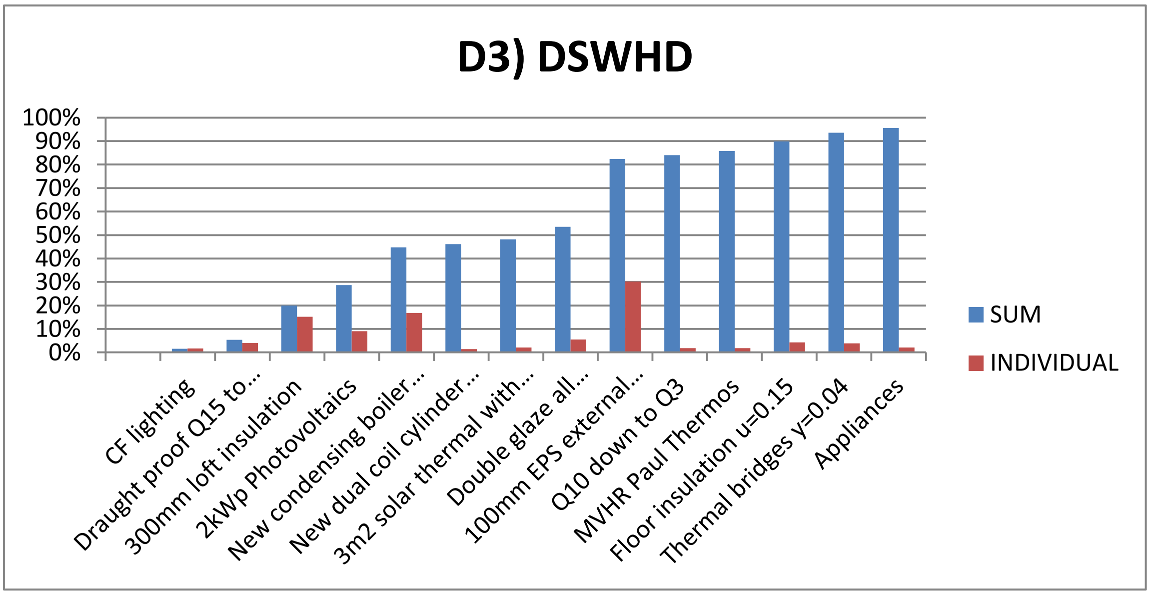
D2

10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Original Solid Wall Detached	9717	0	0%	0%
CF lighting	9564	153	2%	2%
Draught proof Q15 to Q10	9190	374	5%	4%
300mm loft insulation	7778	1412	20%	16%
2kWp Photovoltaics	6934	844	29%	9%
New condensing boiler & controls	5371	1563	45%	18%
New dual coil cylinder & insulated primaries	5240	131	46%	1%
3m2 solar thermal with PV pump	5039	201	48%	2%
Double glaze all windows u=1.4	4525	514	53%	6%
100mm EPS external wall insulation (EWI)	1718	2807	82%	32%
Q10 down to Q3	1554	164	84%	2%
MVHR Paul Thermos	1388	166	86%	2%
Thermal bridges y=0.04	1030	358	89%	4%
Appliances	830	200	91%	2%
		8887		100%
AIR TIGHTNESS CHAMPION				
MVHR designer				
MVHR installer and commissioner				



D3

10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Original Solid Wall Detached	9717	0	0%	0%
CF lighting	9564	153	2%	2%
Draught proof Q15 to Q10	9190	374	5%	4%
300mm loft insulation	7778	1412	20%	15%
2kWp Photovoltaics	6934	844	29%	9%
New condensing boiler & controls	5371	1563	45%	17%
New dual coil cylinder & insulated primaries	5240	131	46%	1%
3m2 solar thermal with PV pump	5039	201	48%	2%
Double glaze all windows u=2.0	4525	514	53%	6%
100mm EPS external wall insulation (EWI)	1718	2807	82%	30%
Q10 down to Q3	1554	164	84%	2%
MVHR Paul Thermos	1388	166	86%	2%
Floor insulation u=0.15	989	399	90%	4%
Thermal bridges y=0.04	625	364	94%	4%
Appliances	425	200	96%	2%
		9292		100%
AIR TIGHTNESS CHAMPION				
MVHR designer				
MVHR installer and commissioner				

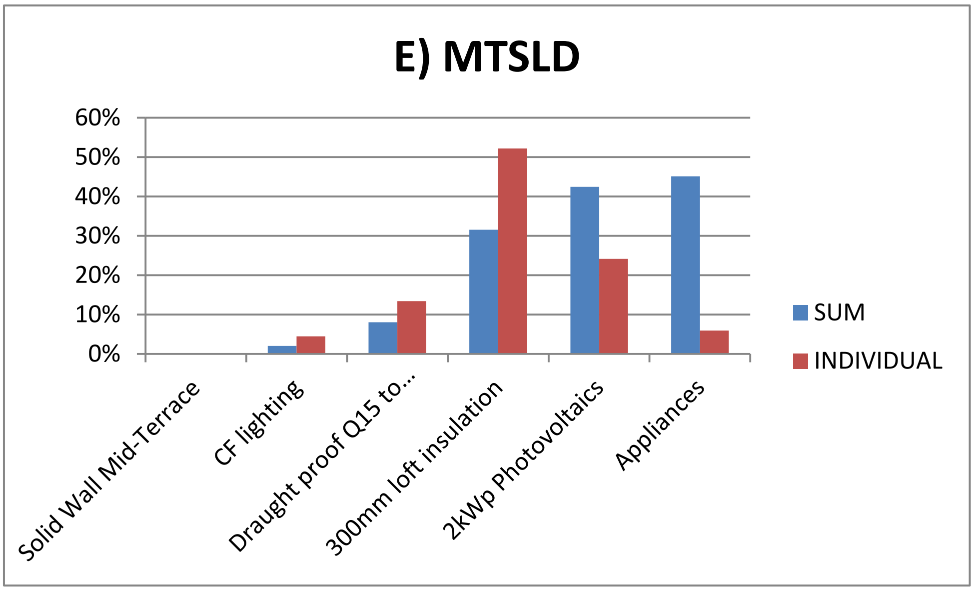


MID-TERRACE SOLID WALL OPTIONS

E

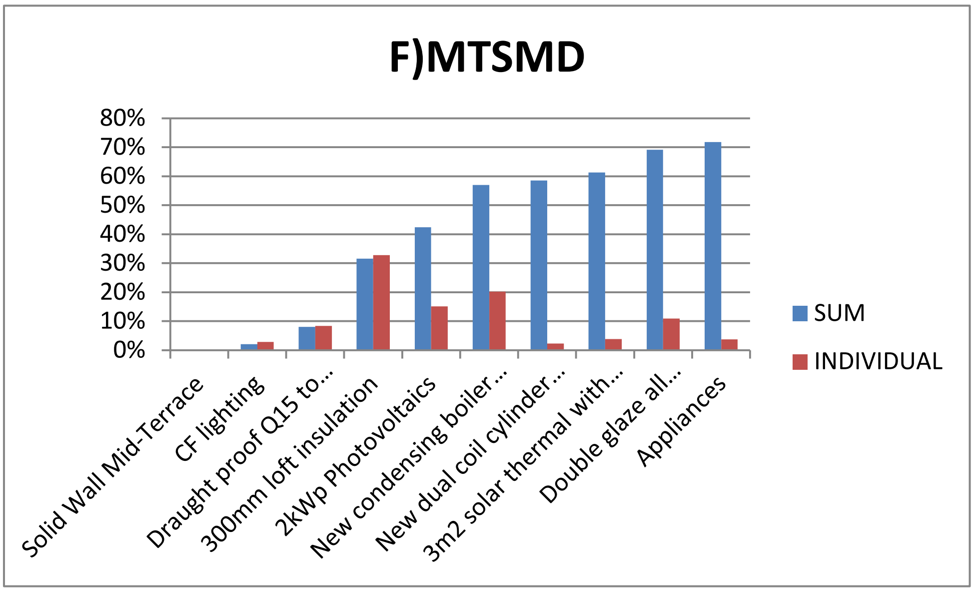
SOLID MID-TERRACE

2 days in house,				
LOW DISRUPTION	REUCTION	SAVED		
Solid Wall Mid-Terrace	7481	0	0%	0%
CF lighting	7331	150	2%	4%
Draught proof Q15 to Q10	6880	451	8%	13%
300mm loft insulation	5121	1759	32%	52%
2kWp Photovoltaics	4308	813	42%	24%
Appliances	4108	200	45%	6%
		3373		
Heating, hot water and drainage available				
Internal access required for draught proofing and roof insulation				
Disruption to electrical services				
Without PV	4921		34%	



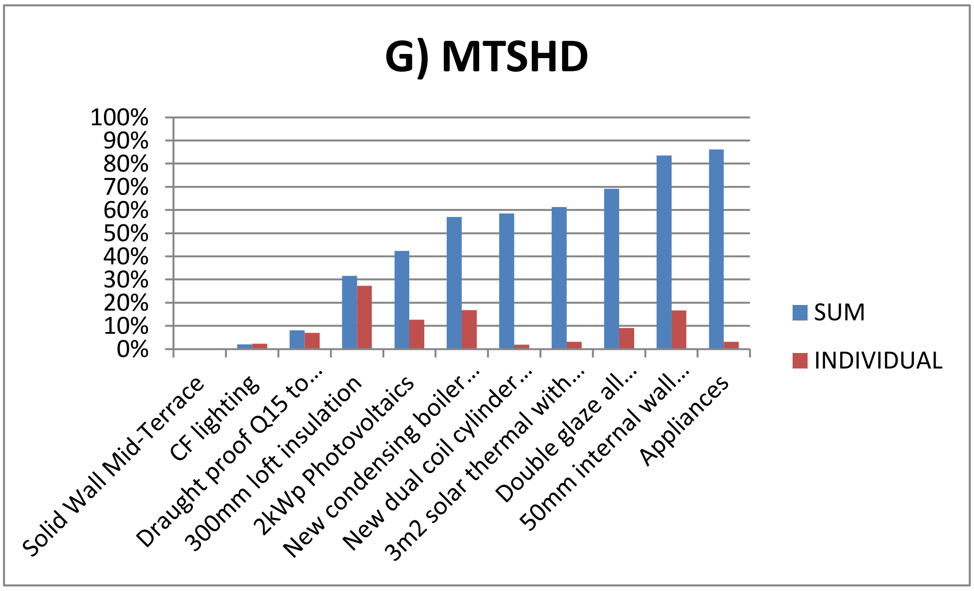
F

5 days in house				
MEDIUM DISRUPTION	REUCTION	SAVED		
Solid Wall Mid-Terrace	7481	0	0%	0%
CF lighting	7331	150	2%	3%
Draught proof Q15 to Q10	6880	451	8%	8%
300mm loft insulation	5121	1759	32%	33%
2kWp Photovoltaics	4308	813	42%	15%
New condensing boiler & controls	3222	1086	57%	20%
New dual coil cylinder & insulated primaries	3099	123	59%	2%
3m2 solar thermal with PV pump	2895	204	61%	4%
Double glaze all windows u = 1.4	2312	583	69%	11%
Appliances	2112	200	72%	4%
		5369		100%
Disruption to heating and hot water				
Internal disruption from window replacement				



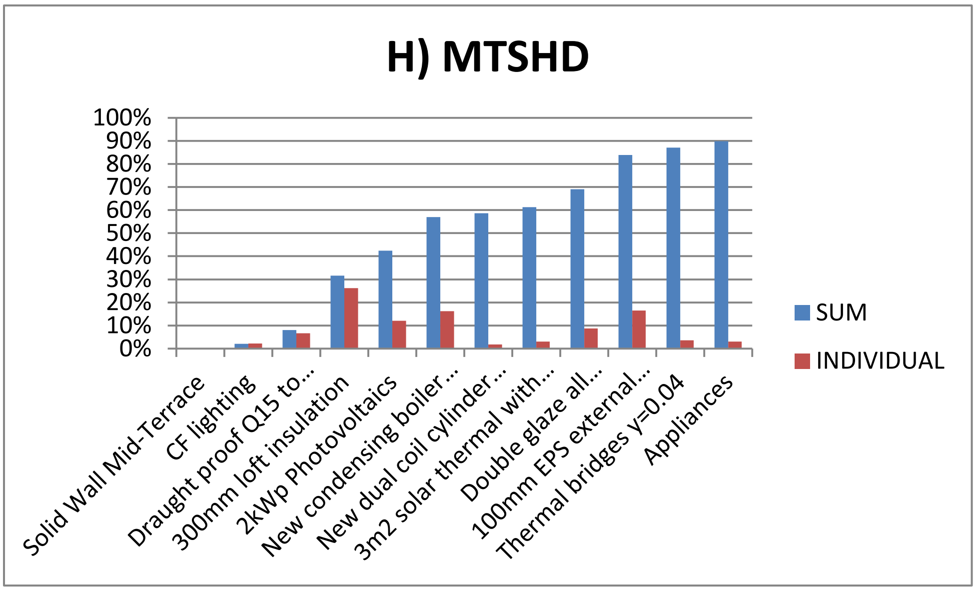
G

10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Solid Wall Mid-Terrace	7481	0	0%	0%
CF lighting	7331	150	2%	2%
Draught proof Q15 to Q10	6880	451	8%	7%
300mm loft insulation	5121	1759	32%	27%
2kWp Photovoltaics	4308	813	42%	13%
New condensing boiler & controls	3222	1086	57%	17%
New dual coil cylinder & insulated primaries	3099	123	59%	2%
3m2 solar thermal with PV pump	2895	204	61%	3%
Double glaze all windows u = 1.4	2312	583	69%	9%
50mm internal wall insulation (IWI)	1238	1074	83%	17%
Appliances	1038	200	86%	3%
		6443		100%
Disruption to heating and hot water				
Internal disrution from window replacement				
Individual rooms need clearing for IWI				
OPTION FOR Q5 + fans or Q3 + MVHR				



H

10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Solid Wall Mid-Terrace	7481	0	0%	0%
CF lighting	7331	150	2%	2%
Draught proof Q15 to Q10	6880	451	8%	7%
300mm loft insulation	5121	1759	32%	26%
2kWp Photovoltaics	4308	813	42%	12%
New condensing boiler & controls	3222	1086	57%	16%
New dual coil cylinder & insulated primaries	3099	123	59%	2%
3m2 solar thermal with PV pump	2895	204	61%	3%
Double glaze all windows u = 1.4	2312	583	69%	9%
100mm EPS external wall insulation (EWI)	1202	1110	84%	17%
Thermal bridges y=0.04	964	238	87%	4%
Appliances	764	200	90%	3%
		6717		100%
Disruption to heating and hot water		0.8978746		
Internal disrution from window replacement				
External facades require preparation				
EWI: re-routing of services & RWPs, SVP & drains?				
EWI: Roof soffits may need extending?				
OPTION FOR Q5 + fans or Q3 + MVHR				

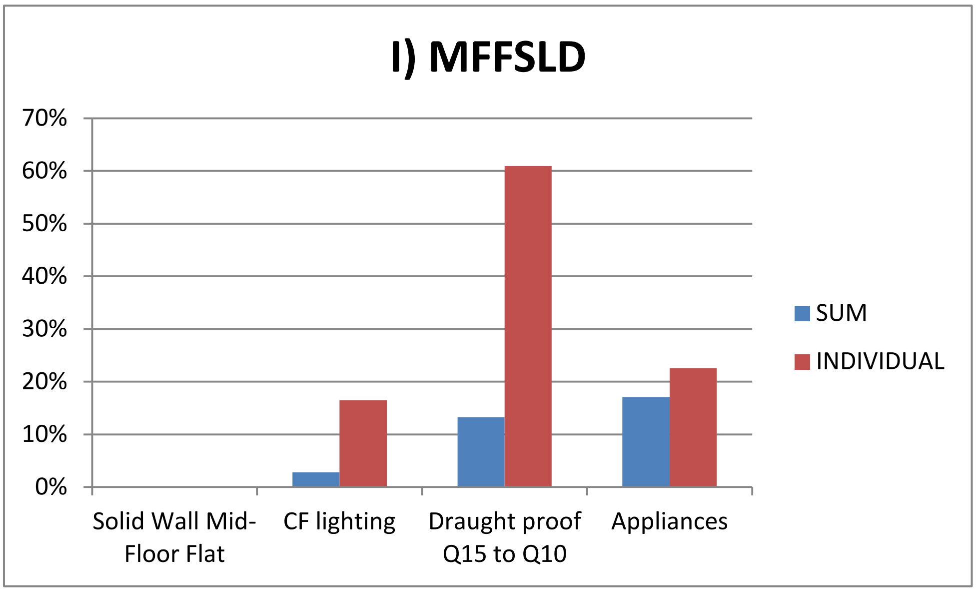


MID-FLOOR FLAT SOLID WALL OPTIONS

I

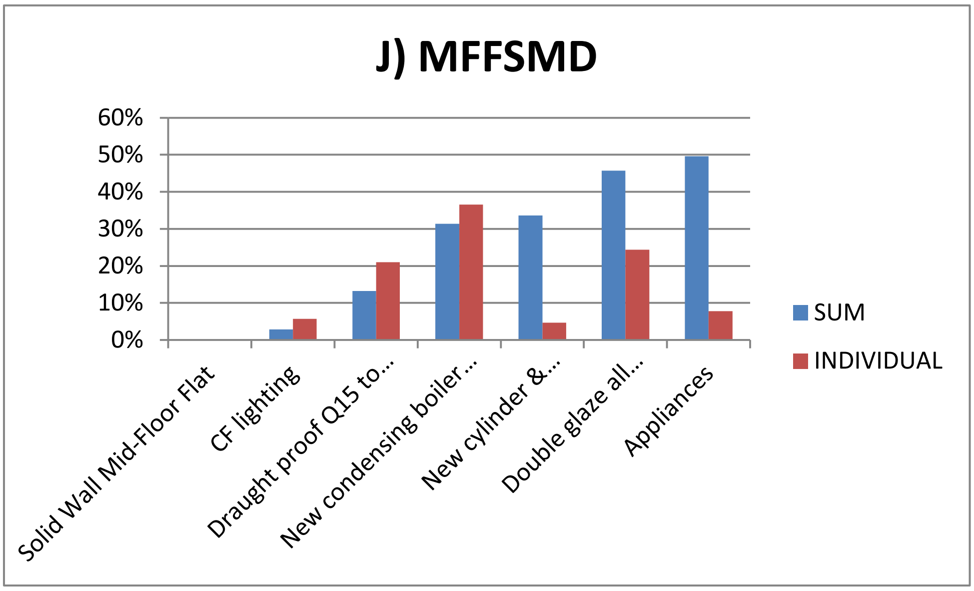
SOLID MID-FLOOR FLAT

2 days in house,				
LOW DISRUPTION	REUCTION	SAVED		
Solid Wall Mid-Floor Flat	5187	0	0%	0%
CF lighting	5041	146	3%	16%
Draught proof Q15 to Q10	4501	540	13%	61%
Appliances	4301	200	17%	23%
		886		100%
Heating, hot water and drainage available				
Internal access required for draught proofing				



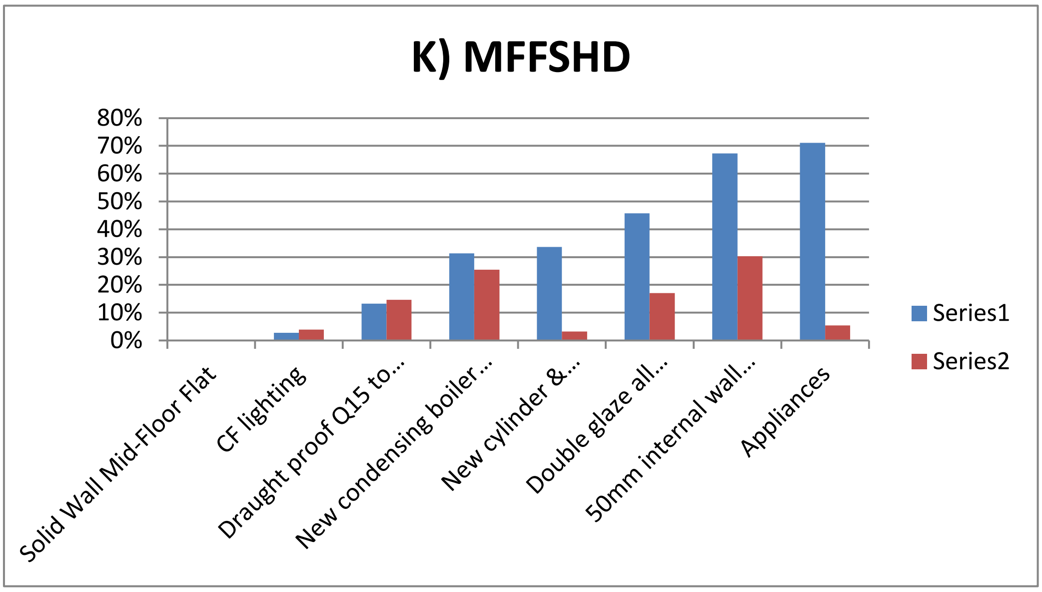
J

5 days in house				
MEDIUM DISRUPTION	REUCTION	SAVED		
Solid Wall Mid-Floor Flat	5187	0	0%	0%
CF lighting	5041	146	3%	6%
Draught proof Q15 to Q10	4501	540	13%	21%
New condensing boiler & controls	3561	940	31%	37%
New cylinder & insulated primaries	3442	119	34%	5%
Double glaze all windows u = 1.4	2815	627	46%	24%
Appliances	2615	200	50%	8%
		2572		100%
Disruption to heating and hot water				
Internal disruption from window replacement				



K

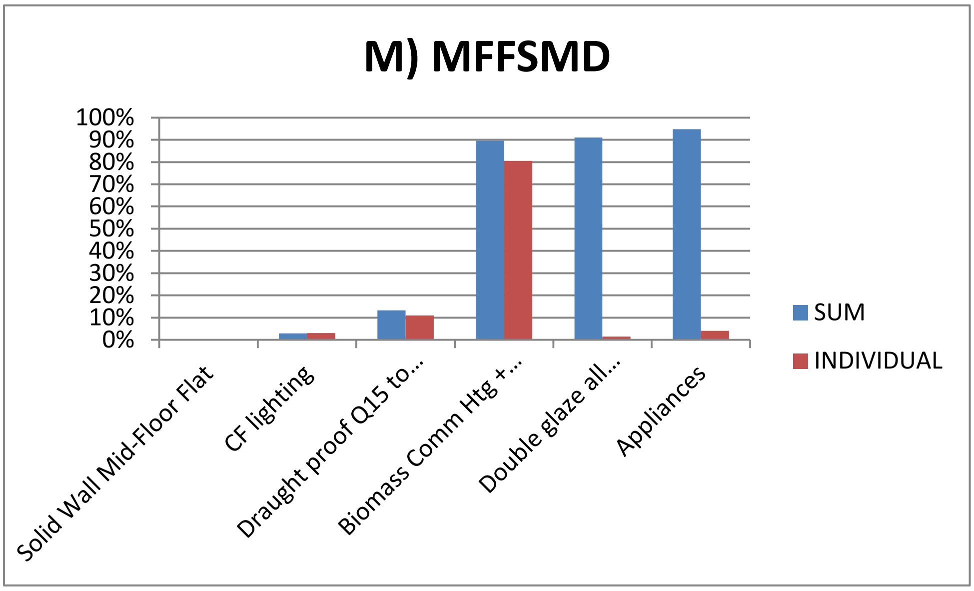
10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Solid Wall Mid-Floor Flat	5187	0	0%	0%
CF lighting	5041	146	3%	4%
Draught proof Q15 to Q10	4501	540	13%	15%
New condensing boiler & controls	3561	940	31%	25%
New cylinder & insulated primaries	3442	119	34%	3%
Double glaze all windows u = 1.4	2815	627	46%	17%
50mm internal wall insulation (IWI) u=0.4	1698	1117	67%	30%
Appliances	1498	200	71%	5%
		3689		100%
Disruption to heating and hot water				
Internal disrution from window replacement				
Individual rooms need clearing for IWI				
OPTION FOR Q5 + fans or Q3 + MVHR				



BIOMASS OPTION (with charges for space heating and hot water)

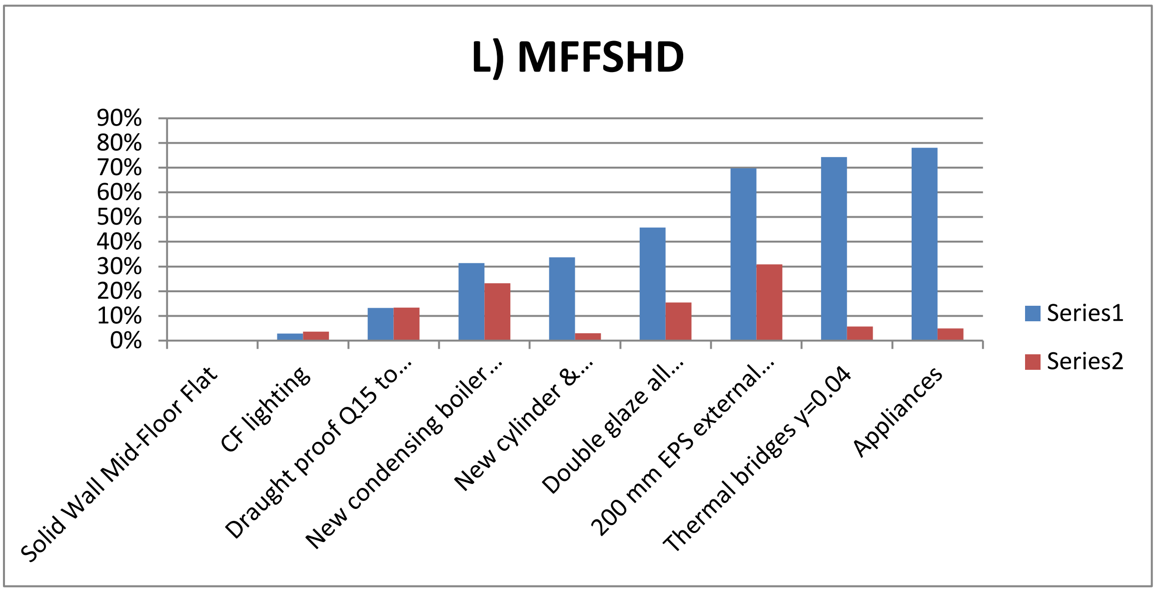
M

5 days in house				
MEDIUM DISRUPTION	REUCTION	SAVED		
Solid Wall Mid-Floor Flat	5187	0	0%	0%
CF lighting	5041	146	3%	3%
Draught proof Q15 to Q10	4501	540	13%	11%
Biomass Comm Htg + charges	542	3959	90%	80%
Double glaze all windows u = 1.4	468	74	91%	2%
Appliances	268	200	95%	4%
		4919		



L

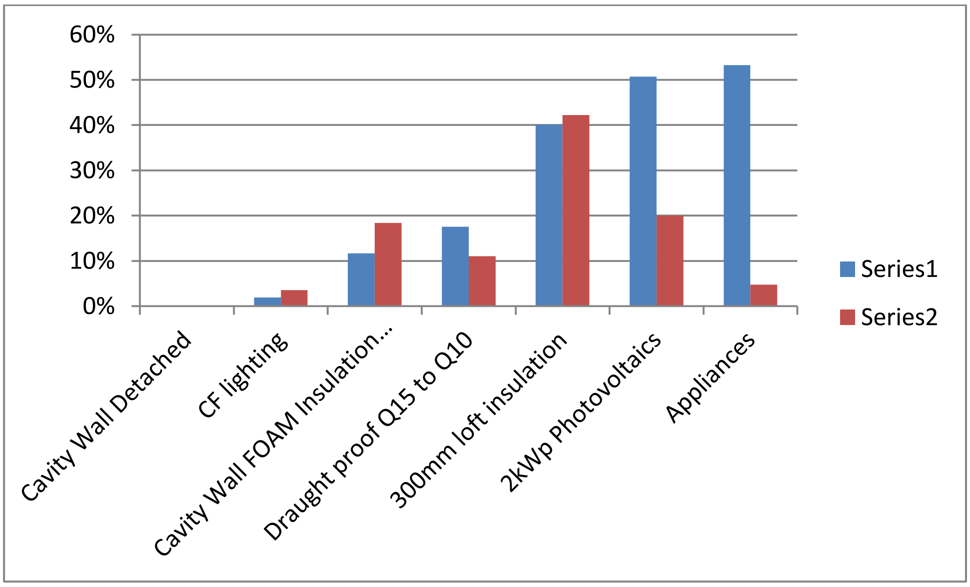
10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Solid Wall Mid-Floor Flat	5187	0	0%	0%
CF lighting	5041	146	3%	4%
Draught proof Q15 to Q10	4501	540	13%	13%
New condensing boiler & controls	3561	940	31%	23%
New cylinder & insulated primaries	3442	119	34%	3%
Double glaze all windows u = 1.4	2815	627	46%	15%
200 mm EPS external wall insulation (EWI) u=0.18	1567	1248	70%	31%
Thermal bridges y=0.04	1337	230	74%	6%
Appliances	1137	200	78%	5%
		4050		100%
Disruption to heating and hot water				
Internal disrution from window replacement				
External facades require preparation BUT NO INTERNAL WALL DISRUPTION				
EWI: re-routing of services & RWPs, SVP & drains?				
EWI: Roof soffits may need extending?				
OPTION FOR Q5 + fans or Q3 + MVHR				



DETACHED CAVITY WALL SOME OPTIONS

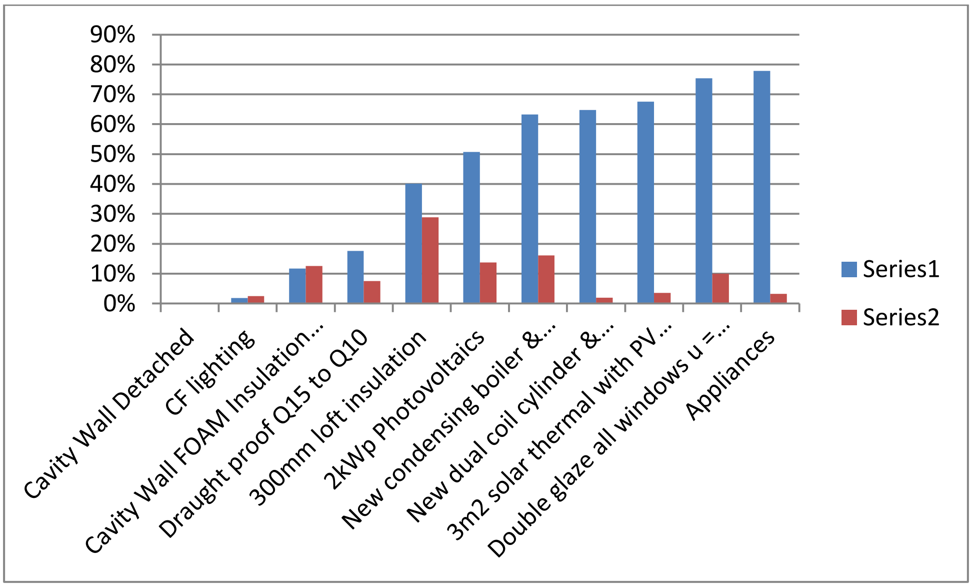
O

2 days in house,				
LOW DISRUPTION	REUCTION	SAVED		
Cavity Wall Detached	7910	0	0%	0%
CF lighting	7760	150	2%	4%
Cavity Wall FOAM Insulation u= 0.5	6985	775	12%	18%
Draught proof Q15 to Q10	6521	464	18%	11%
300mm loft insulation	4741	1780	40%	42%
2kWp Photovoltaics	3897	844	51%	20%
Appliances	3697	200	53%	5%
		4213		
Heating, hot water and drainage available				
Internal access required for draught proofing and roof insulation				
Disruption to electrical services				



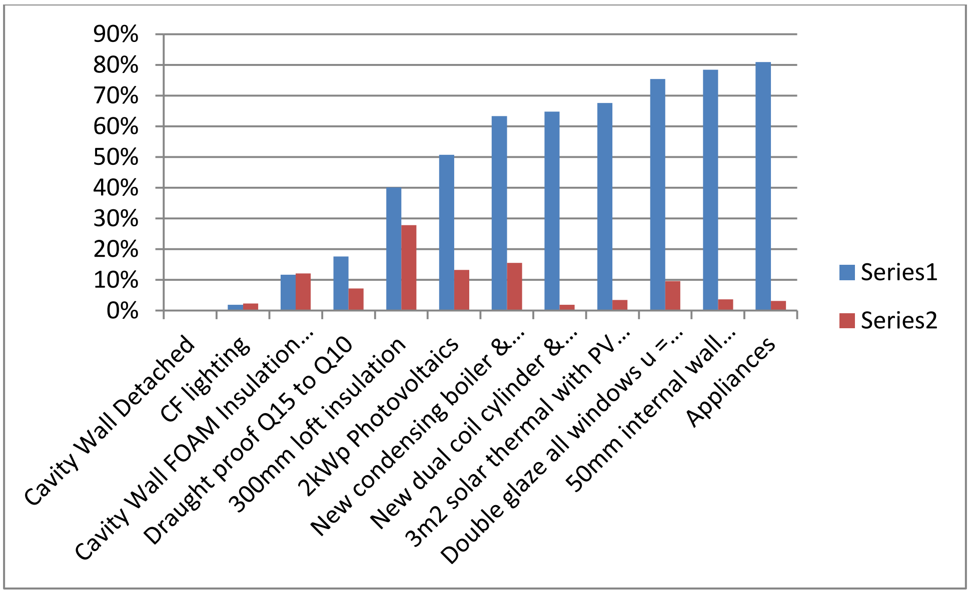
P

5 days in house				
MEDIUM DISRUPTION	REUCTION	SAVED		
Cavity Wall Detached	7910	0	0%	0%
CF lighting	7760	150	2%	2%
Cavity Wall FOAM Insulation u= 0.5	6985	775	12%	13%
Draught proof Q15 to Q10	6521	464	18%	8%
300mm loft insulation	4741	1780	40%	29%
2kWp Photovoltaics	3897	844	51%	14%
New condensing boiler & controls	2903	994	63%	16%
New dual coil cylinder & insulated primaries	2784	119	65%	2%
3m2 solar thermal with PV pump	2565	219	68%	4%
Double glaze all windows u = 1.4	1949	616	75%	10%
Appliances	1749	200	78%	3%
		6161		100%
Disruption to heating and hot water				
Internal disruption from window replacement				



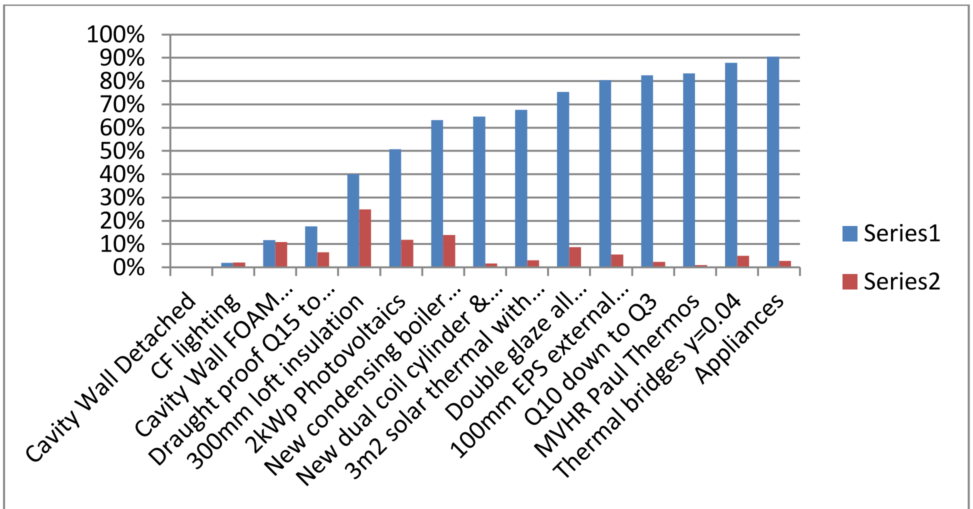
Q

10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Cavity Wall Detached	7910	0	0%	0%
CF lighting	7760	150	2%	2%
Cavity Wall FOAM Insulation u= 0.5	6985	775	12%	12%
Draught proof Q15 to Q10	6521	464	18%	7%
300mm loft insulation	4741	1780	40%	28%
2kWp Photovoltaics	3897	844	51%	13%
New condensing boiler & controls	2903	994	63%	16%
New dual coil cylinder & insulated primaries	2784	119	65%	2%
3m2 solar thermal with PV pump	2565	219	68%	3%
Double glaze all windows u = 1.4	1949	616	75%	10%
50mm internal wall insulation (IWI)0.35	1712	237	78%	4%
Appliances	1512	200	81%	3%
		6398		100%
Disruption to heating and hot water				
Internal disrution from window replacement				
Individual rooms need clearing for IWI				
OPTION FOR Q5 + fans or Q3 + MVHR				



S

10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Cavity Wall Detached	7910	0	0%	0%
CF lighting	7760	150	2%	2%
Cavity Wall FOAM Insulation u= 0.5	6985	775	12%	11%
Draught proof Q15 to Q10	6521	464	18%	6%
300mm loft insulation	4741	1780	40%	25%
2kWp Photovoltaics	3897	844	51%	12%
New condensing boiler & controls	2903	994	63%	14%
New dual coil cylinder & insulated primaries	2784	119	65%	2%
3m2 solar thermal with PV pump	2565	219	68%	3%
Double glaze all windows u = 1.4	1949	616	75%	9%
100mm EPS external wall insulation (EWI)	1551	398	80%	6%
Q10 down to Q3	1385	166	82%	2%
MVHR Paul Thermos	1317	68	83%	1%
Thermal bridges y=0.04	958	359	88%	5%
Appliances	758	200	90%	3%
		7152		100%
AIR TIGHTNESS CHAMPION				
MVHR designer				
MVHR installer and commissioner		IMPORTANT		
Q3 + MVHR		234	3%	3%
Appliances		200	3%	3%

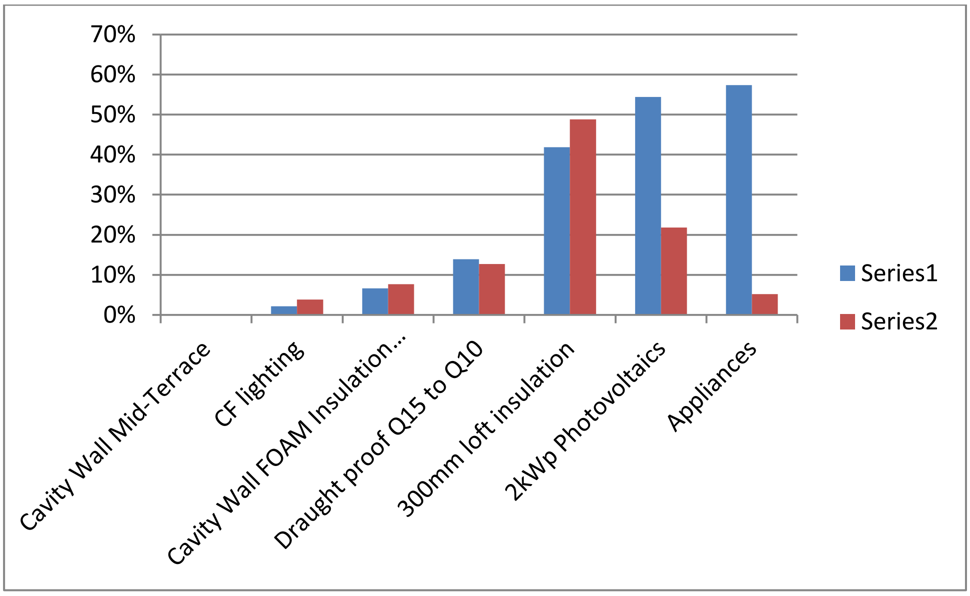


CAVITY WALL MID-TERRACE

Working on injecting cavity - scaffold, do either PV or new windows or BOTH

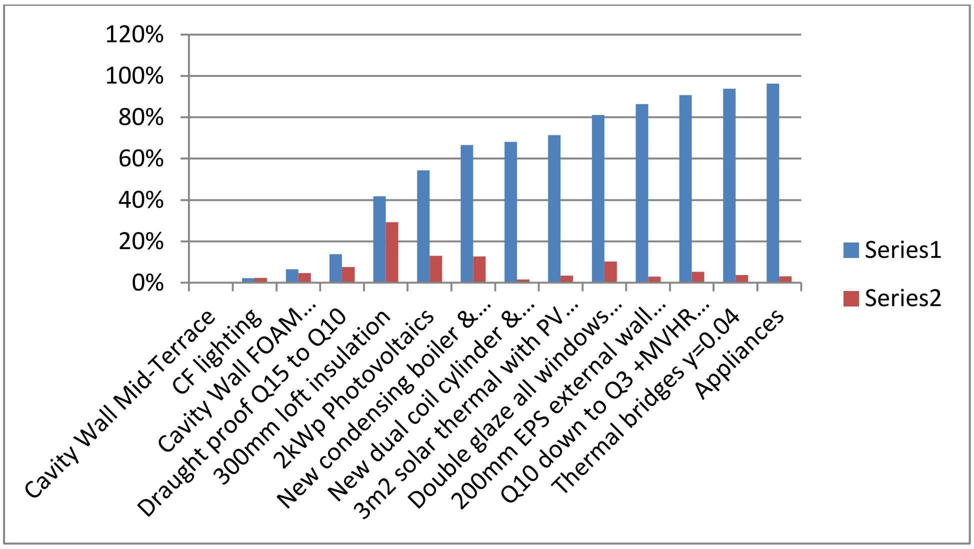
T

2 days in house,				
LOW DISRUPTION	REUCTION	SAVED		
Cavity Wall Mid-Terrace	6741	0	0%	0%
CF lighting	6593	148	2%	4%
Cavity Wall FOAM Insulation u= 0.5	6296	297	7%	8%
Draught proof Q15 to Q10	5806	490	14%	13%
300mm loft insulation	3921	1885	42%	49%
2kWp Photovoltaics	3077	844	54%	22%
Appliances	2877	200	57%	5%
		3864		100%
Heating, hot water and drainage available				
Internal access required for draught proofing and roof insulation				
Disruption to electrical services				



Y2

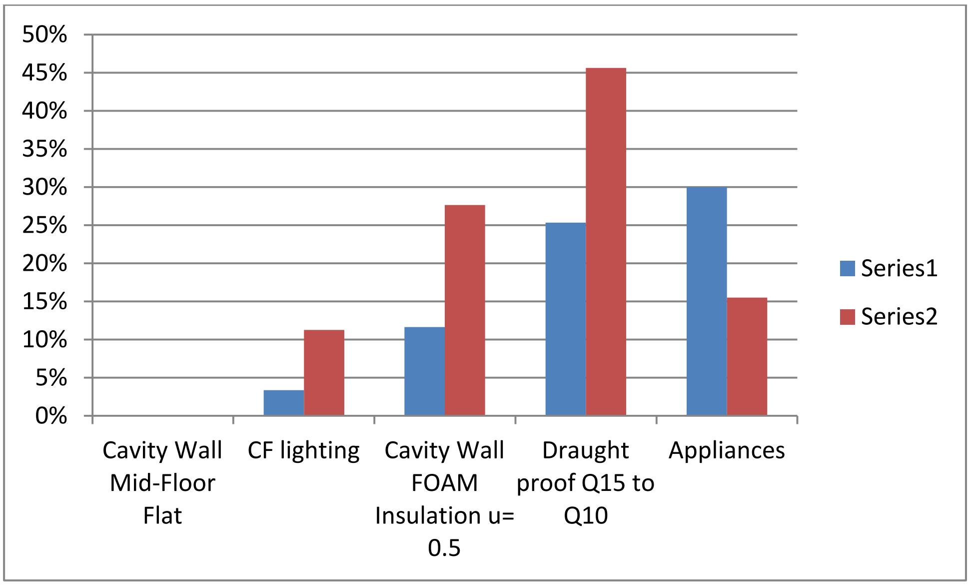
10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Cavity Wall Mid-Terrace	6741	0	0%	0%
CF lighting	6593	148	2%	2%
Cavity Wall FOAM Insulation u= 0.5	6296	297	7%	5%
Draught proof Q15 to Q10	5806	490	14%	8%
300mm loft insulation	3921	1885	42%	29%
2kWp Photovoltaics	3077	844	54%	13%
New condensing boiler & controls	2253	824	67%	13%
New dual coil cylinder & insulated primaries	2150	103	68%	2%
3m2 solar thermal with PV pump	1930	220	71%	3%
Double glaze all windows u = 1.4	1272	658	81%	10%
200mm EPS external wall insulation (EWI) 0.17	1076	196	86%	3%
Q10 down to Q3 +MVHR Paul	735	341	91%	5%
Thermal bridges y=0.04	494	241	94%	4%
Appliances	294	200	96%	3%
		6447		100%
AIR TIGHTNESS CHAMPION MVHR designer MVHR installer and commissioner	IMPORTANT			
Q3 + MVHR		341	5%	
Appliances		200	3%	



CAVITY MID-FLOOR **SOME** FLAT

AA)

2 days in house,				
LOW DISRUPTION	REUCTION	SAVED		
Cavity Wall Mid-Floor Flat	4301	0	0%	0%
CF lighting	4156	145	3%	11%
Cavity Wall FOAM Insulation u= 0.5	3800	356	12%	28%
Draught proof Q15 to Q10	3212	588	25%	46%
Appliances	3012	200	30%	16%
		1289		100%
Heating, hot water and drainage available				
Internal access required for draught proofing				



AD)

10 days in house				
HIGH DISRUPTION	REUCTION	SAVED		
Cavity Wall Mid-Floor Flat	4301	0	0%	0%
CF lighting	4156	145	3%	5%
Cavity Wall FOAM Insulation u= 0.5	3800	356	12%	11%
Draught proof Q15 to Q10	3212	588	25%	19%
New condensing boiler & controls	2569	643	68%	20%
New cylinder & insulated primaries	2464	105	69%	3%
Double glaze all windows u = 1.4	1787	677	77%	22%
200 mm EPS external wall insulation (EWI) u=0.17	1589	198	80%	6%
Thermal bridges y=0.04	1358	231	83%	7%
Appliances	1158	200	85%	6%
		3143		100%
Disruption to heating and hot water				
Internal disrution from window replacement				
External facades require preparation				
EWI: re-routing of services & RWPs, SVP & drains?				
EWI: Roof soffits may need extending?				
OPTION FOR Q5 + fans or Q3 + MVHR