Appendix E: Embodied energy

E.1. Introduction

This appendix provides more detail on the issues underlying the energy balance between refurbishment and housing renewal, taking into account both embodied energy and energy over the lifetime of the dwelling.

E.2. Embodied and operational energy

From an energy perspective, there is ample evidence to support the assertion that there are long-term environmental advantages to be gained from replacing old, inefficient dwellings with super-insulated, airtight ones. The argument requires data on the following:

- Operational energy consumption in the stock (before and after refurbishment)
- Operational energy consumption in new-build (to different standards)
- Embodied energy for new-build and refurbishment

The analysis also depends on a time period over which to make the comparison. The figure of 60 years is used here, following common practice in housing/energy debates, although the stock turnover in the UK housing stock is well over 1000 years at current rates of renewal. The longer the timescale of comparison, the less significant embodied energy becomes.

Data for operational energy consumption in the stock comes from the ECI's UK Domestic Carbon Model using algorithms from BREDEM 8. Monitored energy consumption in recent developments (ie in new-build) is not widely available, but figures used here are the average of space heating energy as recorded at 4 homes in the Gallions Ecopark development, summarised in Joosten et al (2004).[1] There are various low-energy standards for new housing, including from the Passive House Institute (Passive House website), the Association for Environment-Conscious Building's proposed Silver and Gold standards (AECB website), and ZED standards (ZEDFactory website). Data for embodied energy is given in table 1.

Table 1 Figures and sources for embodied energy

Source	Embodied MWh	Notes
Sustainable Homes – low estimate	22	Given as 250 kWh/m2. Assumed floor area = 88 m2 average
Sustainable Homes – high estimate	44	Given as 500 kWh/m2. Assumed floor area = 88 m2 average
Empty Homes Agency	90	See appendix A
Buchanan & Honey – low estimate	60	Based on New Zealand construction - not typical of UK
Buchanan & Honey – mid estimate	103	Based on New Zealand construction - not typical of UK
Buchanan & Honey – high estimate	144	Based on New Zealand construction - not typical of UK

[1] References to Gallions Ecopark are not intended as criticisms of this one development or this one developer, but rather as criticisms of the EcoHomes 'excellent' standard to which the development was built. Gallions Ecopark is only referred to because the Gallions Housing Association very laudably published data on energy consumption in use.

BRE – low estimate	28	Quoted in XCO2 2002
BRE – high estimate	70	Quoted in XCO2 2002
XCO2	80	Based on other studies

Broadly speaking, if the quality of new-build homes is good enough, then a life-cycle analysis will show that demolition and reconstruction is better in terms of energy and carbon than refurbishment. Of course, this only holds true if the assumptions about the performance of new and refurbished homes are that new homes will out-perform refurbished ones in terms of operational energy use.

The Empty Homes Agency gives figures for the embodied energy in new-build as 90 MWh, while extensive refurbishment uses 15 MWh of embodied energy (Ireland 2005). Figure 1 graphs the lifetime impacts of four homes, using these figures for embodied energy and figures for operational energy use from the sources listed above. In fact, the Empty Homes Agency figures for embodied energy of concrete are too high, as they assume that concrete has the same embodied carbon as cement, whereas concrete also contains aggregates, which reduces considerably the carbon impact by mass of the final product (Jones, pers. comm.). Better figures for concrete would tend to swing the argument further in favour of new-build (assuming that new-build uses more concrete than refurbishment).

Figure 1 **Comparison of 60-year energy impacts of refurbishment and new-build**

The four lines in Figure 1 can be read as two pairs of 'scissors': the two solid lines forming one pair, and the two broken lines forming the other. The solid lines represent current practice, while the broken lines represent the improved standards in the 40% House report (Boardman et al 2005). Figure 1 shows the cumulative impact of energy (embodied and space heating) over 60 years. The different starting points of the four lines at year nought reflect the different assumed impacts in terms of embodied energy for refurbishment and new build. For each pair of 'scissors', the lines cross over within the first 15 years, after which time the benefit of the lower operational energy use of new-build increases steadily over time. In other words, new-build has a negative impact for the first decade or so compared to refurbishment, but it shows significant benefits over the longer term.

It can be seen that the total energy impact (embodied plus operational) is lowest for new low-carbon homes (2 MWh/year space heat demand). In the first decade, the additional embodied energy of the new-build means that its total energy is higher, but the lines on the graph cross over after about ten years, and continue to diverge into the future.

The refurbishment standard in the 40% House report is an average of 9 MWh/year space heat demand per dwelling. This is close to the monitored performance of the four Gallions Ecopark units built in 2002 to Ecohomes 'excellent' standard, which had an average 8.2 MWh/year space heat demand during the first year of occupation (Joosten et al 2004). The total energy of a refurbishment to 40% House standards would be just below a new Gallions Ecopark home after 60 years, although the lines do cross (favouring the new-build homes) if the graph is extend to 66 years.

Low-energy housing to advanced standards takes more material to build than current homes, so the embodied energy is likely to be higher. The BedZED Materials Report (Lazarus 2002) records an unusually large quantity of materials used in this development, with extra insulation and heavyweight concrete used to reduce energy demand for space heating in use. The embodied carbon of BedZED is estimated at 675 $kgCO_2/m^2$ compared to a typical figure closer to 550 $kgCO_2/m^2$ for conventional new-build (Lazarus 2002, BRE 2003). To demonstrate the relative insignificance of this extra embodied carbon, Figure 2 uses the same data as Figure 1, except that embodied energy of low-energy new-build is doubled. The BedZED figures were not this high, but the point is still well made: if new-build homes were to represent 180 MWh of embodied energy instead of 90 MWh, then the total energy impact of a new-build home is lower than the refurbished home after about 24 years, and the benefit of the new-build gets larger beyond that time. Comparison of figures 1 Figure 1and Figure 12 demonstrates how relatively insignificant the extra material is when compared to the operational energy use over the life of the building.

The BedZED team applied a whole-life approach to their decision-making and achieved a development with much lower environmental impacts than standard developments or even current 'best practice'.

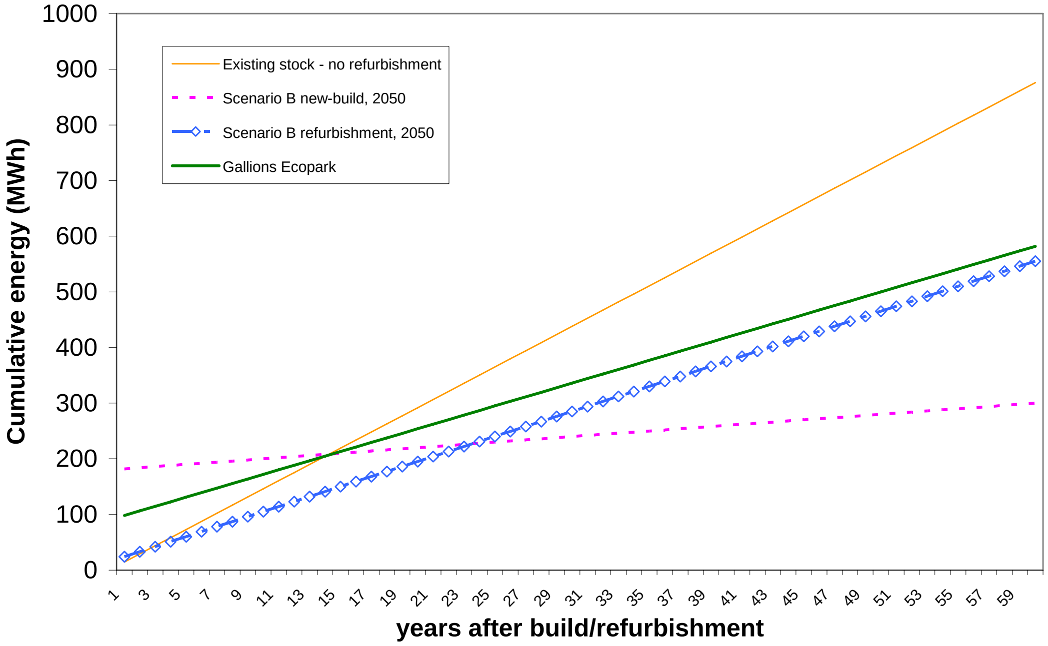

Figure 2 **Comparison of 60-year energy impacts of refurbishment and new-build assuming low-carbon new-build has double the embodied energy of standard new-build**

E.3. Framing the debate

If current best practice (as typified by Gallions Ecopark, built to EcoHomes 'excellent' standard) is taken as the standard of new-build that is needed, then the assertion that refurbishment is preferable to new-build would indeed have some merit. However, any building to this standard – whether new-build or refurbished – is actually consuming four times as much energy for space heating as would be required in new homes in scenario B (see main report to the RCEP). By 2050, this scenario assumes that one-third of homes will be built to these tight standards, and that the remaining two-thirds of the stock are refurbished to a standard close to Gallions Ecopark.

What is needed to achieve the deep cuts in carbon emissions is a step-change in the quality of both new-build and refurbishment. EcoHomes 'excellent' is not good enough for new-build; refurbishment using current cost-effective measures is not good enough; building just one demonstration project in each local authority area to the standard of BedZED is not good enough. From 2020 at the latest, all new developments need to match BedZED in terms of performance (roughly equal to PassivHaus standards, 15 kWh/m2/year for space heating). The consequences in the short term will be a rise in energy consumption for building materials and processes, followed by a long and steep decline in operational energy use.

This technical discussion of energy consumption ignores the important effects of human behaviour on the debate. It could be (and has been) argued that people can wear an extra jumper indoors and turn down their thermostat. Taken far enough, this strategy would result in the same levels of energy demand reduction, and the proponents of such arguments suggest thereby that older housing is compatible with low-carbon living, even without refurbishment.

The reality is that inefficient housing leads directly to over 3,000 excess winter deaths per year in the UK among the fuel poor, and that this is caused by the poor fabric of the homes they inhabit. Across the housing stock as a whole, demand for energy service has steadily increased over the last 30 years, and this social trend is rarely, if ever, addressed by the proponents of the 'extra jumper' theory of low-carbon living.

In a rational policy of housing renewal, the impact of embodied energy needs to be taken into account, but the gains from improving the efficiency of the built fabric far outweigh the losses embodied in the necessary building work.

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