residential retrofit
20 case studies
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CHAPTER 3: POST-1919
CWMBACH [TSB-10] 74
BYRON SQUARE [TSB-25] 78
LYNTON [TSB-68/69] 82
NEWPORT SOMERTON [TSB-60] 86
PASSFIELD DRIVE [TSB-108] 90
STANMORE, LONDON [TSB-72] 94
PENZANCE [TSB-64] 98
HADDINGTON WAY [TSB-31] 102
COACH ROAD [TSB-77 and 78] 106

CHAPTER 4: COMPARATIVE COMMENTARY
WINDOWS 114
AIRTIGHTNESS 119
M&E AND COMFORT VENTILATION 119
USER GUIDE BOARD 122
OCCUPANT INTERFACE 123
FORM FACTOR 123
SKILLS AND UNDERSTANDING 123
COORDINATION 124
PLANNING 124
CDST 125
CONCLUSION 126

ABBREVIATIONS 127

PICTURE CREDITS 128
The UK housing stock holds a strong identity and cultural significance for the British and for people across the world. Rows of Victorian terraces with coloured front doors are often seen as a quintessential part of the British aesthetic. It is a recognizable housing stock and one of the oldest in Europe with 55% of its dwellings dating from before 1960.1

As they were built at a time when the use of fossil fuels, emissions of greenhouse gases and the expectation of changes to our climate were not a concern for people across the planet, the building fabric of these houses was not originally designed to retain heat energy particularly well and their occupants adapted to the vagaries of UK winter temperatures and an average indoor temperature around 12ºC mainly by adjusting their attire.2

Since then, standards of comfort and our outlook on activities surrounding our energy use, in particular in the built environment, have changed vastly. Rising levels of greenhouse gases, mainly CO2, are increasingly becoming a concern for most of the world’s governments. Recent UK governments have recognised this concern and in 2008 introduced a legally binding Act of Parliament targeting a reduction of greenhouse gas emissions of at least 80% by 2050, with a reduction in emissions of at least 34% by 2020 (both targets are set against a 1990 baseline).

DECC (the UK Department of Energy and Climate Change), the key department in charge of implementing these targets, is undertaking extensive research into the field. In particular, they have identified that in 2009, 38% [678 TWh/yr] of the UK total CO2 emissions came from ‘buildings in use’ and more relevantly, that 28% [501 TWh/yr] are directly linked to ‘residential buildings in use’.3 However daunting this sounds, being part of the problem means that those UK residential buildings are also part of the solution.

But retrofit is not only about participating in the reduction of CO2 emissions. It is also about avoiding the dilapidation of buildings that have become uninhabitable, helping to future-proof houses against the risks of fuel poverty and, last but not least, providing comfort for occupants.

SO WHAT ARE THE SOLUTIONS?

With 27 million existing dwellings and only 120,000 new homes built every year, most of which are additional, the solution of relying purely on the new housing stock would fall a long way short of the Climate Change Act target. Over two-thirds of the 2050 housing stock has already been built, therefore the challenge is deciding what can be done with existing buildings. How can we ensure their continuing use, ensure continuing financial investment to avoid dilapidation, ensure that they are still representative of British cultural identity and at the same time deliver the levels of reduction in energy use required to address the impending environmental crisis?

Research needs to be carried out and solutions offered to all parties – homeowners, landlords, builders, tenants, housing associations – to help them achieve the required level of reduction in energy use. Equally important is the need to provide an adequate level of indoor comfort and quality of life for the 18% of all householders falling into fuel poverty,5 most of whom live in the least efficient housing stock.

So what options do we currently know of that could transform old houses to both offer comfortable environments and do so in a way that is responsible and not detrimental to people’s future? Could demolition and rebuild be an option?

Several interesting reports have been written to help answer this question. They do not offer a clear-cut answer, of course, as many factors play an important role in this issue, such as the quality and efficiency of the replacement building, its embodied carbon level and the cost of energy in the future among others. However, the overall balance seems to lean towards a retrofit option rather than demolition and complete rebuild for the following reasons:

- From a societal point of view, retrofit seems to be more acceptable than complete rebuild6 especially when complete relocation would be necessary (see Pathfinder programmes).9 Addressing the issue ‘in situ’ could also provide a boost for existing communities to implement greatly needed revitalisation schemes and help people out of fuel poverty by assisting them to confront increasing fuel prices and adverse effects on their health and standard of living. It could also potentially create long-term employment by encouraging the industry to develop the necessary skills and technologies to implement these retrofits.

3 www.poverty.org.uk/80/index.shtml#g2
4 www.poverty.org.uk/80/index.shtml#g2
5 www.poverty.org.uk/80/index.shtml#g2
6 A. Power, Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability?, Elsevier Ltd (2008).
7 A. Power, Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability?, Elsevier Ltd (2008).
8 A. Power, Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability?, Elsevier Ltd (2008).
9 Grant Shapps [holding answer 10 July 2012]: I refer the right hon. Member to my answer of 25 June 2012, Official Report, column 1086H, which outlines the damaging obsession with demolition under the last Administration’s Pathfinder scheme, and the role of central Government in promoting demolition targets. The figures in the Audit Commission’s reports were provided by local authority pathfinders. I would also note the National Audit Office’s estimate that there were plans for a total of 155,000 properties to be demolished. This Government has cancelled the Pathfinders programme and is instead actively seeking to get empty homes back into productive use.
HOW IS RETROFIT DEFINED?

For the purpose of this publication, it is important to clarify what is meant by ‘retrofit’. It will be defined here as a construction approach involving the action of introducing (retrofitting) new materials, products and equipment into an existing building with the aim of reducing the use of energy of the building. The term ‘retrofit’ is used in this publication to differentiate these projects from ‘renovations’ or ‘refurbishments’, which are often related to making good, repairing and/or aesthetically enhancing an existing building.

The phrase ‘deep retrofit’ is often used. The ‘deep’ character of a retrofit project further implies that the combination of elements introduced will have a very strong impact on the existing building’s level of CO2 emissions, typically aiming for an 80% reduction in line with the Climate Change Act target figure.

It is worth mentioning that achieving a CO2 emission reduction target of 80% implies a level of energy efficiency that vastly surpasses the current Building Regulation (and even BREEAM refurbishment) mandatory requirements for works on existing dwellings, and even surpasses current performance requirements for new build dwellings.

ABOUT THIS BOOK AND THE RETROFIT FOR THE FUTURE PROGRAMME

In this publication, you will find 20 case studies that aim to illustrate how UK practitioners have approached this challenging target in the context of existing residential buildings. All but two of the case studies have been drawn from the Retrofit for the Future programme (described on the following page) and have similar typology (individual houses; there are no flats), tenure (social tenants), budget (including £150,000 funded by TSB) and targets (reducing CO2 emissions by 80%). Each of the Retrofit for the Future project teams followed their own procedures for designing their retrofit strategy, but had the same way of defining a baseline project pre-retrofit against which the proposed measures could be compared and the same energy prices.

These individual houses have also been chosen to represent the UK housing stock in all construction variety – solid masonry, cavity walls, timber frame etc. – classified into two categories as either ‘pre-1919’ or ‘post-1919’ (corresponding to the time when UK construction techniques shifted from solid masonry to more efficient construction with cavity walls), to offer as wide a picture as possible of what retrofit can entail.

From an environmental point of view, retrofits have proven to have typically far lower impact. Retrofitting rather than rebuilding could make an initial saving of 35 tonnes of CO2 per property by removing the need for the energy locked into new build materials and construction. They could also help address the increasing scarcity of materials and pressure on land availability across the country.

So addressing the inefficiency of our building stock by providing instead highly efficient and responsible living places would seem to be a way to play a significant part in achieving CO2 emissions reduction. However, as explained above, this is not purely a matter of limiting damage from the adverse effects of climate change; it is also a much wider opportunity for our society to become more sustainable as a whole.

UK HOUSING STOCK PROFILE – CONDITION

In order to provide some background information for these case studies, it is important to give some basic characteristics for the UK housing stock and reference current government policies that apply to them.

The UK housing stock is one of the oldest in Europe. It includes almost 13 million dwellings built before 1960, including 4.7 million built before 1919, which is the least energy-efficient housing type of all. These now much-loved Victorian homes have a staggering average mean energy use (heating and lighting) of 480 kWh/m$^2$/yr (emitting 9 t CO$_2$/yr), while the more recent post-1990 dwellings’ mean energy use is little more than half of this figure at 270 kWh/m$^2$/yr (emitting 4.5 t CO$_2$/yr)11. This difference is due to a better understanding of building physics through the years, the introduction of cavity wall construction (primarily implemented to prevent the passage of moisture into the interior of the building) and building regulations that are gradually becoming more stringent on the efficiency of building thermal envelopes.

The Victorian housing stock is certainly the most ‘energy-hungry’ of all housing stocks in the UK. However, it is important not to automatically classify it as inherently inefficient.

In fact, a Victorian terraced house property with a small footprint will have a relatively small heat loss factor (area of heat loss/treated floor area, approximate GIA) in comparison with, for example, a detached bungalow built in the 1960s, which will have a vast heat loss area in comparison to its floor area. The lower the ‘form factor’, the lower the insulation thickness required to achieve the same total heat loss.

It would also be wrong to consider all Victorian properties as not inherently airtight either. When the internal layer of plaster is continuous and in good condition, it is not uncommon to find Victorian properties achieving an airtightness of five air changes per hour (ACH). With good care and repairs, this existing layer of plaster can be used in retrofits as part of the airtightness strategy.

These two examples – form factor and airtightness – only point out the importance of approaching a retrofit project free of any preconceived ideas of the existing performance of a building and free of ready-made solutions as there is no ‘one size fits all’ approach in retrofit. Each proposal presented in this publication is unique to the property and the result of a careful assessment by a knowledgeable practitioner.

The Retrofit for the Future (RffF) programme was initiated by the Technology Strategy Board in 2009 with £17 m of funding through the Small Business Research Initiative (SBRI). The aim was to demonstrate innovative approaches to deep retrofitting of the UK’s social housing stock.9

The RffF programme was split into two phases: Phase 1 saw 194 design and feasibility studies developed, while Phase 2 took 86 of these studies and provided each with up to £150,000 to implement the retrofit proposals in more than 100 properties. Eighteen of the 20 projects presented in this publication are drawn from the RffF programme and they represent a cross-section of different building types, ages, regional locations and technological solutions.

Applicants to the RffF competition were required to take a ‘whole house’ approach to achieving an 80% CO2 emission reduction target. This meant considering a household’s energy needs and CO2 impacts as a whole, and establishing a comprehensive package of measures to reduce them. To maximise the amount that the industry could learn from the projects, applicants were also required to include a comprehensive set of monitoring equipment in accordance with a standard specification. A central online database collects energy and environmental performance data from each of the projects and analysis of this data will be a key output from the RffF programme.10

9 www.retrofitthefuture.org/about-the-sbri-database/
10 www.retrofitanalysis.org

11 English House Condition Survey 2007 Annual Report – Communities and Local Government
UK HOUSING STOCK IN COMPARISON WITH EUROPEAN HOUSING STOCK PROFILE

While the UK has a particularly old housing stock (see graph on p.21), all other European countries are of course facing similar issues of having to address the energy efficiency of their own housing stock.

Probably due to the age of the stock, on a climate-corrected basis the UK is a higher consumer of energy per dwelling than the EU27, averages with two-thirds of countries having lower consumption per household in 2008 (see graph below). Since 2000, however, the UK has reduced energy consumption per dwelling by 4%, which places it in the top half of EU27 Member States but below neighbouring countries including France, the Netherlands and Sweden, where consumption reduced by at least 10% over that period.

While the UK has specific issues to address when considering retrofit (sash windows, for example), most other issues that practitioners will come across are common to all European countries and we can hope that the lessons learned will gradually be shared across Europe and the knowledge of best practice disseminated. A recent report, Europe’s buildings under the microscope, a country-by-country review of the energy performance of buildings, kick-started the spread of European data and research on how best to embrace this challenge.13

13 M. Economou et al (2011) ‘Europe’s buildings under the microscope, a country-by-country review of the energy performance of buildings’ Building Performance Institute Europe

Table showing UK housing stock in comparison with European housing stock profile.

Note: The ODYSSEE indicator is scaled to the average European climate, which enables fairer comparisons to be made across EU Member States.

STRATEGIES FOR RETROFIT

So how can the most energy-hungry dwellings be turned into more efficient homes?

In a typical house, the activity that requires the most energy is by far space heating, representing approximately 58% of the total energy use.

So to be most effective, a retrofit strategy should always focus primarily on reducing the space-heating demand, i.e. enhancing the capacity of the building fabric and services to retain the heat inside the building. This is achieved by the retrofitting of low heat transfer elements (that are capable of stopping the heat from escaping), typically with the installation of a significant layer of insulation in the external walls, ground floors and roofs, and the upgrading of windows and doors combined with particular attention to airtightness to avoid draughts and potential heat loss paths. This approach is commonly called the ‘fabric first’ approach, which forms the basic principle of all ‘deep retrofit’ cases that are presented in this publication.

It is fair to say that most of the projects presented here applied a fabric first approach via the criteria set by the PassivHaus standard. Most teams used the PHPP software (PassivHaus planning package) to calculate the energy demand and comfort levels of their design. In summary, the PassivHaus criteria include:

- airtightness: 0.6 ACH@50 Pa (a comfort criterion)
- a surface temperature 6°C (a comfort criterion)
- a summer overheating limit of maximum 10% over 25°C (a comfort criterion)
- a ventilation rate of 30 m³/hr/person (a comfort criterion)
- a heating demand 125 kWh/m²yr (an energy criterion)
- a primary energy demand 120 kWh/m²yr (an energy criterion)

The aim of this standard is to provide low energy demand but also a very comfortable living environment for the occupants as most of the criteria above relate to ‘comfort’ rather than solely to ‘energy’ demand.


7.3 Energy intensity is measured as primary energy consumption per unit of Gross Domestic Product (GDP). To enable meaningful comparisons to be made across EU Member States.

7.4 After adjusting for PPP, the UK has the lowest energy intensity of countries selected in chart 7.1.

7.5 The non-OECD countries shown have much higher energy intensity than the UK, China three times and India double in 2010.

7.6 Energy efficiency-household-trends-art.pdf

7.7 In July 2012, qualitative analysis by the American Council for an Energy Efficiency Economy (ACEEE) showed that, of the 12 largest world economies, the UK is performing best overall on energy efficiency-household-trends-art.pdf

7.8 Since there is a strong correlation between domestic energy consumption and heating demand (ACEEE)69 showed that, of the 12 largest world economies, the UK is performing best overall on energy efficiency-household-trends-art.pdf

7.9 While the UK has a particularly old housing stock (see graph on p22), all other European countries are of course facing similar issues of having to address the energy efficiency of their own housing stock.

13 M. Economou et al (2011) ‘Europe’s buildings under the microscope, a country-by-country review of the energy performance of buildings’ Building Performance Institute Europe

Note: The ODYSSEE indicator is scaled to the average European climate, which enables fairer comparisons to be made across EU Member States.
The Act provides for a step change in the provision of energy efficiency measures to homes and businesses, and makes improvements to our framework to enable and secure low carbon energy supplies and fair competition in the energy markets.

Two years after the launch of the RftF competition an Energy Act 2011 was adopted in Parliament. It included provision for a different approach to financing energy performance improvements in buildings known as the Green Deal. None of the projects from this publication benefitted from this programme as under this policy, finance packages (loans) used to fund energy efficiency retrofits are tied to the property rather than to the owner or occupier. In this way a much longer time can be allowed for the energy savings to repay the original investment because it does not have to be achieved within the period of single ownership or tenancy. Projects within the Green Deal should generally comply with the Golden Rule, which stipulates that the value of energy savings should be equal to, or greater than, the finance repayments over the course of each year. In addition, the new Energy Company Obligation (ECO) will provide a subsidy to help cover the extra cost of providing insulation in solid wall and hard-to-treat properties. Together, these policies should help stimulate a growth in the market for energy-efficient retrofits in the UK.

**AGE PROFILE OF RESIDENTIAL FLOOR SPACE**

**GREEN DEAL AND ECO**

Together, these policies should help stimulate a growth in the market for energy-efficient retrofits in the UK.

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15. www.guardian.co.uk/environment/2012/jul/02/mps-loan-plan-home-insulation