Client Report :

Assessment of energy efficiency impact of Building Regulations compliance

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Executive Summary

1. An earlier study by BRE, for ODPM, of a small number of dwellings had shown that about two-thirds were failing to achieve air permeabilities of 10 $m^3/h/m^2$. There had also been indications that other aspects of the guidance of Approved Document L1 (ADL1) were not being adopted generally in dwellings. The Energy Saving Trust, on behalf of the Energy Efficiency Partnership for Homes, commissioned BRE and National Energy Services to identify a larger sample of dwellings of a wide range of types, to carry out measurements of air permeability and to make observations of other relevant as-built details.

2. In the current study 99 new dwellings were visited and tested, including 36 flats, 31 terraced, 21 semi-detached and 11 detached properties, over a broad geographical range in England. The results showed that, of the whole sample, two thirds (68%) had achieved air permeabilities of $10m^3/h/m^2$ or better at 50Pa. However, many common and readily observable routes for air leakage were still apparent in many of the sample.

3. Flats had been under-represented in the earlier sample and so the results for flats and other dwelling types in the new sample were also analysed separately. Flats may potentially be better performers as the number of door and window openings can be less than other dwelling types of equivalent area. These results indicated that 87% of the flats in the sample had achieved $10m^3/h/m^2$ or better, compared with 57% of the remaining sample of houses (terraces, semis and detached).

4. While these results for air permeability seem to indicate that more dwellings are achieving $10m^3/h/m^2$ or better than in the earlier sample it must be noted that both samples, particularly the earlier one, are small and differences between the samples are unlikely to be significant. In addition, a lower target value would often be implicit in the SAP and carbon calculation methodology, particularly for some flats.

5. Causes of air leakage noted during the study in both houses and flats included a lack of sealing around boiler flues and service pipe penetrations in kitchens and bathrooms. Unsealed penetrations could be hidden behind vanity units in the more 'luxury' dwellings, which also often had more than one bathroom and more kitchen equipment, and hence more pipe penetrations. Gaps or poor sealing were noted around some external doors and window frames, and loft hatches. Some doors were simply a poor fit in the frame, and one or two were significantly distorted (although it is unclear whether this distortion occurred after occupancy). Many trickle ventilators leaked air when closed.

6. Other aspects of as-built construction noted included, where possible, the boiler type and model for comparison with the efficiency used in the initial (proposal) SAP calculation. These were generally similar except in 22 of the sample where standard boilers (approx 78% efficiency) had been installed in place of the proposed condensing boilers (approx 90% efficiency). However, this represents a discrepancy only with the initial SAP calculation, rather than a non-compliance with ADL1.

7. Up to 3 low energy light fittings had been installed in the dwellings, but few remained at the time of the visit. Many had been replaced by the occupants, and those remaining were likely to be replaced soon. At least one occupant noted the lack of suitable lamp-shades as a reason for their removal, and it was observed that those lamps that remained were unshaded.

8. Loft insulation appeared to have been satisfactorily installed, but some pipe insulation was absent from hot water pipes near hot water tanks. Windows were generally as specified, although air gaps may have differed, and there was some evidence that glazing had occasionally been fitted with the low-e coating on the internal rather than external face.

9. Most householders were unable to produce any documentation relating to the specific installed boiler, heating system and controls, although some had general manufacturer brochures. None were aware of having been provided with a copy of a FENSA certificate (it is not known whether this was provided to Building Control). However, many admitted they had lost or thrown away documents or brochures, and so it is unclear what information had originally been provided.

Contents

1 Introduction

An earlier study by BRE, for ODPM, of a small number of dwellings had shown that about two-thirds were failing to achieve air permeabilities of 10 $m^3/h/m^2$. There had also been indications elsewhere that other aspects of the guidance of Approved Document L1 (ADL1) were not being fully complied with or effectively enforced in new dwellings. The Energy Saving Trust, on behalf of the Energy Efficiency Partnership for Homes, contracted BRE and National Energy Services (NES) to investigate the extent and effect of non-compliance in a more extensive sample of new dwellings, and the impact that the lack of compliance or enforcement might have on the Government's targets for reducing carbon emissions.

The project is intended to provide information on the extent of, and where possible the reasons for, non-compliance so that the Energy Efficiency Partnership for Homes may provide information to assist the consultation on the 2005 revisions to Part L of the Building Regulations.

The work is the subject of Contract EST/OPS/04/11.

2 Description of the project

BRE, assisted by National Energy Services (NES), have identified and inspected a sample of 99 dwellings constructed to the April 2002 edition of Approved Document L1 (ADL1) of the Building Regulations. The sample included a range of dwelling types in both social and private sectors, and included a number of geographical locations throughout England. At each dwelling BRE carried out an airtightness test[1] using Infiltec air pressurisation fans and inspected, where possible, a number of additional factors relating to compliance with the provisions of ADL1. These included determining details of the boiler installation, loft and pipe insulation, electric lighting, glazing and the information provided to the householder primarily regarding the operation and use of the boiler system.

Not all the information could be obtained at every location, as in some instances access was not available to loft spaces to inspect the level of insulation, and it was not always possible to readily observe heating and hot water pipework to check the presence of insulation. The task relied significantly on obtaining co-operation from householders.

[1] BRE airtightness testing has UKAS accreditation.

3 The sample of dwellings

A sample of 99 dwellings constructed to the provisions of the 2002 revision to ADL1 of the Building Regulations has been inspected. The composition of the sample was not pre-selected in detail, and depended ultimately on the number of positive responses from householders that had been circulated with a letter of invitation to take part in the study, and their subsequent availability to make firm appointments for the dwelling visit and test within the project timetable. The sample ultimately comprised:

- 36 flats
- 21 terraced houses
- 10 end of terrace houses
- 19 semi-detached houses
- 10 detached houses
- 2 semi detached bungalows
- 1 detached bungalow

The geographical base of the sample was:

- Cambridge
- Hull
- Leeds
- Milton Keynes
- Northolt
- South Oxhey
- Spalding
- Sunbury-on-Thames
- Thamesmead
- Watford
- Wembley
- Weston Super Mare

Two-thirds of the dwellings in the sample were in private ownership and the remaining one-third were constructed as social housing.

4 Air permeability results

The 99 measurements of air permeability were taken following the procedure described in the guidance of CIBSE TM23 (2000): "Testing buildings for air leakage". The results are summarised in Figure 1 below, which indicates the air permeabilities achieved by the sample, and the cumulative frequency distribution of the permeabilities achieved.

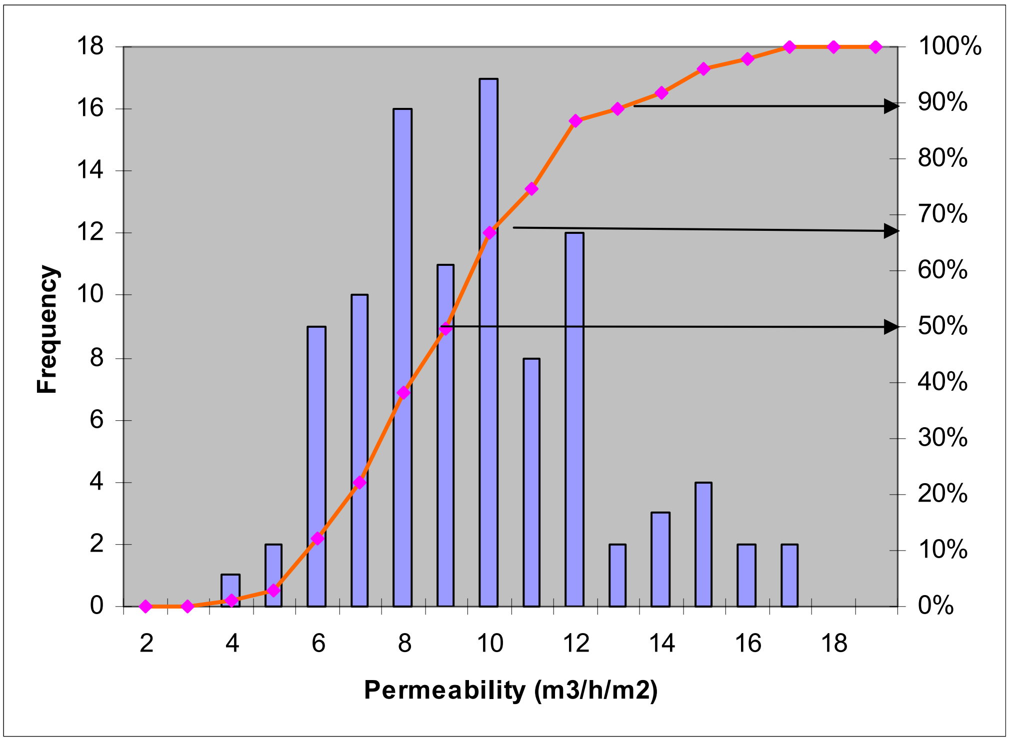

Figure 1. Distribution of measured air permeabilities ($m^3/h/m^2$ at 50Pa)

The air permeability measurements indicate that:

- The range of air permeabilities was from 3.2 to 16.9 $m^3/h/m^2$ at 50 Pa, with a mean of 9.2 $m^3/h/m^2$ at 50 Pa
- Two-thirds (68%) of the sample had achieved the recommended maximum level of 10 $m^3/h/m^2$ at 50 Pa, or better.
- Half of the sample achieved 9 $m^3/h/m^2$ at 50 Pa, or better.
- 90% of the sample achieved 13 $m^3/h/m^2$ at 50 Pa, or better.
- The remaining 10% of the sample achieved between 13 and 17 $m^3/h/m^2$ at 50 Pa.

The proportion of dwellings achieving 10$m^3/h/m^2$ or better appeared to have improved from the earlier, smaller, sample. Flats had been less represented in the earlier sample and so to investigate whether this might have influenced the improvement the results for flats and other dwelling types have been analysed separately in Figures 2 and 3 below. These show that:

- The range of permeabilities for flats was from 3.2 to 12.4 $m^3/h/m^2$ at 50 Pa, with a mean of 8.0 $m^3/h/m^2$ at 50 Pa.

- 83% of flats had achieved 10m^3/h/m^2 or better
- The range of permeabilities for houses was from 5.6 to 16.7 m^3/h/m^2 at 50 Pa, with a mean of 9.8 m^3/h/m^2 at 50 Pa.
- 57% of houses had achieved 10m^3/h/m^2 or better

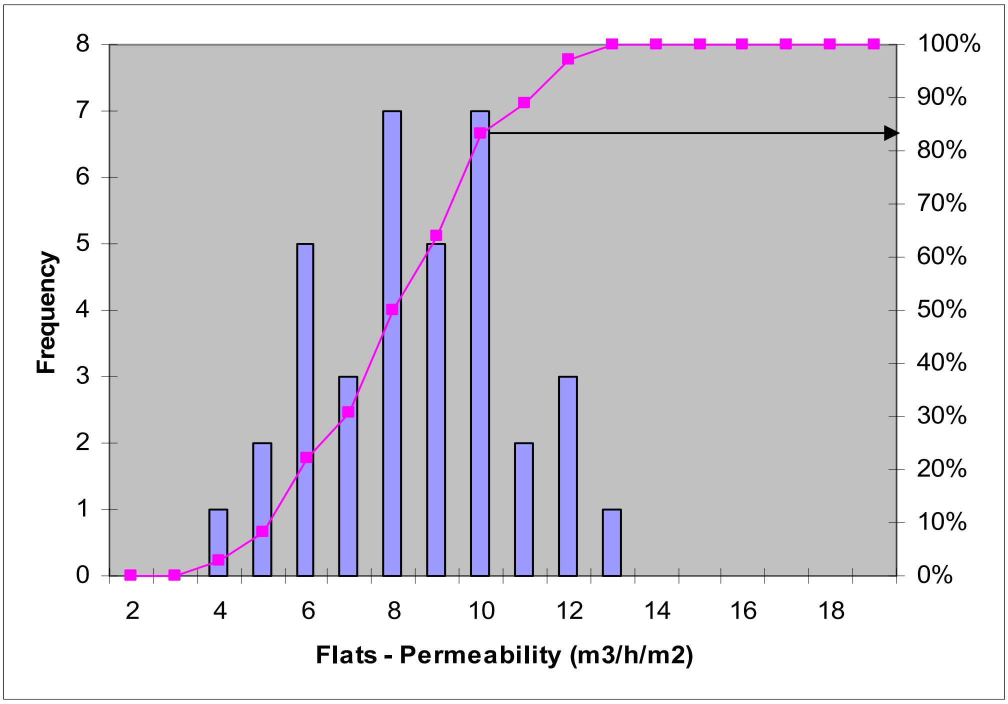

Figure 2. Distribution of measured air permeabilities in flats (m^3/h/m^2 at 50Pa)

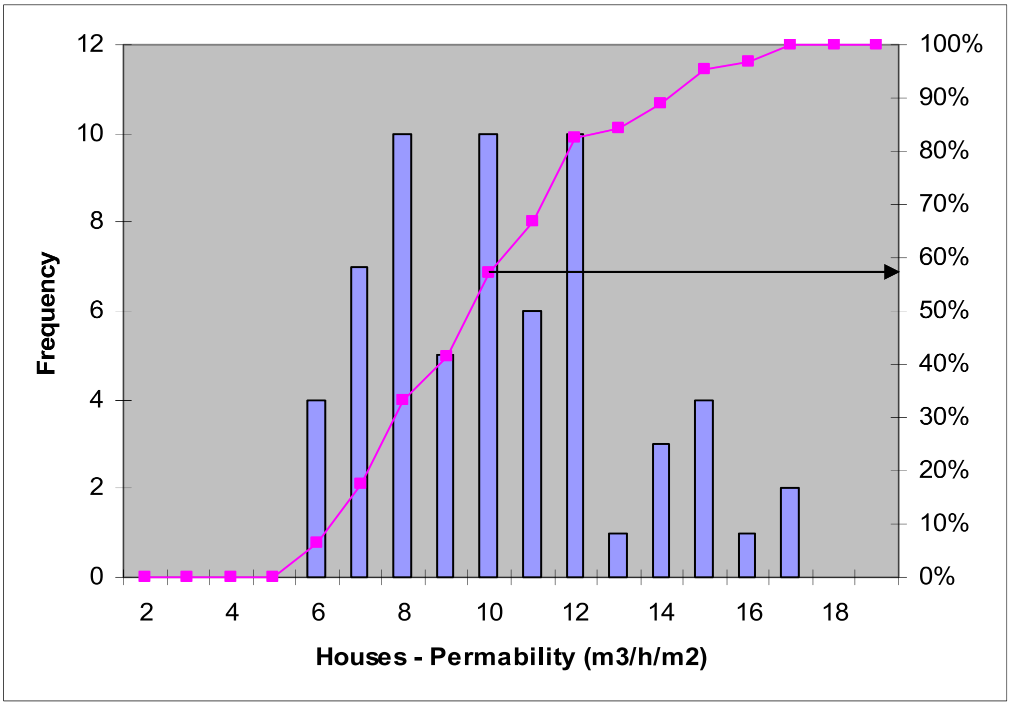

Figure 3. Distribution of measured air permeabilities in houses (m^3/h/m^2 at 50Pa)

4.1 Air permeability observations

Some common air leakage paths could be observed fairly readily in most of the sample, including in dwellings that had achieved the recommended level of airtightness.

Observed air leakage paths included (not necessarily in order of significance):

- Service pipe and boiler flue penetrations through external walls
- Around external doors
- Through windows that did not close tightly
- Through access panels to lofts
- Through closed trickle ventilators
- Wall to floor junctions

Service pipe penetrations include those associated with the waste pipes of kitchen and bathroom sinks, baths and WCs, and also penetrations made for specific appliances such as washing machines and dishwashers. It was observed that service penetrations were more likely to have been sealed in social housing, where the penetrations were readily visible to inspection. These penetrations were often hidden from direct view by vanity units in some of the more 'prestigious' dwellings, and often had not been sealed. Some dwellings, including some flats, also contained more than one bathroom and more kitchen equipment and hence more service penetrations. These were among the worst performers, where the penetrations had not been sealed.

Air leakage around external doors was particularly noted in two of the worst performers, with significant gaps visible between the door and frame. Testing is usually carried out by installing the pressurising/depressurising fan into the open front doorway of a dwelling. However, in one particular case a visible gap was observed between the front door and its frame on closing the door after testing. The result in this case might thus underestimate the actual air permeability of the dwelling.

Air leakage was noted around window frames in some dwellings, and it was more generally noted that many of the trickle ventilators appeared to leak as much closed as when open. In a small number of dwellings the seals for loft access panels had been fitted incorrectly - in the worst case missing the jointing surfaces altogether.

5 Boiler installation

Boiler details were observed, where possible, to obtain estimates of the efficiency of the installed boiler. Occupants were also asked whether they had been provided with adequate instructions on the use of the boiler and controls.

The boiler efficiencies noted in the initial SAP calculations provided by NES are shown below in Figure 4. The Figure shows that the majority of new dwellings are submitted for approval with either an A-rated boiler (90% efficiency or better) or a D-rated boiler (between 78% and 82% efficiency). The efficiencies of the boilers actually installed, shown in Figure 5, indicate that almost 75% of the boilers installed were D-rated boilers. Figure 6 indicates the difference between the 'proposed' and 'as-built' efficiencies. The Figures show the results for the 90 dwellings fitted with gas boilers. Nine dwellings were heated using panel convector heaters.

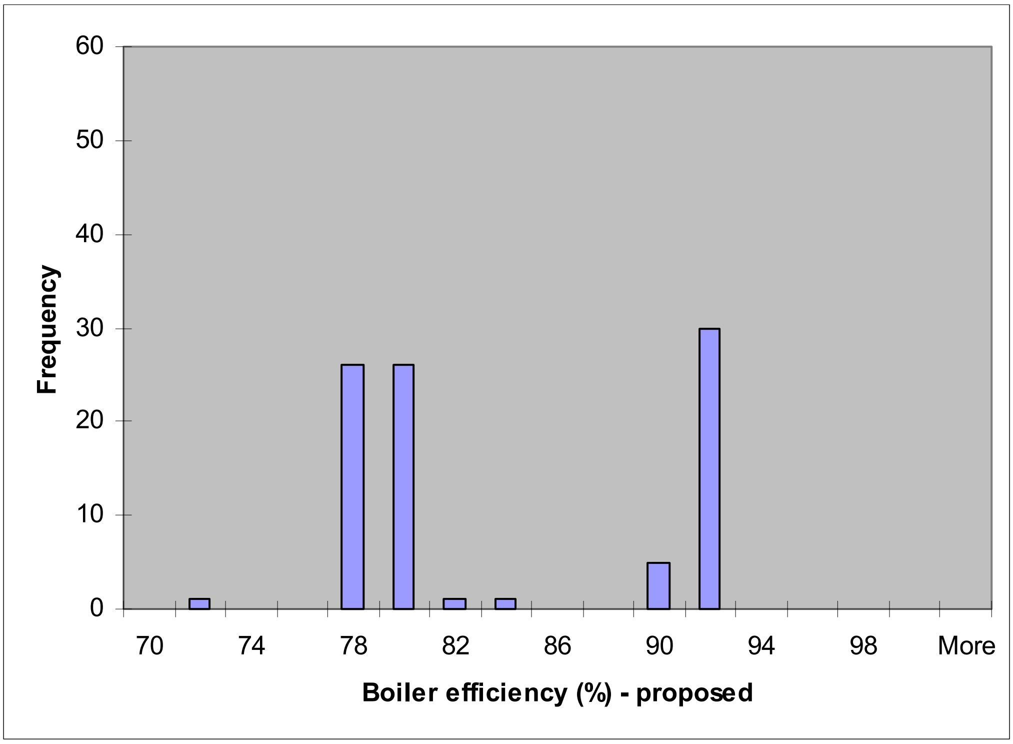

Figure 4. Efficiencies of boilers noted in initial calculations

The main differences noted occur where, in 22 dwellings at a number of locations, boilers of about 78% efficiency were observed rather than the 90.5% efficiency that had been indicated by NES' initial SAP calculation. It is not known whether the higher efficiency boilers were originally intended to balance another less efficient aspect of design. However, there were also a small number of dwellings where the difference was reversed, and boilers of 90.5% efficiency were found where the initial calculation had indicated 78%.

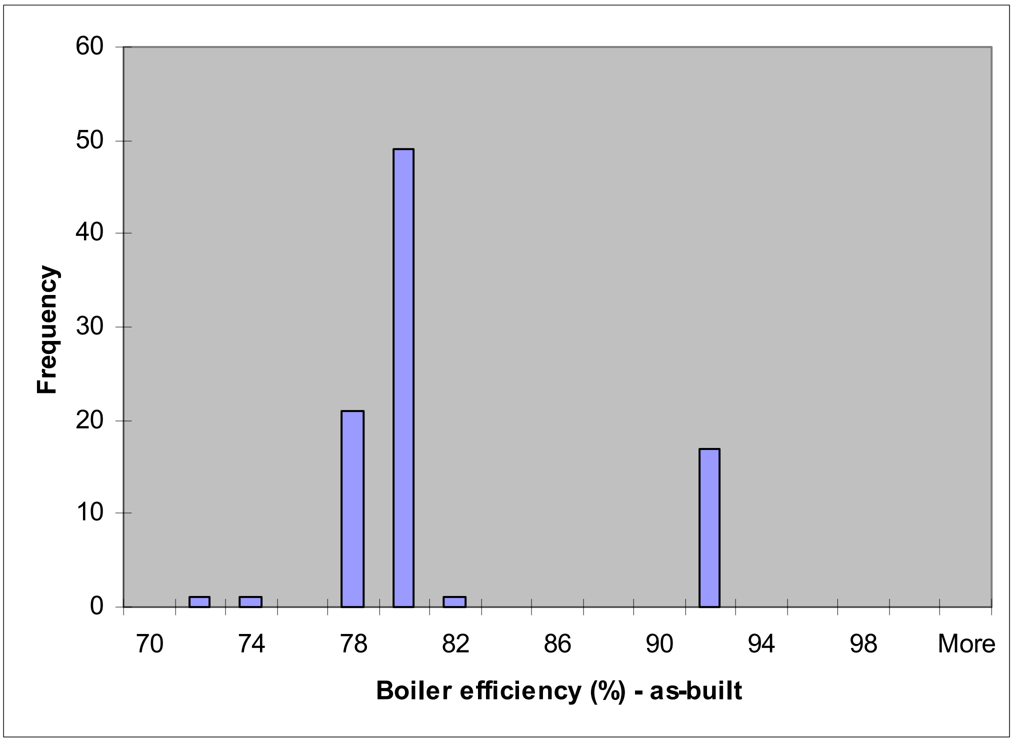

Figure 5. Efficiencies of boilers observed 'as-built'

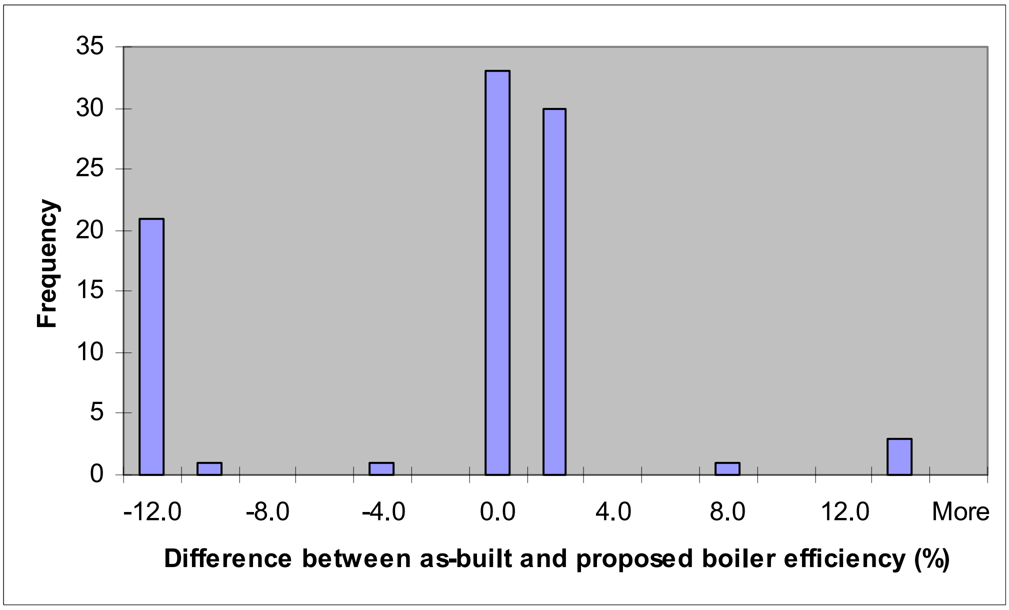

Figure 6. Difference in efficiency in boilers between 'as-built' and calculation

6 Other as-built observations

6.1 Installation of low energy lamp fittings

Up to 3 low energy lamp fittings had been specified in the original proposals for the dwellings in the sample. The fittings had generally been installed in hallways, landings and in some bedrooms, but few remained in the completed and occupied dwellings. Most had been removed by the occupants, and occupants expressed their intention to replace soon those few that remained. At least one occupant noted the scarcity of lampshades suitable for the low energy fittings. The remaining lamps were observed to be in use without lampshades.

The calculation procedure used could not identify the impact of the loss of these fittings.

6.2 Loft and pipe insulation

In the dwellings where it was possible and safe to access loft spaces, loft insulation was generally considered adequate. To minimise risks both to staff and to the homeowners, staff undertaking the surveys did not physically enter lofts or disturb the insulation to make direct measurement of depth. However, from the open loft hatch continuous layers of insulation were observed above the level of the joists. The occupant of one dwelling reported discovering on moving in that the loft insulation had been left in unpacked rolls in the loft, but this had subsequently been rectified. (We could not check whether or not this was factual.)

In some dwellings pipe insulation was absent from the sections of pipe visible near hot water tanks. The impact of such lack of insulation was not calculated, as the full extent to which insulation might have been omitted could not be verified by observation.

6.3 Windows and glazing

The presence and orientation of a surface coating (assumed to be a low-e coating) were observed in a sub-set of the sample, using an optical coating detector. It was observed that most of these windows had been (correctly) installed with the low-e coating on the exterior pane. A small number had the low-e coating on the interior pane, but the impact of such a change is not immediately clear, and there is potential for uncertainty in the observation of the coated surface using the coating detector under some lighting conditions, and so the any impact of this aspect could not be calculated.

6.4 Provision of information

A very small number of householders were able to produce comprehensive information on the installed boiler system, and instructions in its use. However, most householders were unable to produce any information at all relating to the boiler installation, or operating instructions. Some were able to produce general information covering a boiler manufacturer's range of domestic boilers or controllers, but the precise model installed in their dwelling had not been noted. It is not possible to say how many had actually been provided with this information on occupancy, as many admitted that they had either lost, or had thrown away, any information that might initially have been provided. At least one householder did wish to adjust the controls of the heating system, but had been unable to find any relevant information.

No householders were able to produce a copy of a FENSA certificate for the window installation, although the caveat above would apply equally to this information.

7 Overall impacts of as-built observations

7.1 Overall effects on carbon dioxide emissions

The carbon dioxide emissions originally calculated for the dwellings are summarised in Figure 7. These are based on the SAP/BREDEM calculation method, and using constructional details for each dwelling as input factors. Calculated emissions varied from 13.2 to 28.7kg/m^2/yr, with a mean of 19.5 kg/m^2/yr.

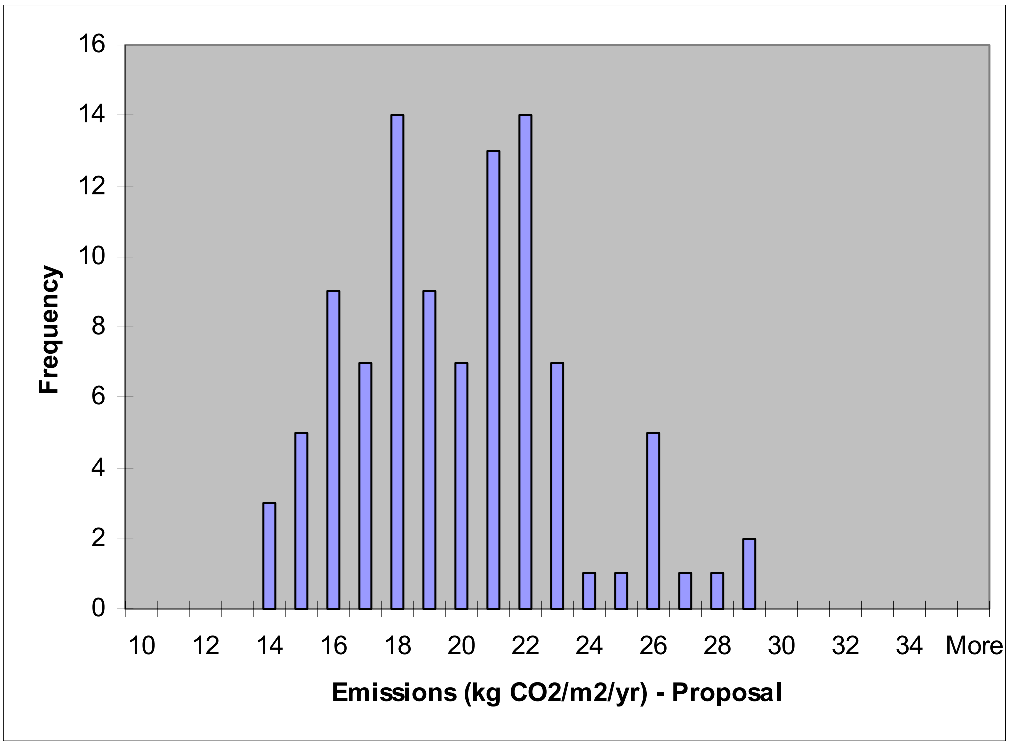

Figure 7. Carbon dioxide emissions, expected from the initial design details

The emissions were recalculated following the air leakage tests and other observations, inputting the air permeability result (expressed in air changes per hour) directly into the calculation, with the results summarised in Figure 8.

Figure 9 summarises the extent to which the resultant carbon dioxide emissions differed from the original intent. Negative values represent an improvement and positive values a deterioration in performance.

The mean as-built emissions were 20.4 kg/m^2/yr, representing an average increase in carbon dioxide emissions among the sample of 0.9kg/m^2/yr.

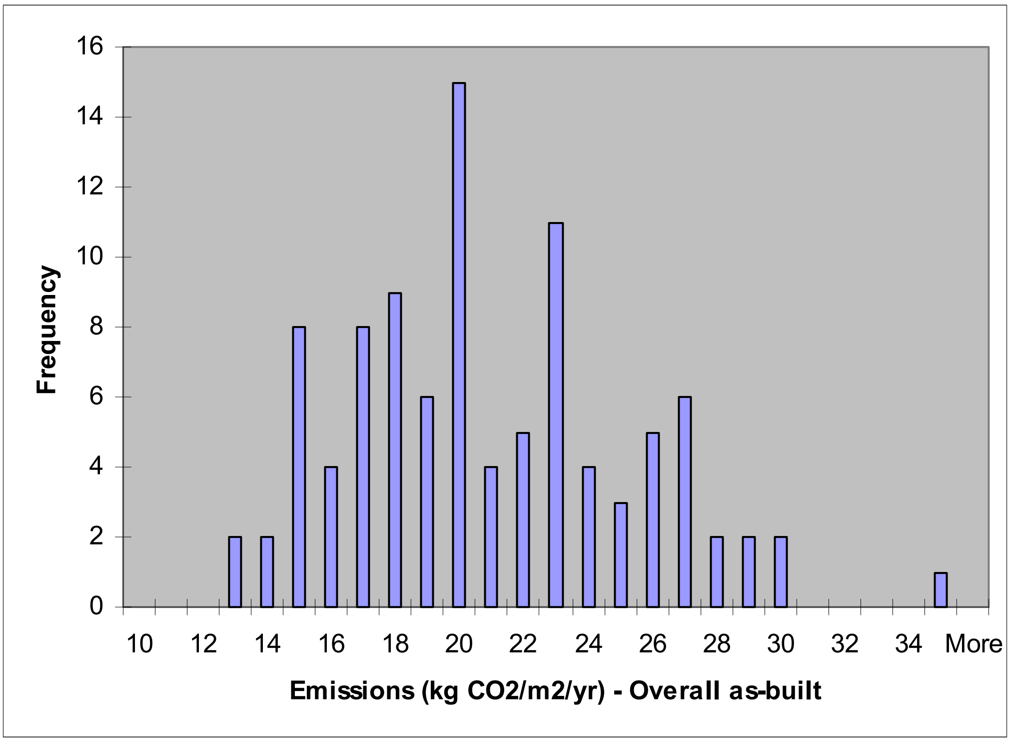

Figure 8. Carbon dioxide emissions, resulting from as-built details (boiler and air permeability)

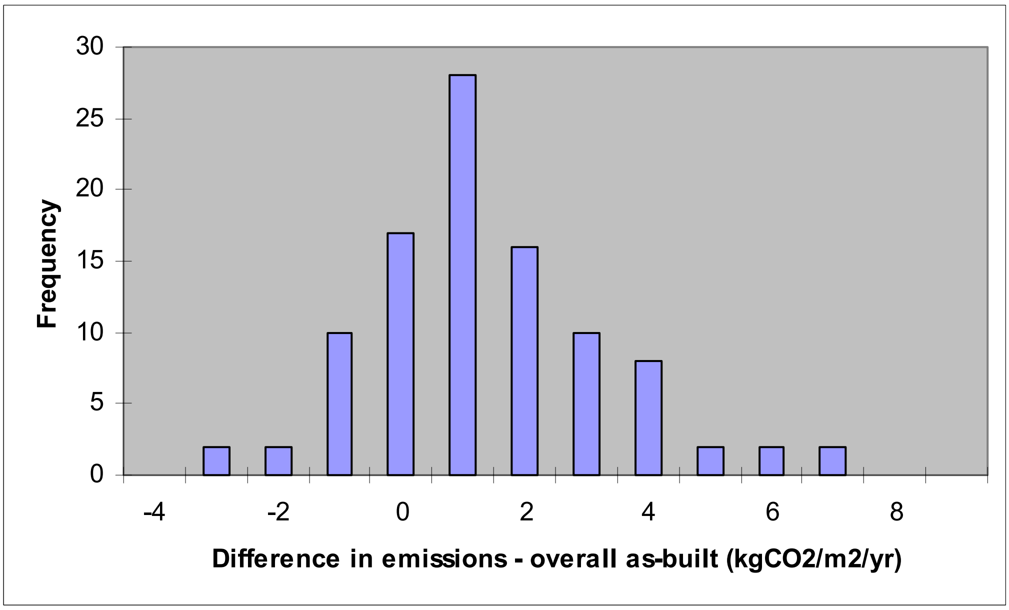

Figure 9. Effect of as-built boiler and air permeability on annual carbon dioxide emissions

7.2 Overall effects on SAP

Figure 10 indicates the SAP rating resulting from the 'as designed' dwelling specifications obtained by NES. Calculated SAP values varied from 54 to 112, with a mean of 95.6. The lowest SAP values are associated with the electrically heated dwellings. Among the gas heated dwellings the mean calculated SAP value was 96.7.

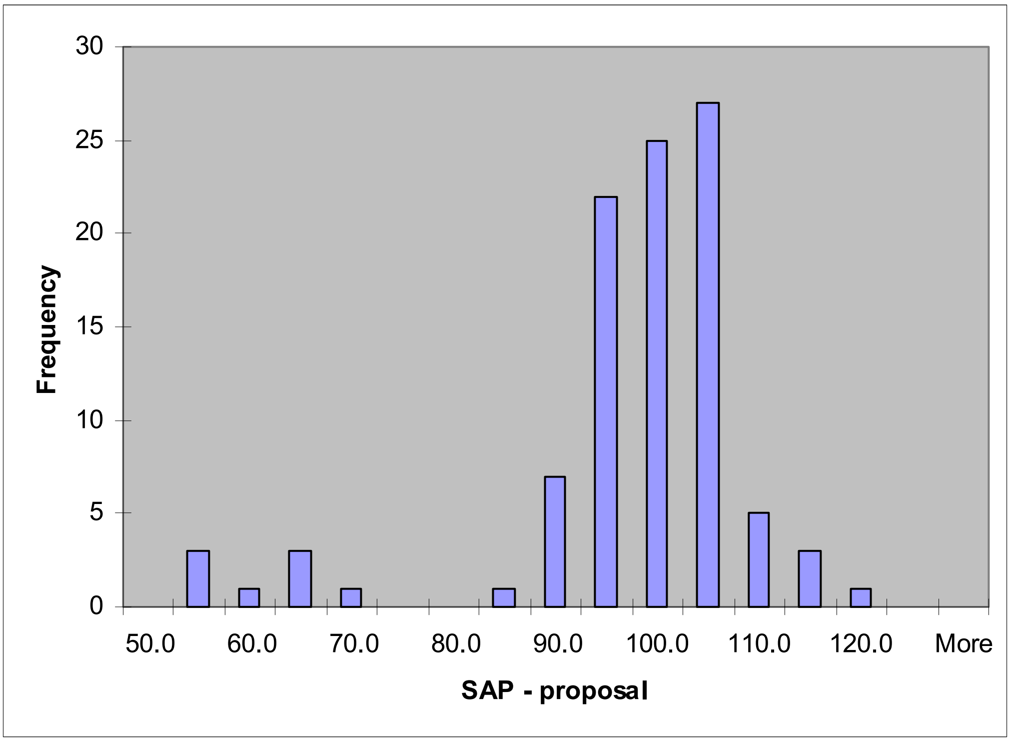

Figure 10. SAP calculated using 'as designed' dwelling specifications

Figure 11 shows the SAP re-calculated on the basis of the observed boiler details and air permeabilities. The as-built mean value of SAP was 93.9, with an average decrease among the sample of 1.6 (an average worsening of 1.6 SAP points).

Figure 12 summarises the extent to which the resultant SAP differed from that of the original design specification. Positive values represent an improvement and negative values a deterioration in performance.

The differences shown in Figure 12 indicate that the as-built SAP ratings of most of the sample were worsened from those calculated for the initial proposal, with some decreasing by up to 11 SAP points.

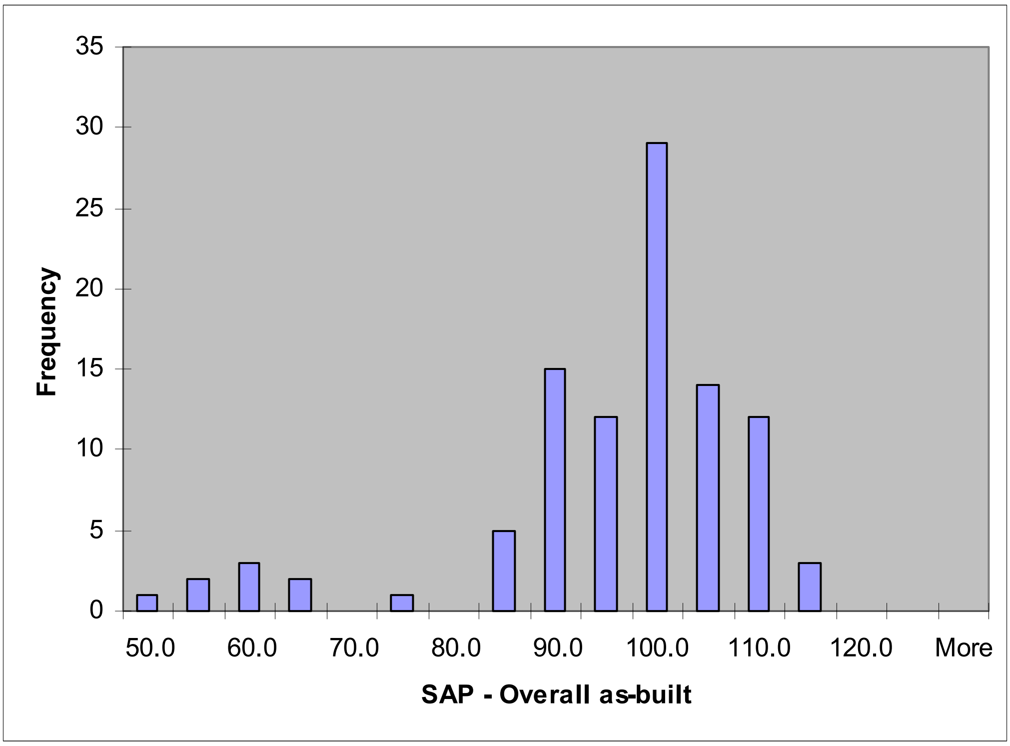

Figure 11. SAP resulting from as-built boiler details and air permeabilities

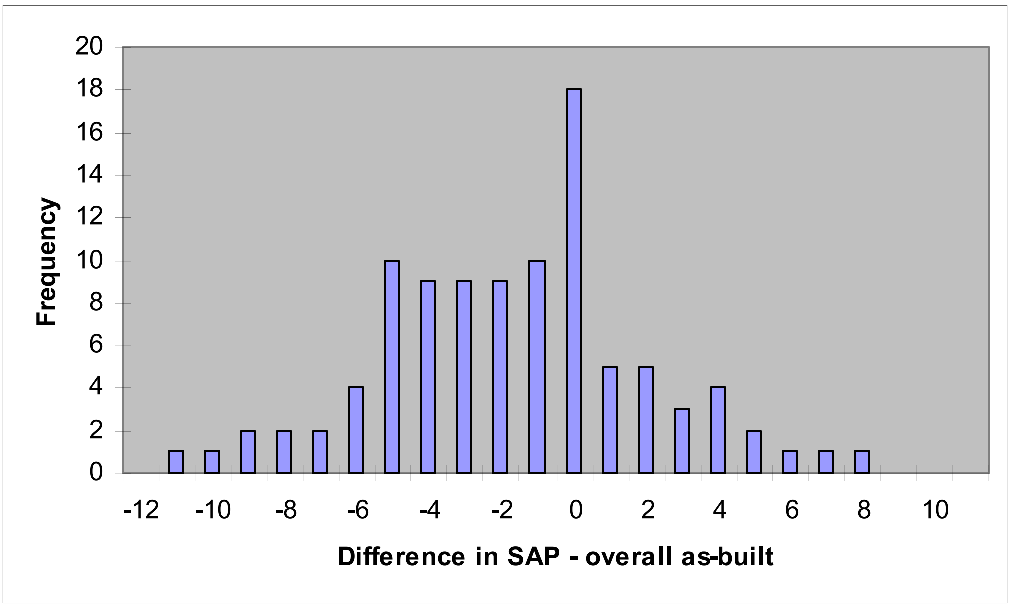

Figure 12. Effect of as-built boiler details and air permeabilities on SAP

7.3 Overall effects on Carbon Index

Figure 13 indicates the Carbon Index resulting from the 'as designed' dwelling specifications obtained by NES. Carbon Index varied from 6.7 to 9.7 with a mean value of 7.83. Of the sample, 60% had achieved a calculated Carbon Index of less than 8 and would thus not have complied using this calculation approach.

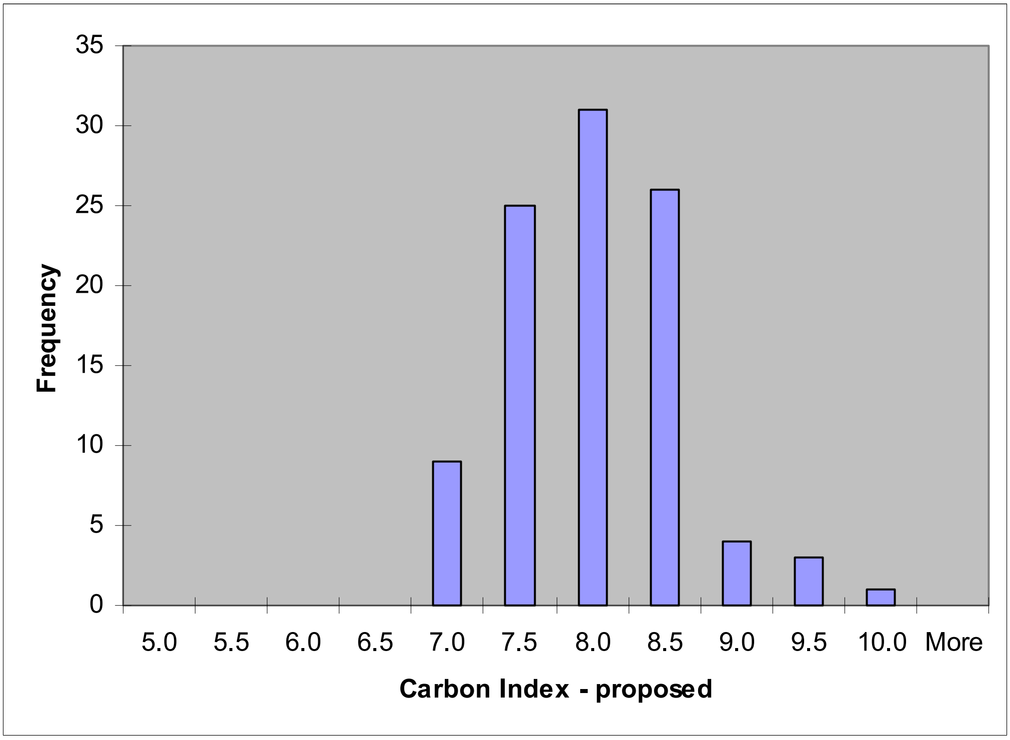

Figure 13. Carbon Index calculated using 'as designed' dwelling specifications

Figure 14 shows the Carbon Index re-calculated on the basis of all the observed details. The as-built mean Carbon Index was 7.71, with an average decrease among the sample of 0.12 (an average worsening in Carbon Index of 0.12). Of the sample, the proportion that had not achieved a calculated Carbon Index of less than 8 increased to 66%.

Figure 15 summarises the extent to which the resultant Carbon Index differed from that of the original design specification. Positive values represent an improvement and negative values a deterioration in performance.

The differences shown in Figure 15 indicate that the as-built Carbon Index of most of the sample was worsened from that calculated for the initial proposal.

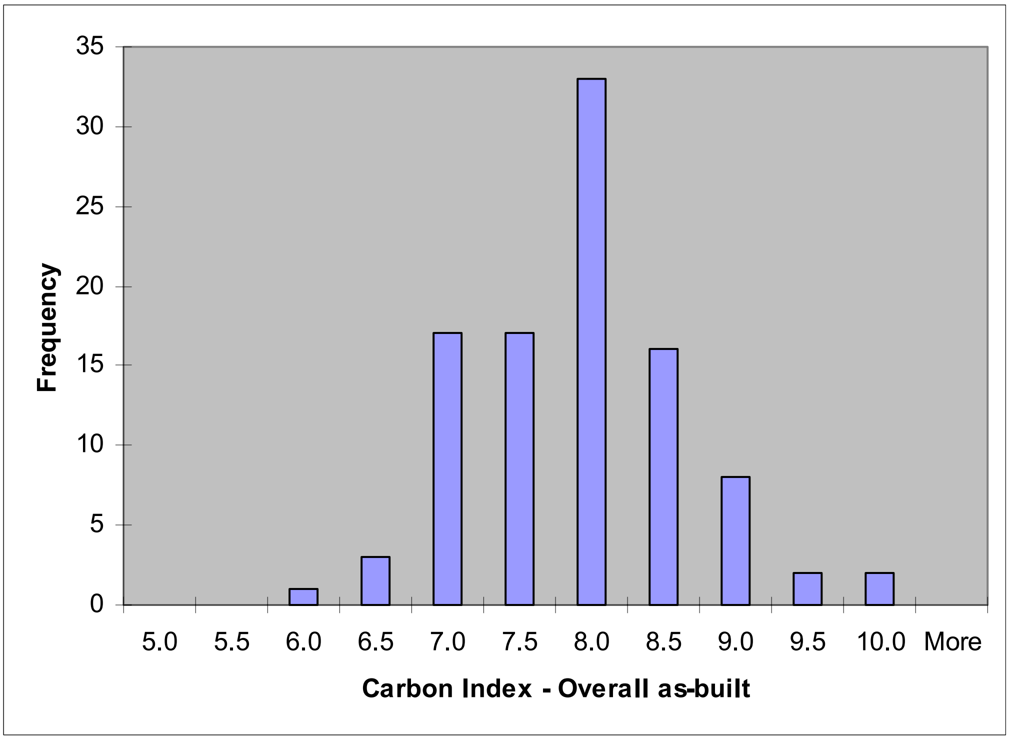

Figure 14. Carbon Index resulting from as-built boiler details and air permeabilities

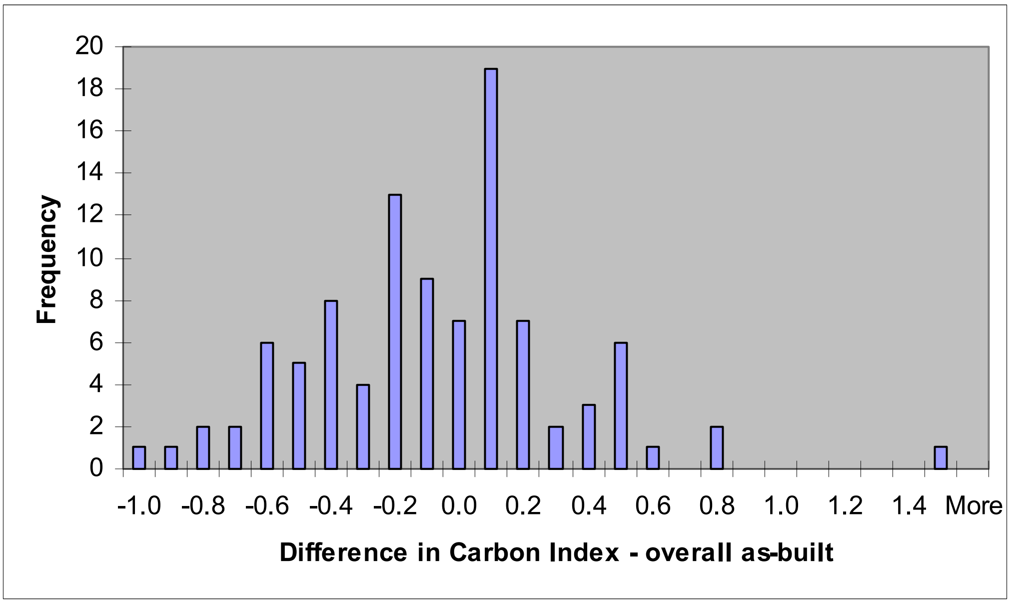

Figure 15. Effect of as-built boiler details and air permeabilities on Carbon Index

8 Individual effects of as-built air permeability and boiler installation on carbon dioxide emissions, SAP and Carbon Index

8.1 Air permeability

The individual effects of as-built air permeability on carbon dioxide emissions, SAP and Carbon Index are indicated in Figures 16, 17 and 18 respectively. The average effects among the sample were:

- An increase in carbon dioxide emissions of 0.32 $kg/m^2/yr$.
- A decrease in SAP of 0.55 (worsening of 0.55).
- A decrease in Carbon Index of 0.04 (worsening of 0.04)

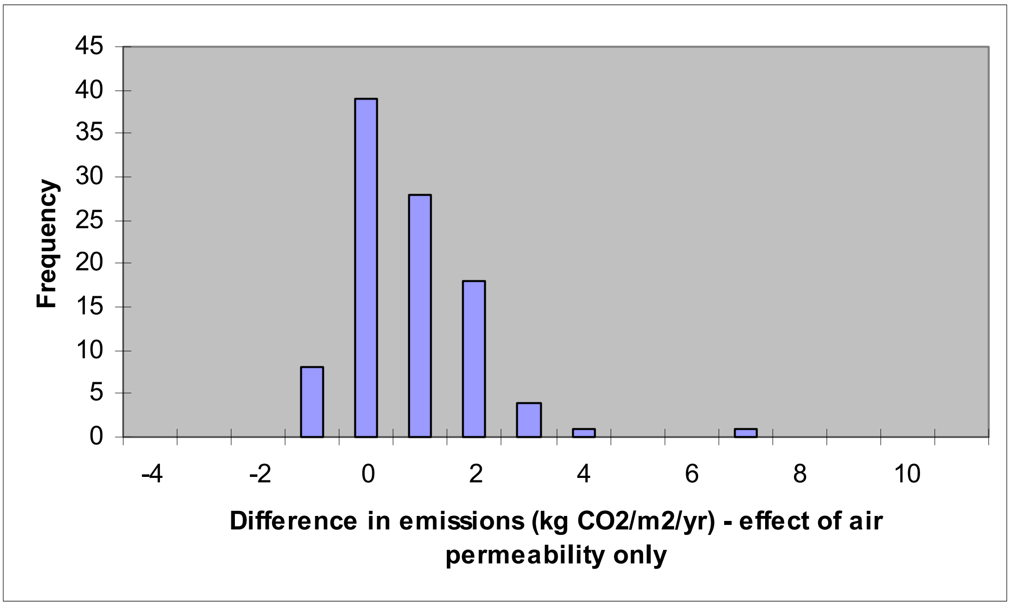

Figure 16. Individual effect of as-built air permeability on carbon dioxide emissions

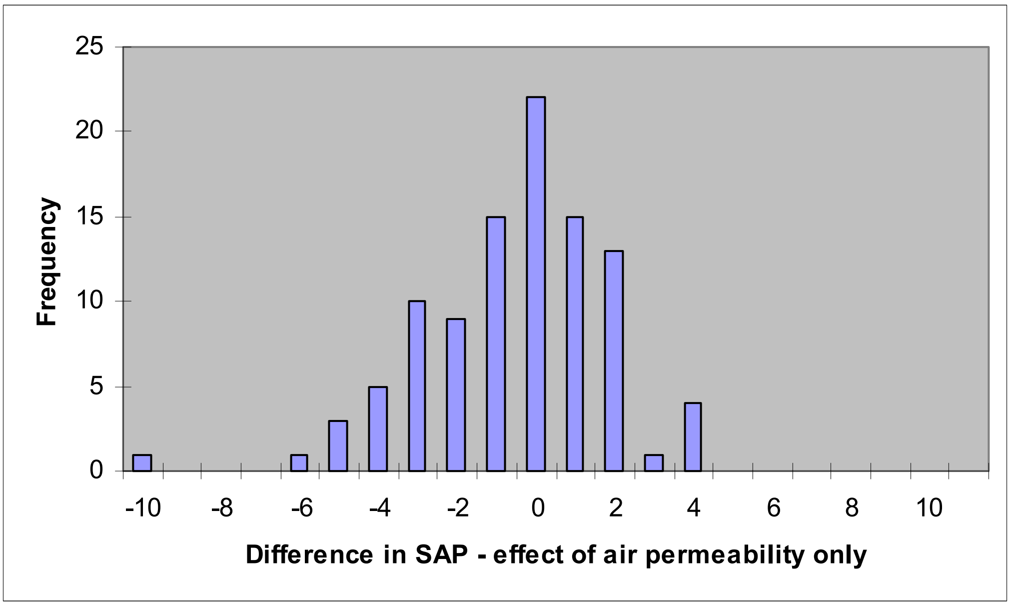

Figure 17. Individual effect of as-built air permeability on calculated SAP

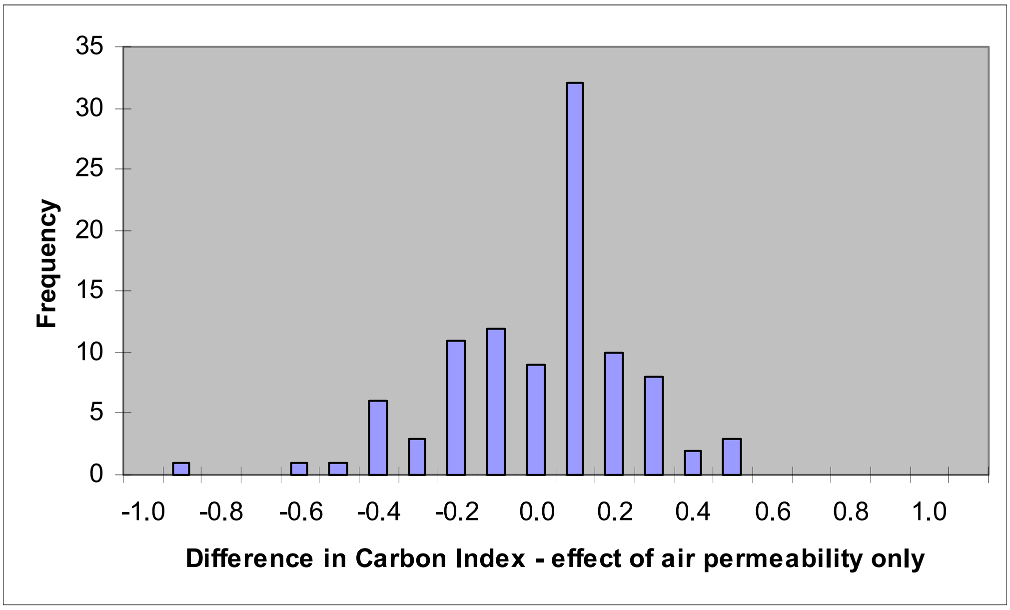

Figure 18. Individual effect of as-built air permeability on calculated Carbon Index

8.2 As-built boiler

The individual effects of the as-built boiler on carbon dioxide emissions, SAP and Carbon Index are indicated in Figures 19, 20 and 21 respectively. The average effects among the sample were:

- An increase in carbon dioxide emissions of 0.64 kg/m^2/yr.
- A decrease in SAP of 1.2 (worsening of 1.2).
- A decrease in Carbon Index of 0.11 (worsening of 0.11)

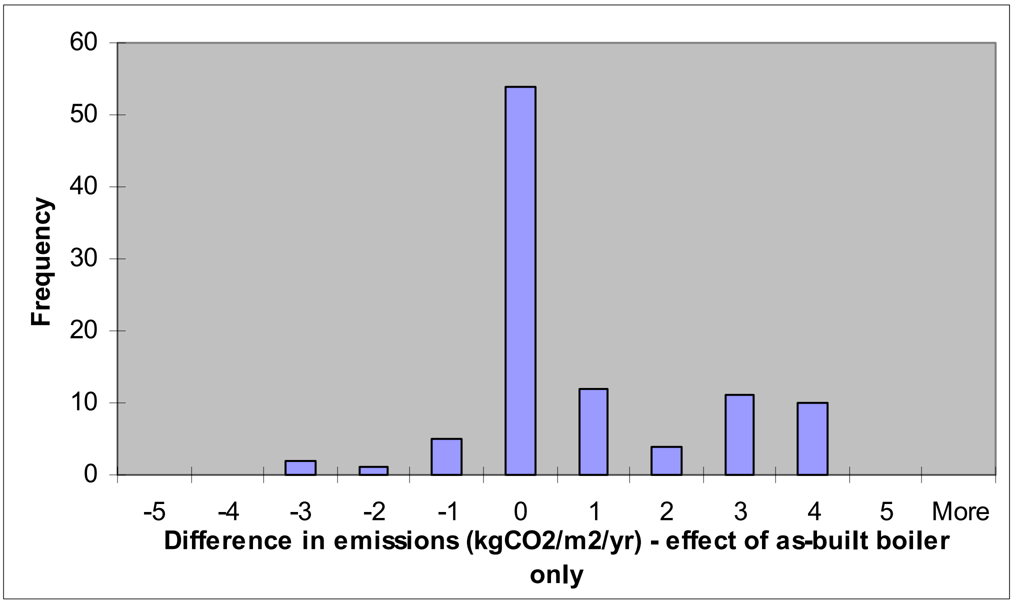

Figure 19. Individual effect of as-built boiler on carbon dioxide emissions

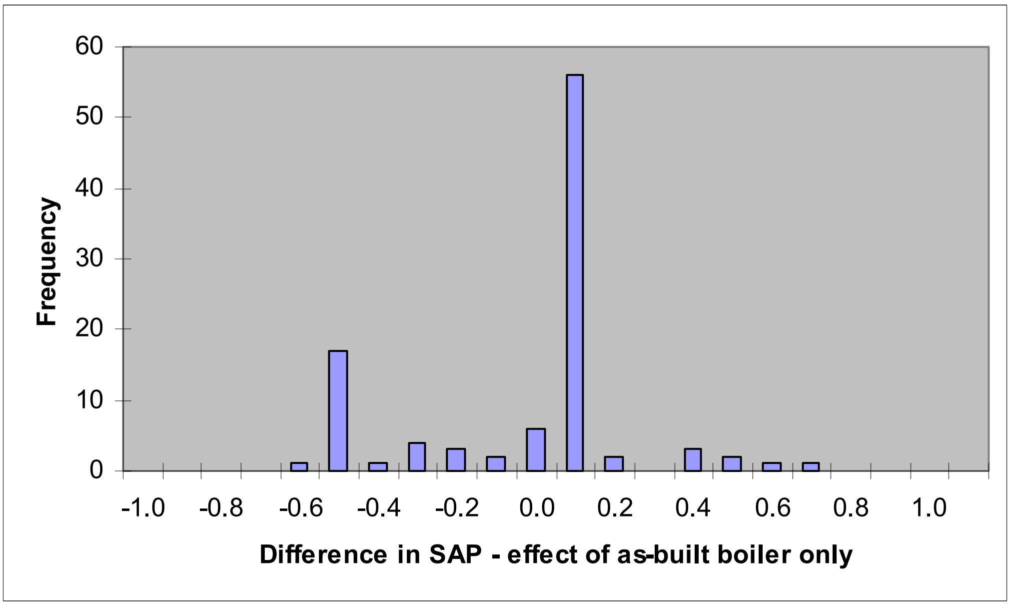

Figure 20. Individual effect of as-built boiler on calculated SAP

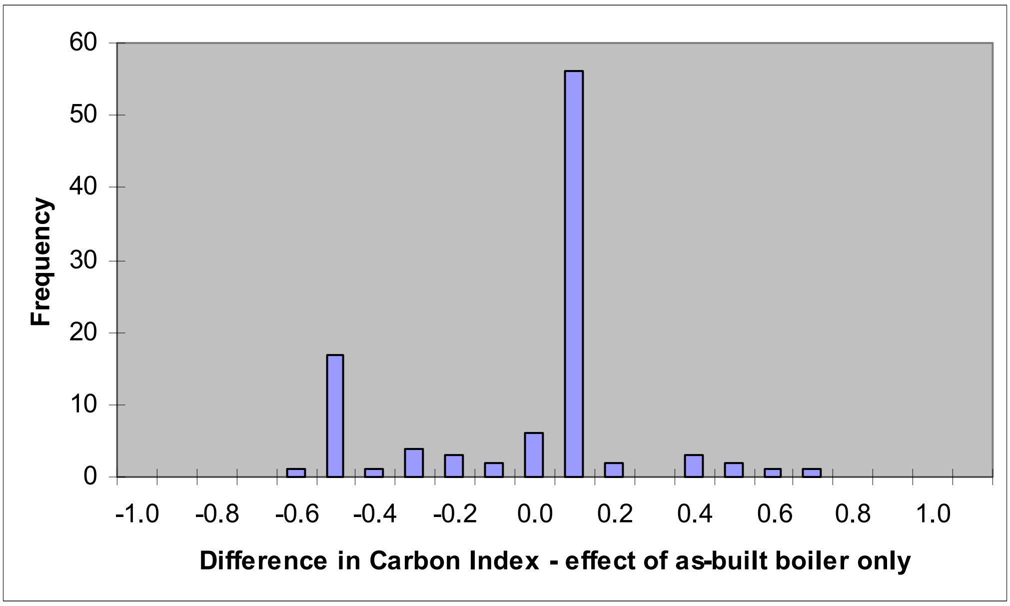

Figure 21. Individual effect of as-built boiler on calculated Carbon Index

Conclusions

The study has shown that, although two thirds of the new dwellings in this sample had achieved, or achieved better than, the guideline maximum allowable air permeability, many were still falling well short of this standard. The air leakage paths that were noted are still occurring in areas of construction that are both well known and relatively simple to observe, such as unsealed gaps remaining around flue and service pipe penetrations through the building fabric, and poorly fitting or sealed doors and windows.

The effects of air permeabilities in excess of the guideline $10m^3/h/m^2$ do not follow straightforwardly from the air permeability measurements or from the comparison of the initial and 'as-built' calculation results. The initial calculations use constructional details as input parameters, and the initial result may imply a better or worse airtightness standard than the guideline figure. The as-built results are calculated using the achieved air permeability (more precisely the air changes per hour at 50Pa) as a direct input parameter. The implied air permeability in the initial calculation of a flat with concrete floors, no external doors (such as to a balcony) and few windows might be well below $10m^3/h/m^2$, and that of a house with suspended timber floors, fireplaces with chimneys, and additional external doors and windows might exceed $10m^3/h/m^2$. Hence, where such dwellings achieve this level, this may be represented in the comparison by either an increase or reduction in carbon dioxide emissions.

The installed boiler efficiencies generally complied with the guidance of ADL1, although these had been reduced in some cases from the efficiencies used in the original SAP calculations. The impacts are much simpler to interpret. None of the boilers was non-compliant. However, the comparison between proposed and as-built calculation indicates an increase in emissions, but this reflects only on the difference between proposed and as-built SAP rating rather than any aspect of compliance.

The information concerning the boiler and controls installation and their use appeared inadequate, although some householders admitted having lost or thrown away some documents. Some had been provided only with general brochures or catalogues in which they could not identify the particular equipment installed in their home.

The acceptability of low energy light fittings appeared low among householders and most fittings had been replaced or were about to be replaced. It is not clear whether the fittings and bulbs themselves are not accepted, but at least one householder did express the view that they were being removed simply because suitable lamp-shades are not available.