

An Analysis of Display Energy Certificates for Public Buildings, 2008 to 2012

A Report to the Chartered Institution of Building Services Engineers

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Summary of findings

Results are reported from an analysis of the Display Energy Certificates for public buildings lodged between 2008 and mid-2012. A total of 120,253 records from 46,441 buildings were acquired for the study. After the removal of duplicates and certain other types of record, 73,160 DEC records for 31,802 buildings were used in the analysis. Comparisons are made against the CIBSE *TM46* energy benchmarks on which the scheme rests. Statistics for DEC records deposited since March 2010 are compared with the findings of an earlier report on DEC records deposited before that date. A longitudinal analysis is made of all buildings for which DEC records were lodged in the three successive years 2009, 2010 and 2011. Rates of compliance with the scheme are estimated. The system of classification of building types used by *TM46* is discussed.

The key findings are as follows:

- The data are dominated numerically by two benchmark categories: 'Schools and seasonal public buildings' and 'General office'. Together these account for 70% of DEC records in the post-2010 data set. Total CO₂ emissions are greatest from these and two more categories, 'Hospital – clinical and research' and 'University campus'.
- Of the major categories, 'Swimming pool centre' and 'Hospital – clinical and research' have the highest intensity of electricity and fossil-thermal energy use.
- More than half of buildings in the 12 out of 14 benchmark categories with the largest numbers were rated D or better, indicating that the benchmark values are generous.
- Median operational ratings in 9 out of 14 benchmark categories fell more than 10% away from the respective *TM46* benchmark values, suggesting that revisions to the benchmarks would be justified in many of the categories.
- In many benchmark categories there is higher electricity use and lower fossil thermal energy use than the benchmark values. This echoes the findings of the earlier review. The two opposite effects tend to cancel each other out in the overall operational ratings.
- On the other hand the three-year longitudinal analysis shows no significant change in electricity use in 6 major benchmark categories. It does however reveal a clear decline in fossil thermal energy use; there has as a consequence been a general improvement in DEC grades in these groups over the period. Comparison of the pre and post-2010 data sets confirms the declining trend in fossil thermal use in 13 benchmark categories.
- Some 3.3% of all buildings in the complete data set have electricity as the main heating fuel. There are implications here for benchmarking electrically heated buildings.
- Analysis of central and local government office buildings claiming extended occupancy indicates a small increase in electricity use, but no detectable increase in fossil thermal use, with increasing hours of occupation.
- Just 12% of buildings in the complete data set have lodged four or more DEC records in the past four years.
- Comparisons with other sources of data on non-domestic buildings suggest that compliance with the DEC records scheme is patchy, and that in several major benchmark categories more than half of all eligible buildings have had no certificates over the life of the scheme.

- Problems exist in the *TM46* classifications of building types and their allocation to benchmark categories. Many of these could be resolved with minor modifications, revisions and deletions. In other cases reallocation of building types to categories would be desirable. This would help surveyors, and would make benchmarks and the statistical analysis of DEC data more meaningful.
- The *TM46* classification lacks many of the building types needed should the scheme be extended to commercial buildings. The system of classification developed by the Valuation Office Agency provides a model for the DEC scheme as a whole.

Acknowledgements

The authors are grateful for advice and comments from Robert Cohen, Phil Jones, Bill Bordass, Hywel Davies, John Field and the membership of the CIBSE Benchmarks Committee. Robert Cohen in particular went to much trouble to check the data preparation and analysis procedures. The authors were also able to make use of and adapt the methods and programs developed by the late Harry Bruhns.

1 Introduction

In 2008 the British government set up a scheme requiring the owners or occupiers of public buildings to lodge Display Energy Certificates (DECs) showing those buildings' energy performance and carbon emissions. The scheme is operated by the Landmark Information Group¹ for the Department for Communities and Local Government (DCLG). The DECs convert carbon emissions into ratings signified by letters from A (the best, i.e. lowest) to G (the worst, i.e. highest). They must be put on prominent show in the buildings to which they relate. Up until 2012 this requirement applied to buildings with floor area greater than 1000 m². The threshold was lowered in 2013 to 500 m² (DCLG, 2012). This report presents the results of an analysis of all DECs deposited until mid-2012. It is a sequel to an earlier document prepared in May 2011, which reported on the scheme up until February 2010 (Bruhns, Jones and Cohen, 2011). The lapse of time means that it is now possible to make comparative cross-sectional analyses of certificates issued before and after 2010. It also allows the examination of trends over four years.

The report is divided into six parts. Part 2 describes how the raw data were cleaned and processed for the purposes of analysis. Part 3 presents the results of the cross-sectional analyses, covering numbers and sizes of buildings, consumption of electricity and fossil fuels, CO₂ emissions, and alphabetic DEC ratings. These are given for the benchmark categories and building types specified in the Chartered Institution of Building Services Engineers (CIBSE) publication *TM46: Energy Benchmarks* (CIBSE, 2008) on which the DEC scheme rests. Part 4 follows trends in these same variables over time as revealed by the longitudinal analysis. Part 5 presents the results from the analyses of DEC records that were separated from the main analyses. These include statistics for electrically heated buildings, composites DECs, pro-rated DECs, occupancy hours and separable energy uses. Part 6 analyses the extent to which the owners and operators of eligible buildings have complied with the requirement to deposit DECs. Part 7 discusses some issues arising out of the current classifications of building types, and the benchmark categories under which the types are grouped. Lastly, appendices are included describing the variables in the raw DEC data, energy and floor area statistics by building type, distribution of DEC records by main heating fuel type, and tabulations of buildings by their internal environments.

The report is not intended as a policy document in itself. Its purpose is rather to provide a set of analytical results that can inform policy for the DEC scheme and support any future revision of *TM46*. The fact that the scheme has now been running for more than five years means that a wealth of consumption data is available against which the benchmark categories and values can be evaluated. As was indicated in the 2011 report, it has become clear that some benchmarks were set originally at appropriate levels, while others were too high or too low. The present report provides data and analyses to throw more light on these issues, and to explore and inform possible revisions.

¹ For Landmark Information Group, see: <http://www.landmark.co.uk/>

² For SAS 9.3, see: <http://support.sas.com/documentation/93/index.html>

2 Preparing Data

2.1 Cleaning and processing the raw data

The DEC data are collected and held by the Landmark Information Group on behalf of DCLG. Landmark provided the CIBSE Benchmarks Committee with a database for the present analysis, of all DEC records lodged until June 2012. The file contains 120,253 records including flags for cancelled records. The records relate to 46,441 different buildings (or sites), many of which have multiple records. A series of steps were taken to make these data suitable for analysis. These are listed in Table 2-1, which also shows the numbers of records and buildings remaining after a series of omissions, explained below. A manual check was made first on the benchmark and building type classifications. These were corrected and reclassified, where necessary, in particular to ensure that building types appeared under the correct benchmarks. Statistical Analysis Software (SAS) 9.3² was used to prepare and analyse the data in the report.

Table 2-1 Summary of the data processing steps

| # | Name | Description | No. of Records after each step | No. of Buildings after each step |
|---|---|--|--------------------------------|----------------------------------|
| 1 | Import raw data | Import the raw data from Landmark into SAS database table | 120,253 | 46,441 |
| 2 | Reclassification of benchmark categories and building types | Manual correction of errors found in listing of unique combinations of benchmarks and building types (incl. composite benchmarks). | “ | “ |
| 3 | Removal of uncertain records | Remove records which were flagged according to the criteria specified in section 2.1 | 86,549 | 36,652 |
| 4 | Corrections and early renewals | Remove DEC records that were renewed early | 86,068 | 36,632 |
| 5 | Duplicate DECs | Remove duplicate records | 84,364 | 36,538 |
| 6 | Pro-rated DECs | Remove pro-rated DECs | 73,160 | 31,802 |

The following sections describe the rationale behind the data processing steps as well as the criteria used to remove uncertain records.

² For SAS 9.3, see: <http://support.sas.com/documentation/93/index.html>

2.1.1 Removal of uncertain data

The first step was to flag records for which the values of key variables seemed dubious, and for that reason should be excluded. The criteria were as follows:

Records where the Operational Rating (OR)³ was not between 5 and 1000 were flagged and excluded. It was decided that an OR less than 5 is very unlikely to be achieved in an occupied building, and probably means that the building is vacant. At the opposite extreme, the highest OR values observed in valid DEC's are of the order of 700 or 800, and values over 1000 are therefore likely to be errors.

Records where the Operational Rating was given as 200 or 9999 were excluded, since these are default⁴ values given to DEC's lodged with insufficient information on energy consumption.

On occasion DEC assessors may lodge a certificate and then realise that it contains mistakes, cancel it, and replace it with an amended certificate. Some cancelled DEC's remained in the database from Landmark. These were removed.

Records where the total useful floor area was given as less than 50 m² were removed, since such figures are likely to be errors. (Many DEC's were however registered with floor areas between 50 m² and 1000 m² despite the fact that 1000 m² was the lower threshold of size throughout the period covered by the analysis: these are retained.)

Records where total CO₂ emissions were greater than 100,000 tonneCO₂/yr were removed as being extreme outliers.

Records where the Electricity Energy Use Index (EUI) was given as 0 were removed, since it is extremely improbable that any occupied building would use no grid electricity. These are therefore almost certainly errors.

Electrically heated buildings

Buildings where electricity is the main heating fuel are flagged and treated separately in the analysis, since these are likely to have characteristically different patterns of energy use from buildings heated by fossil fuels (see section 5.1). Approximately 3% (1,543) of all buildings in the data were electrically heated. Once these were set aside, then any remaining records where the fossil thermal EUI was 0 were removed, since this would imply no heating at all, and such cases were thought likely to be errors. (Although there do exist some occupied non-domestic buildings that use no energy for heating as such, including certain types of shop.)

Composite DEC's

The DEC methodology allows buildings with mixed uses falling under different benchmark categories to measure their energy use by means of a 'composite benchmark'. This involves dividing the

³ The operational rating is used as a basis for grading the energy performance of buildings. The rating is produced by dividing the actual energy consumption by adjusted benchmarks and multiplying the ratio by 100.

⁴ An operational rating of 200 is a default rating given to a building if valid meter readings for its energy consumption are not available. The default rating was later changed to 9999 in March 2010 and no longer allowed from 14 April 2011.

useable floor area of the building between the different uses, and applying the appropriate benchmarks in proportion to those areas. This means of course that such buildings cannot be assigned as a whole to a unique benchmark for the purposes of analysis. Because of the complications involved, it was decided to analyse these composite DEC's separately (see section 5.2).

These various criteria thus removed records that were likely to be erroneous, and set aside electrically heated buildings and composite DEC's. At the end of the process there were 86,549 records remaining, relating to 36,652 buildings (see Table 2-1). Some further DEC's were removed, of four different kinds.

2.1.2 Corrections and early renewals

There are occasions when a new DEC is lodged a matter of months after another – they are only required annually - in order for example to report reduced energy consumption or to make other corrections. It is clearly desirable for the analysis to have no more than one DEC per building per year, if possible. Analysis of the number of days elapsing between the lodging of one DEC and its successor indicated that 0.6% of certificates in the data (754 out of 120,253) were lodged with assessment end dates less than six months from the previous lodgement. It was decided therefore to eliminate all records where the assessment period of the later record overlapped with the earlier record by up to 182 days.

2.1.3 Duplicate records

In principle, all duplicate records should have been removed from the database supplied by Landmark. A 'report status' variable should in theory have been used to indicate where records had been cancelled. Examination of this variable however showed that the relevant flag was not being rigorously applied and that approximately 0.6% of records showed the same consumption for the same building in the same assessment period. It was therefore necessary to devise a way of removing these unflagged duplicates. In order to avoid any uncertainties it was decided to discount all cases where more than one DEC had been lodged with the same energy consumption figures for the same period.

2.1.4 Pro rata and site DEC's

At the start of the DEC scheme a special arrangement was made for any institution with multiple buildings on one site, for example a hospital or a large school, to lodge a single DEC for the entire site (a 'site DEC'). This means that separate buildings with very different sizes, construction, using different fuels and so on would all be assessed collectively. The arrangement was phased out in November 2009 and replaced with a provision that DEC's could be lodged for buildings on shared sites, but without separate sub-metering, on a pro rata basis. It should, however, be noted that the 'site DEC' was allowed on a voluntary basis from this date.

To calculate the pro rata DEC's the consumption for the entire site was divided between the separate buildings in proportion to floor area. However the problem remains, that pro rata DEC's make no allowance for the different characteristics of the various buildings. For these reasons, pro rata DEC's have been removed from the analysis. Pro rata DEC's were identified by the fact that they have the same site reference number, assessment end date and EUI values for electricity and fossil thermal energy.

Table 2.1 shows the reductions in the numbers brought about by these successive omissions, resulting in a final total of 73,160 records relating to 31,802 buildings (or sites).

2.2 Creating datasets for the analyses

The dataset that has been prepared for analysis comprises all DECs lodged between the end of 2008 and mid-2012. This means that there are numerous cases where several DECs were lodged for the same building in different years. Having access to such data provides opportunities therefore to examine the energy performance of buildings within specified time periods in *cross-sectional* analyses, as well as to follow trends over several years through *longitudinal* analyses.

The distinctively different nature of the two forms of analysis means that it has been necessary to adopt different methods for selecting the relevant DECs in each case. The following sections describe that process in detail.

2.2.1 Cross-sectional dataset

The cross-sectional analyses were carried out to examine the current energy performance of buildings based on their most recently deposited DECs. These might be for 2012, or they might be for some previous year, with no DECs deposited since. A dataset was therefore created, based on just the *latest* DEC from each building, to provide a sample representing current or recent performance. This was the methodology used in the previous review by Bruhns, Jones and Cohen (2011). What should be noted, however, is that this dataset does not include any of the DECs analysed in 2011. That previous work was based on DECs lodged between October 2008 and February 2010. This meant that it was necessary to create a subset of DECs lodged between March 2010 and June 2012, to ensure that the present analysis is based solely on the new records.

Figure 2-1 gives a notional illustration of how the latest DECs were selected from the complete dataset. The figure shows buildings A to H, all of which have varying numbers of DECs lodged in different years, indicated by dots. The cells coloured in light blue indicate the latest DECs selected for the present cross-sectional analyses. Notice that the latest DECs for buildings B, C, G and H were not selected, since these were lodged before February 2010, indicating that they would have been analysed in the previous work.

| Building | Assessment end dates | | | | | |
|----------|----------------------|------|-----------------|----------------|------|----------|
| | Oct 2008 | 2009 | Before Feb 2010 | After Mar 2010 | 2011 | Jun 2012 |
| A | | • | • | | • | • |
| B | • | • | | | | |
| C | • | | | | | |
| D | | • | | • | • | |
| E | | | | | • | • |
| F | • | • | | • | | |
| G | | • | • | | | |
| H | | • | | | | |

Figure 2-1 Illustration of how the latest DECs were selected for the present cross-sectional analyses

Table 2-2 below shows the number of DECs in the dataset selected for the cross-sectional analyses, and the percentages of total records that these represent. In all, there were 22,151 buildings used for the analyses. This represents approximately 70% of all buildings (31,802) that have lodged DECs since the inauguration of the scheme.

Table 2-2 Number of buildings in the cross-sectional dataset by benchmark category

| Benchmark category | N | % of all |
|--|---------------|-----------------|
| 1 General office | 2,911 | 13% |
| 2 High street agency | 30 | 0% |
| 3 General retail | 33 | 0% |
| 4 Large non-food shop | 1 | 0% |
| 5 Small food store | 0 | 0% |
| 6 Large food store | 0 | 0% |
| 7 Restaurant | 21 | 0% |
| 8 Bar, pub or licensed club | 7 | 0% |
| 9 Hotel | 16 | 0% |
| 10 Cultural activities | 544 | 2% |
| 11 Entertainment halls | 203 | 1% |
| 12 Swimming pool centre | 261 | 1% |
| 13 Fitness and health centre | 42 | 0% |
| 14 Dry sports and leisure facility | 606 | 3% |
| 15 Covered car park | 0 | 0% |
| 16 Public buildings with light usage | 4 | 0% |
| 17 Schools and seasonal public buildings | 12,563 | 57% |
| 18 University campus | 1,442 | 7% |
| 19 Clinic | 728 | 3% |
| 20 Hospital - clinical and research | 573 | 3% |
| 21 Long term residential | 990 | 4% |
| 22 General accommodation | 196 | 1% |
| 23 Emergency services | 746 | 3% |
| 24 Laboratory or operating theatre | 74 | 0% |
| 25 Public waiting or circulation | 5 | 0% |
| 26 Terminal | 2 | 0% |
| 27 Workshop | 128 | 1% |
| 28 Storage facility | 25 | 0% |
| 29 Cold storage | 0 | 0% |
| All | 22,151 | 100% |

2.2.2 Longitudinal dataset

The accumulation of DEC's over the past four years means that it is now possible to examine how the patterns of energy use in different building types have changed over the period. An important feature of the database created for the longitudinal analyses is that it tracks the energy performance of the same buildings over the period. This is to ensure that continuous trends can be followed for specified activities, year by year.

A preliminary examination of these trends indicated that 2008 - the first year of the scheme's operation - was anomalous, and that the data revealed some uncertainties. There were perhaps some initial teething problems. All records for this year were therefore removed. DEC's lodged in 2012 up to June were also discounted because of the year being incomplete. The result was to leave buildings that had lodged DEC's in each of the three consecutive years 2009, 2010 and 2011 as the basis for the analysis. Figure 2.2 gives a notional illustration of this process of selection. Again, dots mark the registration of DEC's, and the light blue shows the data selected.

| Building | Assessment end dates | | | | |
|----------|----------------------|------|------|------|----------|
| | Oct 2008 | 2009 | 2010 | 2011 | Jun 2012 |
| A | | • | • | • | |
| B | • | • | • | • | • |
| C | • | | | | |
| D | | • | | | |
| E | | | | • | • |
| F | | • | • | • | |
| G | • | • | | • | |
| H | | | | • | • |

Figure 2-2 Illustration of how the DEC's were selected for the longitudinal analyses

Table 2-3 (next page) shows the number of buildings in each category that have lodged DEC's for each of the three years. Notice that there were several benchmark categories in which there were no such continuous runs of records. In total, 8,535 buildings have lodged DEC's over the three consecutive years. This indicates that approximately 27% of all buildings in the complete DEC dataset (31,802) have lodged DEC's consistently year on year. (It is possible that some of these buildings have lodged four DEC's, given that records for 2012 were excluded.)

Table 2-3 Number of buildings in the longitudinal dataset in each year by benchmark category

| Benchmark category | Number of buildings in each year |
|--|---|
| 1 General office | 1,071 |
| 2 High street agency | 0 |
| 3 General retail | 15 |
| 4 Large non-food shop | 1 |
| 5 Small food store | 0 |
| 6 Large food store | 0 |
| 7 Restaurant | 6 |
| 8 Bar, pub or licensed club | 4 |
| 9 Hotel | 4 |
| 10 Cultural activities | 230 |
| 11 Entertainment halls | 96 |
| 12 Swimming pool centre | 98 |
| 13 Fitness and health centre | 8 |
| 14 Dry sports and leisure facility | 218 |
| 15 Covered car park | 0 |
| 16 Public buildings with light usage | 1 |
| 17 Schools and seasonal public buildings | 5,137 |
| 18 University campus | 415 |
| 19 Clinic | 236 |
| 20 Hospital - clinical and research | 182 |
| 21 Long term residential | 383 |
| 22 General accommodation | 55 |
| 23 Emergency services | 326 |
| 24 Laboratory or operating theatre | 14 |
| 25 Public waiting or circulation | 4 |
| 26 Terminal | 0 |
| 27 Workshop | 21 |
| 28 Storage facility | 10 |
| 29 Cold storage | 0 |
| All | 8,535 |

2.2.3 Reprocessing the DEC's used in the 2011 analyses

As mentioned, an opportunity presented by the latest DEC data is to compare the performance of buildings described in section 2.2.1 with the results from the analyses carried out in 2011 (Bruhns, Jones and Cohen 2011). However, comparing the results for the two periods, before and after February 2010, requires the previous dataset to be prepared using the same methods as for the present study. This is due to the refinements that have been made to the data preparation methodology since the previous analysis. The dataset from the 2011 analysis was therefore cleaned and processed by taking the same steps as described in section 2.1.

Table 2-4 Number of buildings in the reprocessed 2011 dataset by benchmark category

| Benchmark category | N | % of total |
|--|---------------|-------------------|
| 1 General office | 2,702 | 12% |
| 2 High street agency | 291 | 1% |
| 3 General retail | 29 | 0% |
| 4 Large non-food shop | 2 | 0% |
| 5 Small food store | 0 | 0% |
| 6 Large food store | 1 | 0% |
| 7 Restaurant | 17 | 0% |
| 8 Bar, pub or licensed club | 5 | 0% |
| 9 Hotel | 13 | 0% |
| 10 Cultural activities | 542 | 2% |
| 11 Entertainment halls | 173 | 1% |
| 12 Swimming pool centre | 260 | 1% |
| 13 Fitness and health centre | 60 | 0% |
| 14 Dry sports and leisure facility | 546 | 2% |
| 15 Covered car park | 1 | 0% |
| 16 Public buildings with light usage | 4 | 0% |
| 17 Schools and seasonal public buildings | 13,113 | 57% |
| 18 University campus | 1,319 | 6% |
| 19 Clinic | 582 | 3% |
| 20 Hospital (clinical and research) | 691 | 3% |
| 21 Long term residential | 1,230 | 5% |
| 22 General accommodation | 212 | 1% |
| 23 Emergency services | 712 | 3% |
| 24 Laboratory or operating theatre | 57 | 0% |
| 25 Public waiting or circulation | 5 | 0% |
| 26 Terminal | 0 | 0% |
| 27 Workshop | 350 | 2% |
| 28 Storage facility | 57 | 0% |
| 29 Cold storage | 0 | 0% |
| All | 22,974 | 100% |

As shown in Table 2-4, there were 22,974 buildings in the reprocessed dataset. This is a significantly smaller number than the 29,320 records analysed in the previous report. The difference is caused by the additional steps taken to remove uncertain and inappropriate records, including composite and pro-rated DECs.

3 Cross-sectional analyses

3.1 Numbers and sizes of buildings

Figure 3-1 shows the number of buildings in each benchmark category. The figure also illustrates the number of buildings from the reprocessed dataset described in Section 2.2.3.

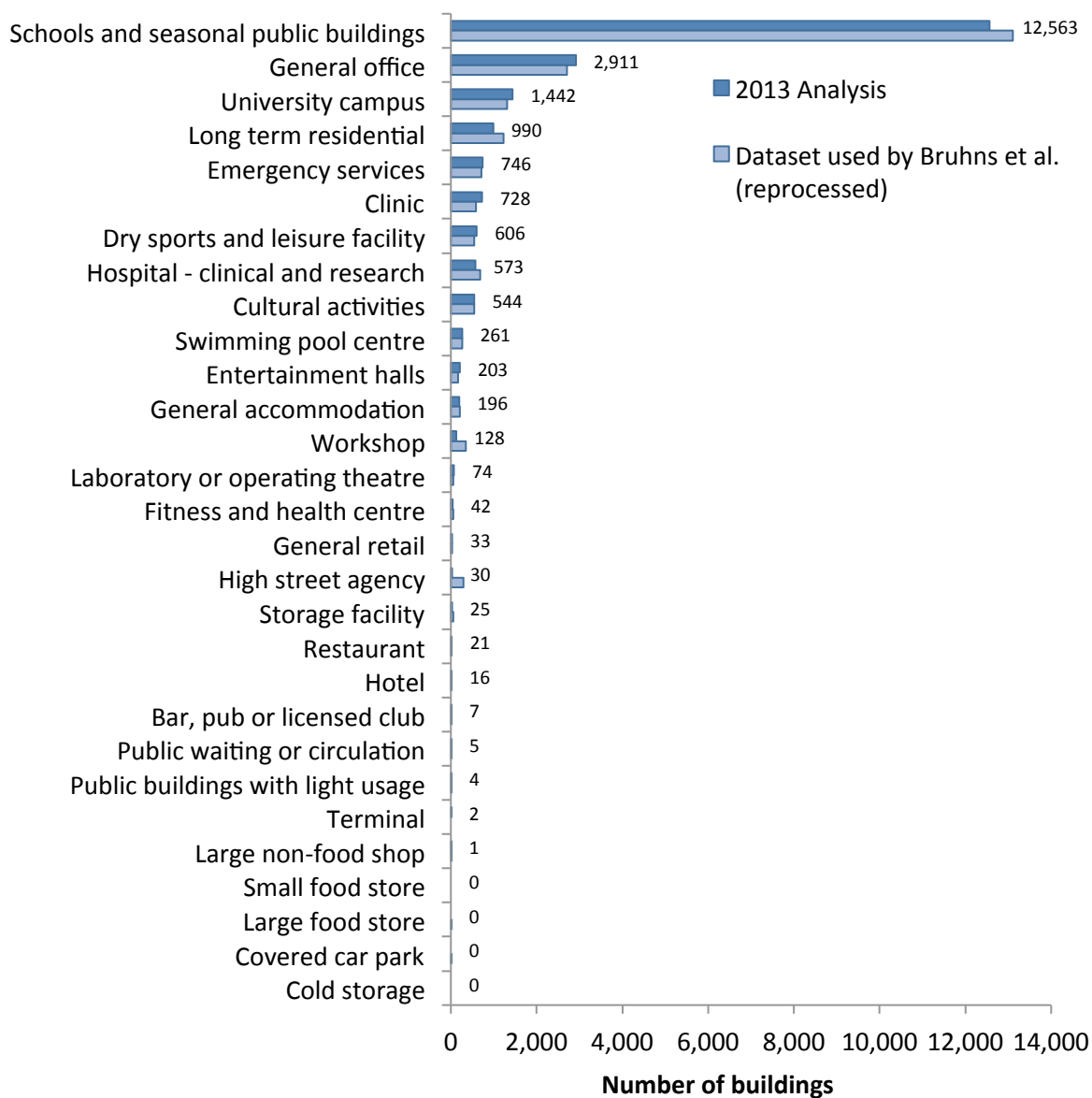


Figure 3-1 Comparison of the number of buildings in each benchmark category between the 2011 and 2013 reviews (numbers on bars refer to 2013 data)

The figure clearly shows that majority of the DEC records in the two cross-sectional datasets belong to the ‘Schools and seasonal public buildings’ category. There are also large numbers of buildings under the ‘General office’, ‘University campus’ and ‘Long term residential’ categories. The figure also shows that there are numerous benchmark categories under which there are very small numbers of buildings. This is mostly because the building types in these categories are rarely found in the public sector (e.g. large food store, cold storage).

Figure 3-2 below shows the mean floor area of buildings in each benchmark category. The categories are ranked in order from the largest to the smallest buildings. The figure shows that hospitals, on average, are the largest buildings followed by terminals and hotels.

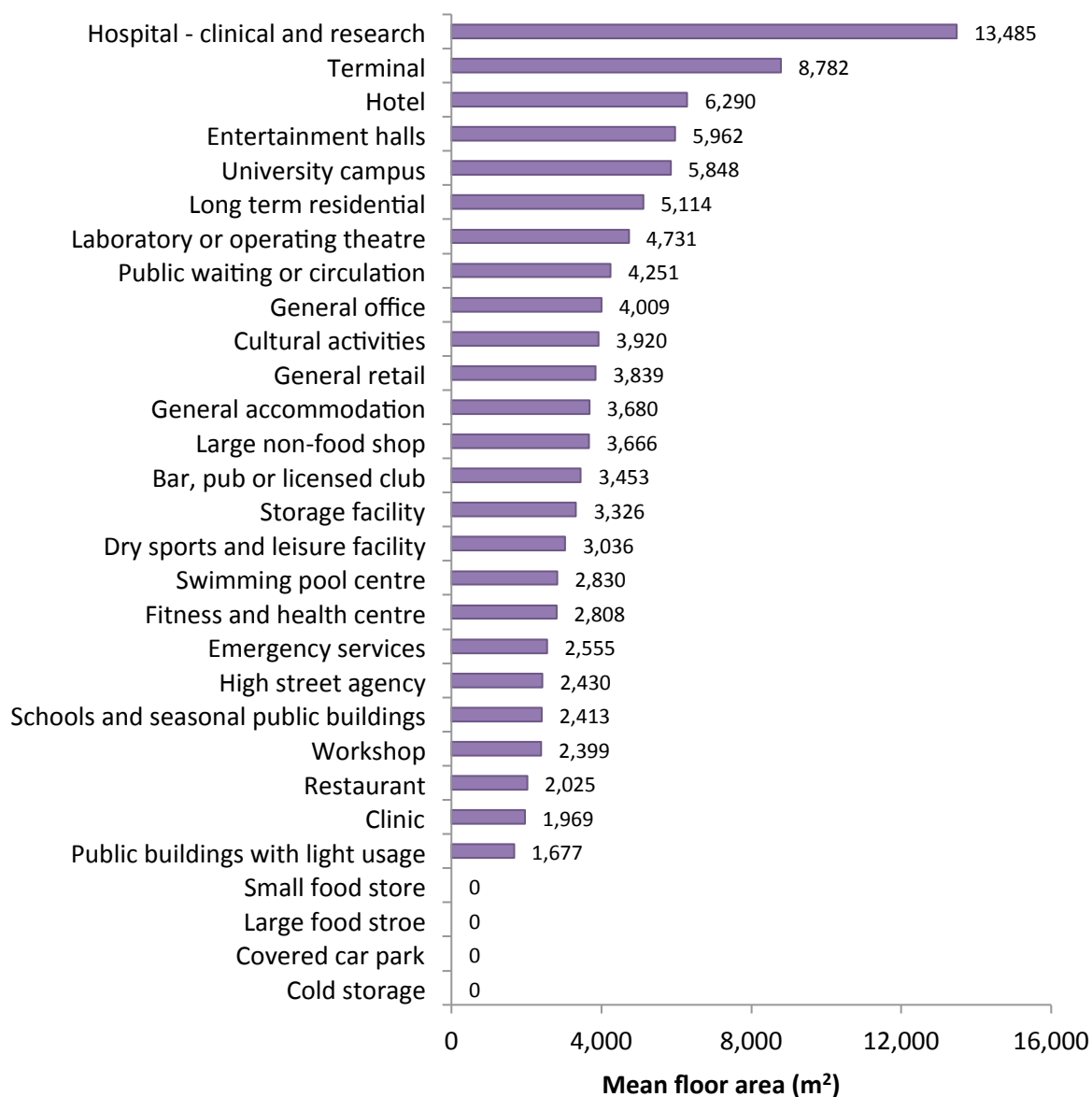


Figure 3-2 Mean floor area of buildings under each benchmark category

3.2 Total floor areas and CO₂ emissions in each category

Figure 3-3 shows the total floor area of buildings in each category. Schools account for the largest proportion of the total floor area, which reflects the sheer number of records in this category. Buildings under the 'General office', 'University campus' and 'Hospitals' account for significant proportions of the total floor area in the dataset, despite much smaller sample sizes.

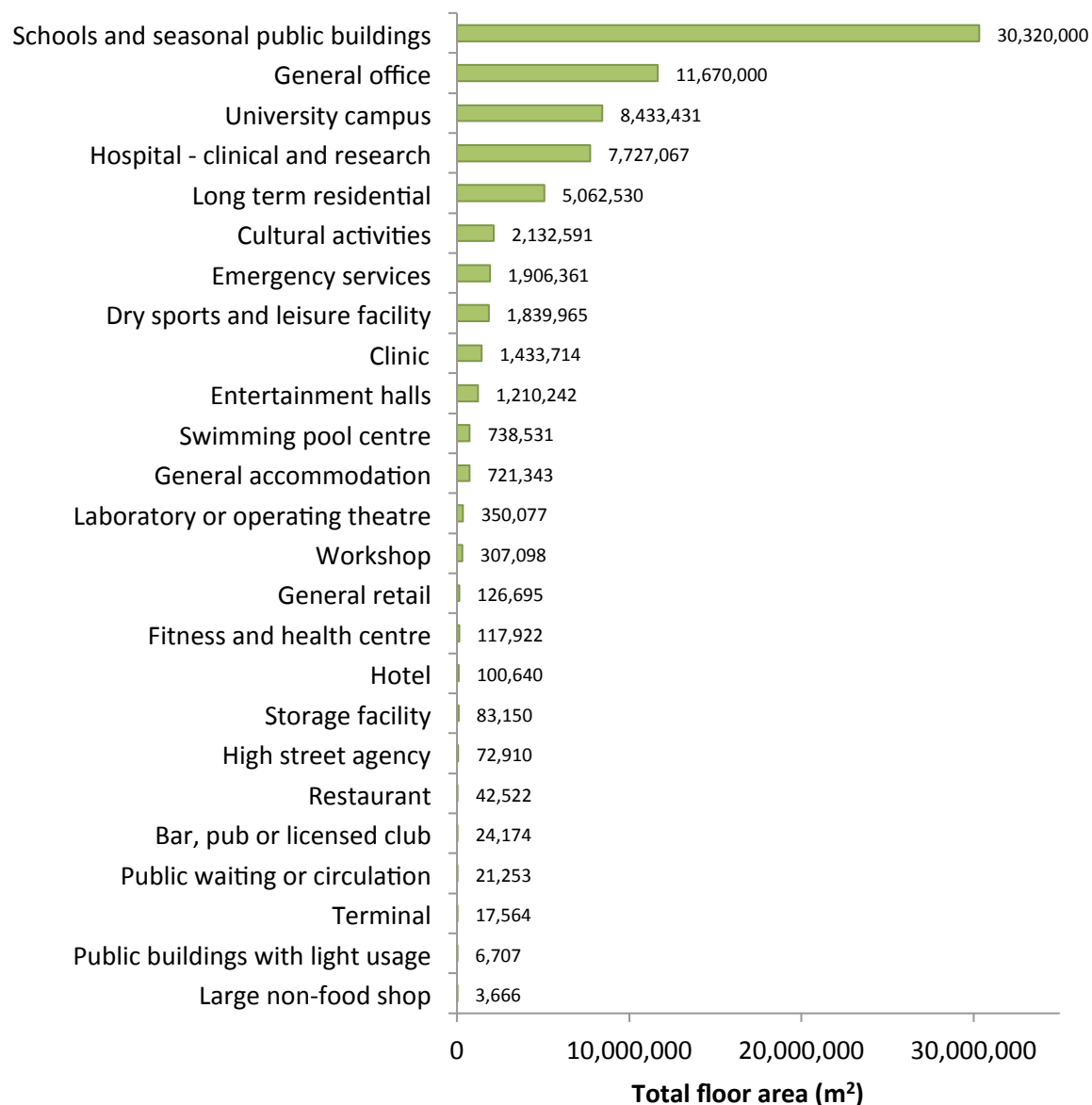


Figure 3-3 Total floor area of buildings in each category

Figure 3-4 shows the total CO₂ emissions from buildings in each benchmark category. The categories are arranged in descending order of emissions.

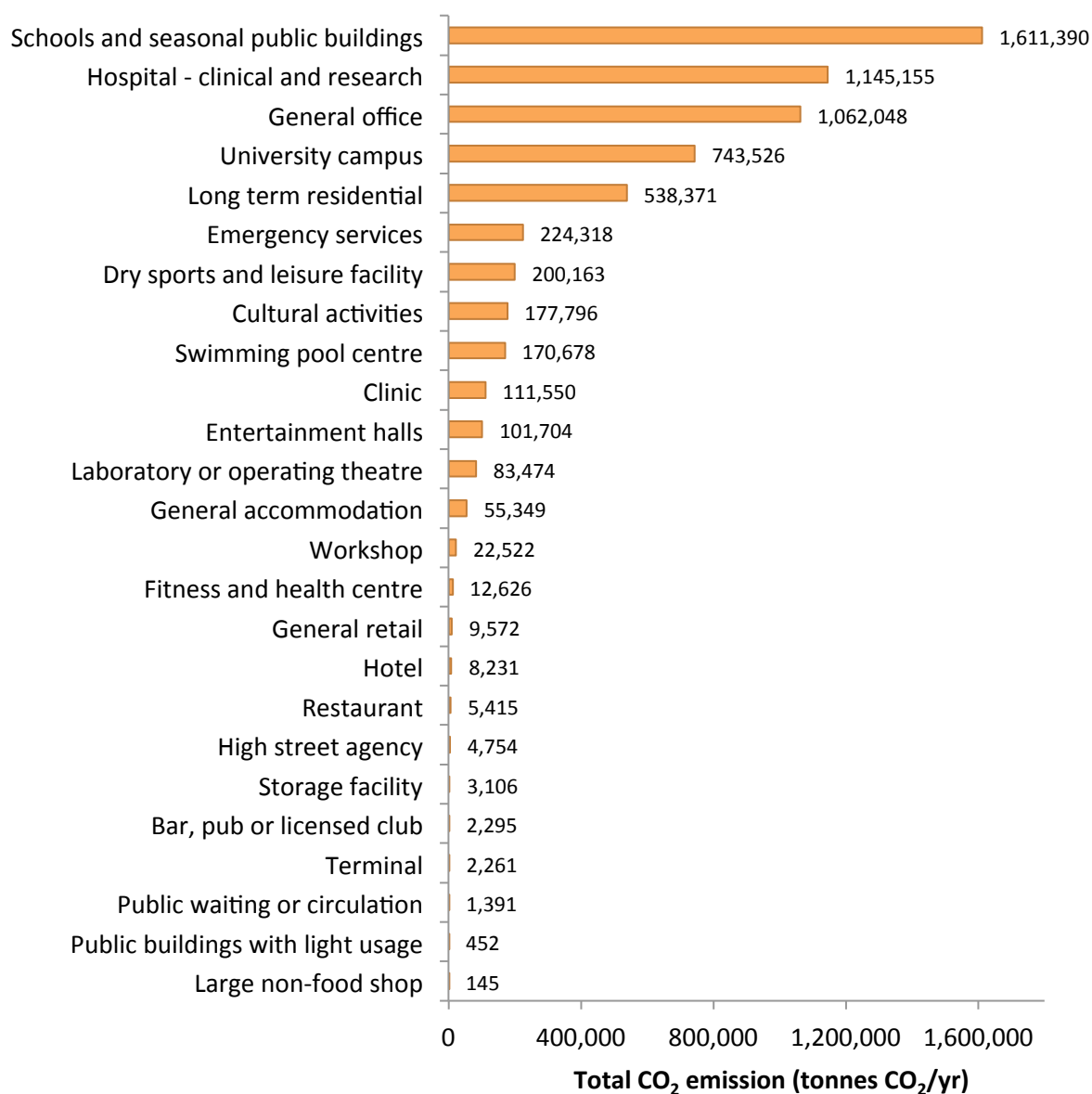


Figure 3-4 Total CO₂ emissions from buildings in each category

As shown in Figure 3-4, total CO₂ emissions are greatest from buildings under the ‘Schools and seasonal public buildings’ category. This is not because schools are more energy-intensive but simply due to the very large number of records in this group (see Figure 3-1). Hospitals on the other hand are the second largest emitters of CO₂ despite having only 573 records. This is because of their large size (Figure 3-3) as well as the fact that they are much more energy-intensive than schools, as a result of different requirements for equipment, internal conditions and occupancy hours. Similar patterns can be seen in the ‘General office’ and ‘University campus’ categories, which also have high emissions despite smaller sample sizes.

3.3 Distribution of building sizes

Figure 3-5 shows the distribution of sizes of buildings in each category ranging from buildings with floor areas between 30 and 100m² to buildings with floor areas greater than 30,000m².

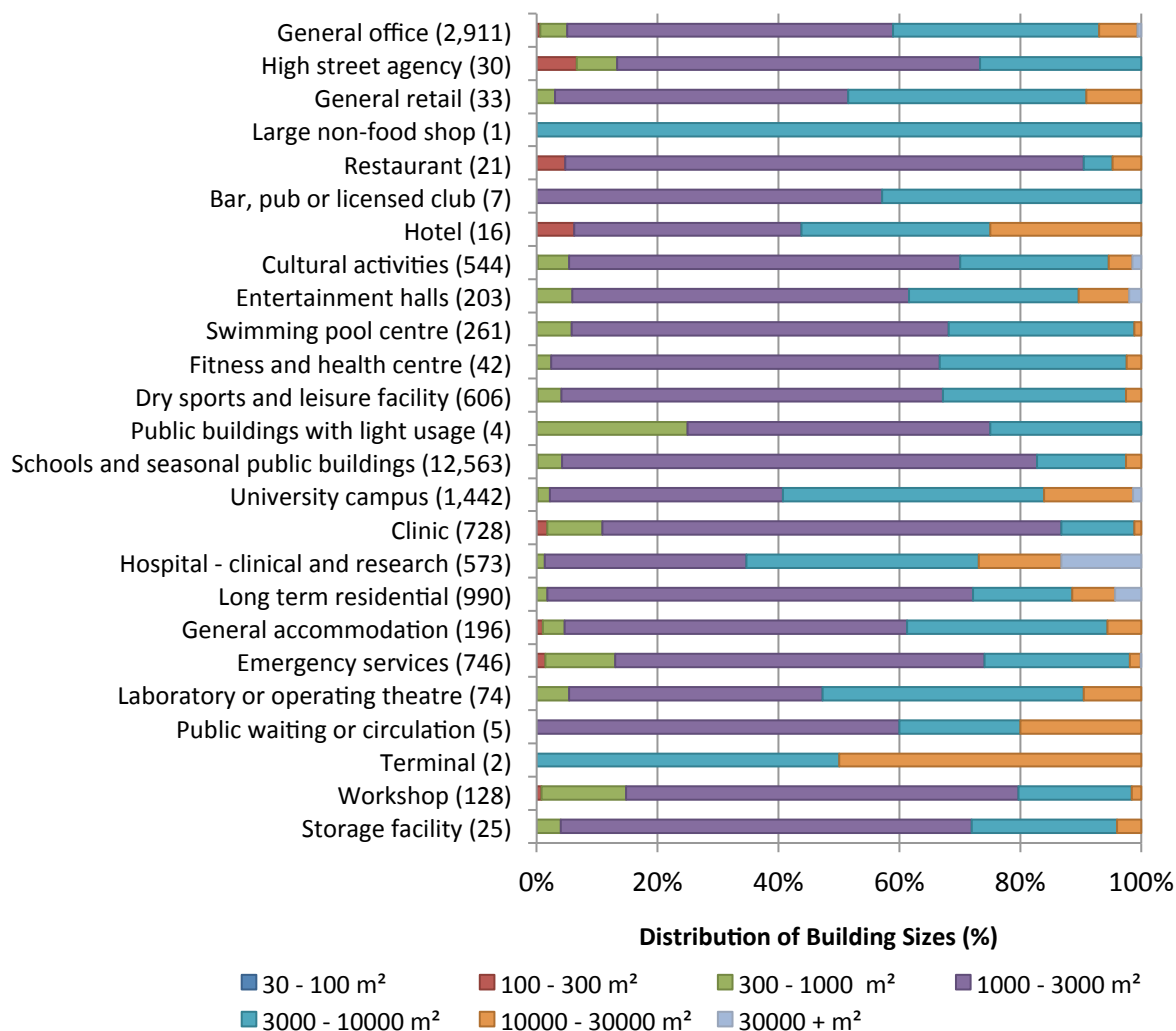


Figure 3-5 Distribution of buildings in size categories (m², percentages of all buildings)

The distribution indicates the following:

- The majority of buildings are between 1,000 and 3,000m² in size. (Recall that buildings of less than 1,000m² were not required to have DEC's in the time period in question.)
- Higher proportions of buildings with large floor areas (greater than 10,000m²) are found under the 'Hospital – clinical and research' and 'Long term residential' categories, echoing the high mean floor areas shown in Figure 3-2.
- The very largest buildings (greater than 30,000m²) are mainly hospitals and prisons. There are also a few large public museums.
- 1,012 buildings were smaller than 1,000m² in floor area. Inspection of a sample of these indicated that they are mostly nurseries or individual buildings within primary schools.

3.4 Distribution of DEC grades and operational ratings

Figure 3-6 shows the distribution of DEC grades within benchmark categories. The figure only shows those categories where there are more than 50 records.

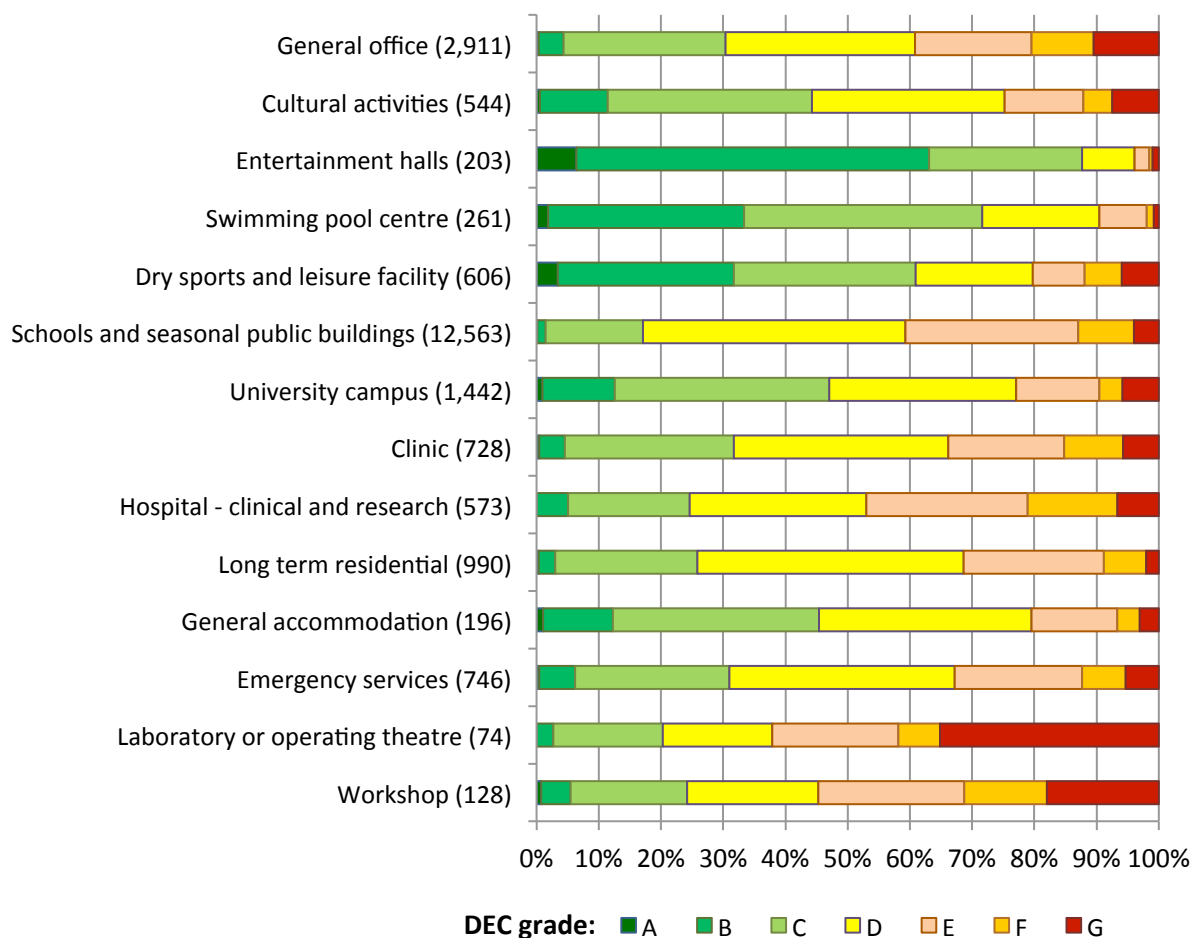


Figure 3-6 Distribution of DEC grades in each benchmark category

The distribution indicates the following:

- More than half of the buildings in 12 of the 14 benchmark categories analysed were rated D or better, which indicates that the benchmarks are generous.
- The median operational ratings of buildings under the ‘Hospital – clinical and research’ and ‘Workshop’ categories are within 5% of the benchmarks.
- More than 80% of buildings under the ‘Entertainment halls’ category have DEC grades better than C.
- The highest proportion of buildings rated G (approximately 35%) occur in the ‘Laboratory or operating theatre’ category. This is followed by buildings under the ‘Workshop’ category with close to 20%.

Figure 3-7 shows distributions of operational ratings by benchmark category, with box and whisker plots. (See Figure 3-8 for an explanation of this format.) It should be noted that only those categories with sample sizes greater than 50 were plotted in the figure.

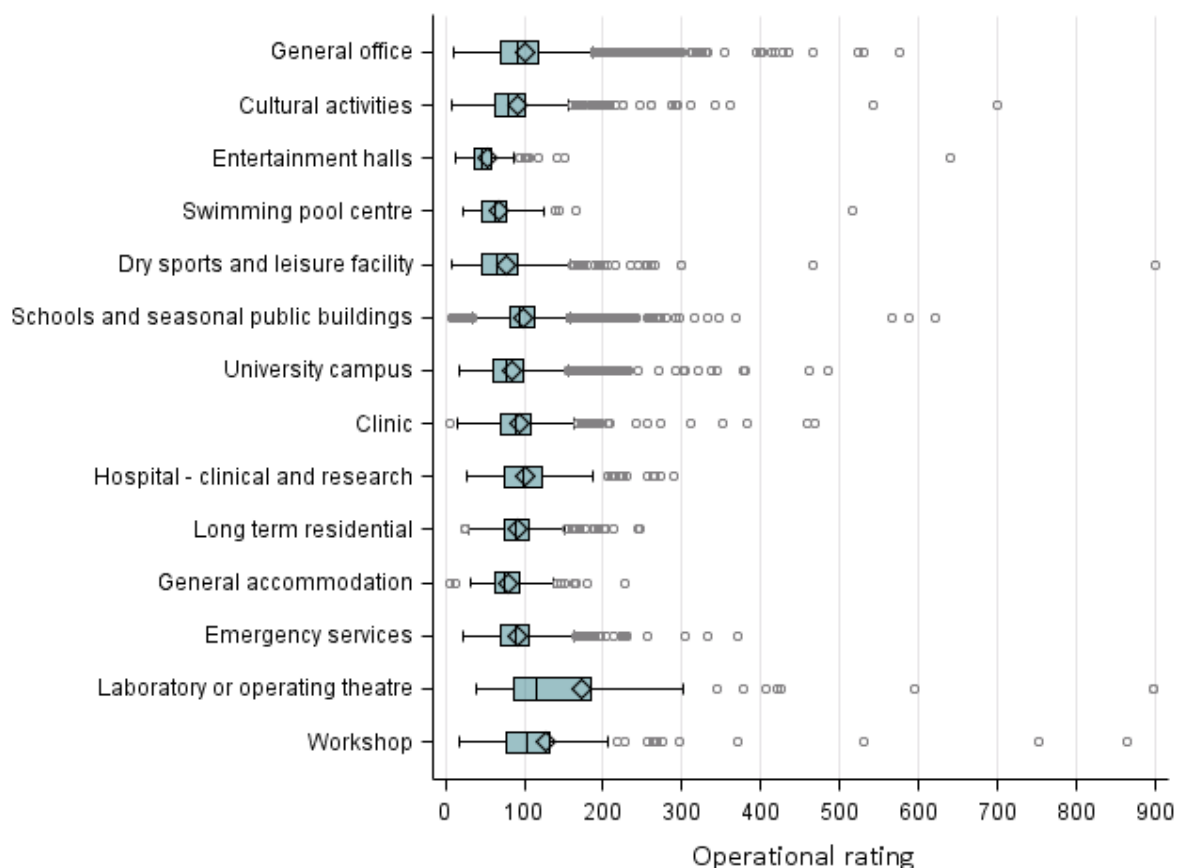


Figure 3-7 Box-and-whisker plots of operational ratings by benchmark category

The distribution shows the following:

- Large variations in operational ratings are observed in many categories. The least variation in operational ratings was found in the ‘Entertainment halls’ group with an inter-quartile range of 22. The ‘Laboratory and operating theatre’ category had the most variation with an inter-quartile range of 98. (See Figure 3-7 for explanation)
- The lowest operational ratings were found in the ‘Clinic’ and ‘General accommodation’ categories with ORs of 6. The highest ratings, exceeding 800, were found on the other hand in the benchmark categories ‘Dry sports and leisure facility’, ‘Laboratory or operating theatre’ and ‘Workshop’.
- Approximately 2% of all buildings received operational rating greater than 200. More than 60% (210) of these buildings were under the ‘General office’ and ‘Schools and seasonal public buildings’ categories. Relative to the total sample sizes in each category, however, the proportion of buildings that received ORs greater than 200 was the highest (24%) in the ‘Laboratory and operating theatre category’.

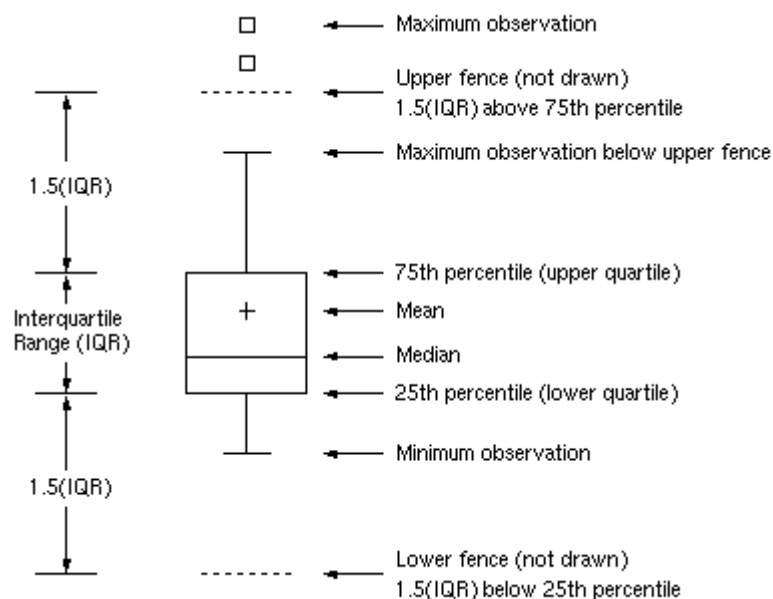


Figure 3-8 Diagram of box-and-whiskers plot

3.4 Operational ratings by fuel type

In this section and other parts of the report, the energy performance of buildings was examined in relation to the benchmarks set out in CIBSE *TM46* based on *operational ratings* for electricity and fossil-thermal energy use. These ratings are derived using the equation (1) below:

$$\text{Operational rating} = \frac{\text{Actual electrical or fossil-thermal EUI (kWh/m}^2\text{)}}{\text{Adjusted electrical or fossil-thermal benchmarks (kWh/m}^2\text{)}} \times 100 \quad (1)$$

This means that buildings with electricity or fossil-thermal ratings of 100 would have energy consumption comparable to the typical performance of buildings in that category.

The benefit of using these ratings rather than the actual energy consumption (kWh/m²) is that they are derived in relation to benchmarks which are adjusted to account for the circumstances of individual buildings, such as regional and seasonal variations in weather, as well as occupancy hours. The adjustment process also allows buildings in certain categories to deduct *separable* energy uses, which further reduce the discrepancy in characteristics between a building and the benchmark.

Figure 3-9 shows deviations of median ratings for electricity and fossil-thermal fuel use from 100, the value that represents typical performance in *TM46* benchmarks. The figure also shows the median operational ratings for each benchmark category, which are based on consumption of both fuel types together. The bars extending to the left of zero indicates that the median ratings are below the benchmarks. The bars extending to the right indicates that the ratings are greater than the benchmarks. (Note that benchmark categories that do not have records are also displayed on the chart.)

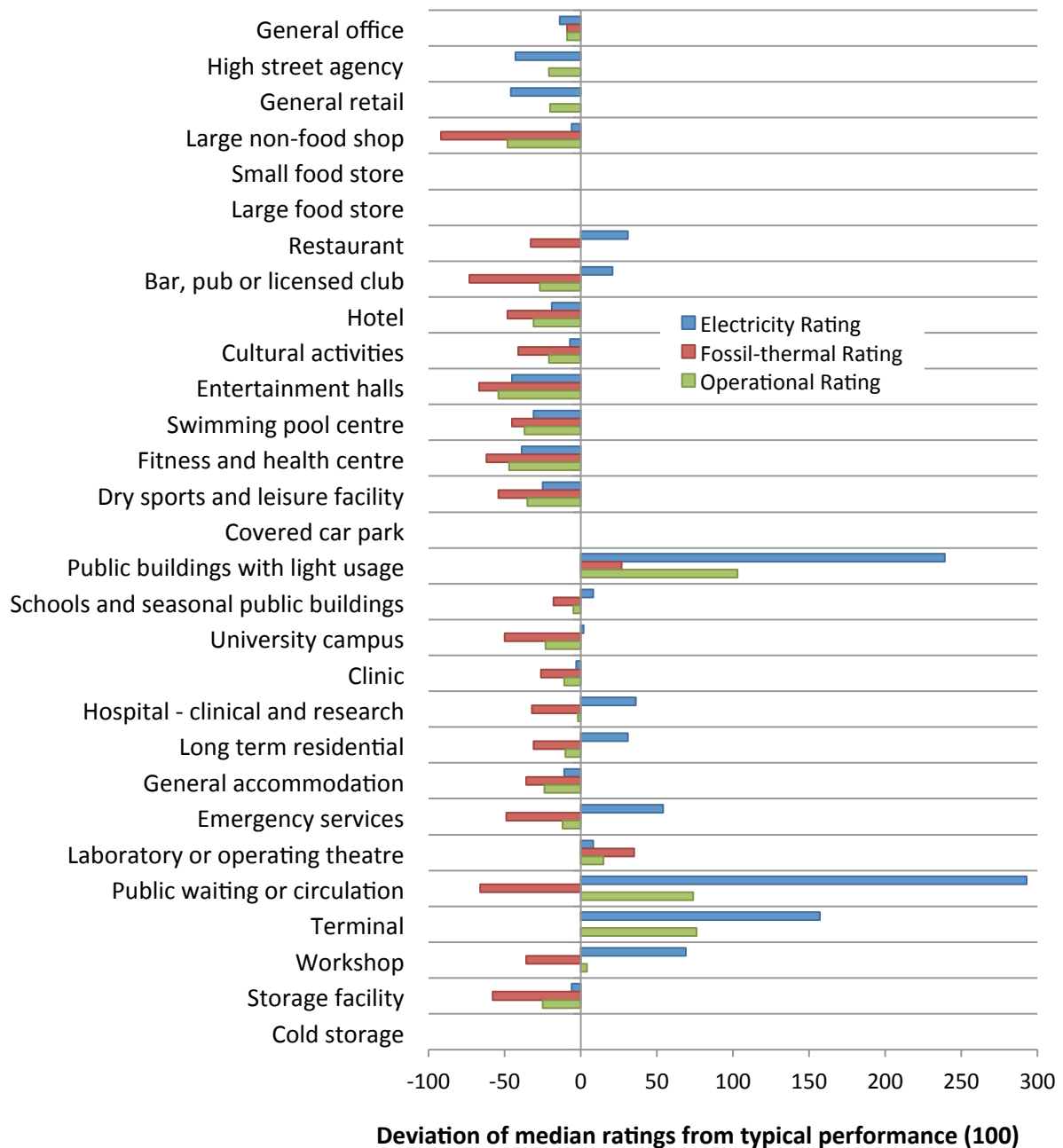


Figure 3-9 Energy ratings by fuel type by benchmark category

The figure indicates the following:

- Many categories show a trend towards higher electricity consumption and lower fossil-thermal energy use compared with the benchmarks. This confirms the findings of the previous review by Bruhns et al. (2011).
- As a result, the differences in ratings for the two fuel types, in the two directions, are cancelled out in some of the combined operational ratings. The 'Hospital – clinical and research' category, for example, shows that the resultant operational rating is very close to the benchmark (98) despite the highly deviating median ratings for electricity (136) and fossil-thermal energy uses (68).
- The operational ratings for the majority of the benchmark categories are below 100.

Figure 3-9 also shows some extremely high ratings in categories where the sample sizes are small. A closer examination of the records under these categories showed that these are mostly due to a few very highly energy-intensive buildings. Under the 'Public buildings with light usage' category, for example, were a barracks and a crematorium, neither of which are 'light usage'. Both buildings were using more than five times the electricity consumption of the benchmark for the category. Similarly, the 'Public waiting or circulation' and 'Terminal' categories were used to classify transport interchanges, airports and ferry terminals, some of which were using up to six times the electricity benchmark.

3.5 ‘Traffic light’ analyses

Table 3-1 shows results from a ‘traffic light’ analysis where the median ratings for electricity and fossil-thermal energy, and the operational ratings, are coded with colours based on the sample size and the rating. The criteria used for the analysis are as in the previous review by Bruhns et al. (2011) where:

- **Green** cells indicate that the median rating is less than 25% (or one grade) away from the benchmark, and that immediate revision of the benchmark value may not be justified.
- **Red** cells indicate that the median rating is more than 25% (or one grade) away from the benchmark, indicating that the benchmark value needs attention.
- **Light grey** coloured cells indicate that the sample sizes in these categories are smaller than 50, and are thus insufficient to allow meaningful evaluation of the benchmarks until larger samples are collected.

Table 3-1 Traffic light analysis by benchmark category

| Benchmark Category | No. of buildings | Electrical Rating Median | Fossil-thermal Rating Median | Operational Rating Median |
|---------------------------------------|------------------|--------------------------|------------------------------|---------------------------|
| General office | 2,911 | 86 | 91 | 91 |
| High street agency | 30 | 57 | . | 79 |
| General retail | 33 | 54 | . | 80 |
| Large non-food shop | 1 | 94 | 8 | 52 |
| Restaurant | 21 | 131 | 67 | 100 |
| Bar, pub or licensed club | 7 | 121 | 27 | 73 |
| Hotel | 16 | 81 | 52 | 69 |
| Cultural activities | 544 | 93 | 59 | 79 |
| Entertainment halls | 203 | 55 | 33 | 46 |
| Swimming pool centre | 261 | 69 | 55 | 63 |
| Fitness and health centre | 42 | 61 | 38 | 53 |
| Dry sports and leisure facility | 606 | 75 | 46 | 65 |
| Public buildings with light usage | 4 | 339 | 127 | 203 |
| Schools and seasonal public buildings | 12,563 | 108 | 82 | 95 |
| University campus | 1,442 | 102 | 50 | 77 |
| Clinic | 728 | 97 | 74 | 89 |
| Hospital - clinical and research | 573 | 136 | 68 | 98 |
| Long term residential | 990 | 131 | 69 | 90 |
| General accommodation | 196 | 89 | 64 | 76 |
| Emergency services | 746 | 154 | 51 | 88 |
| Laboratory or operating theatre | 74 | 108 | 135 | 115 |
| Public waiting or circulation | 5 | 393 | 34 | 174 |
| Terminal | 2 | 257 | 100 | 176 |
| Workshop | 128 | 169 | 64 | 104 |
| Storage facility | 25 | 94 | 42 | 75 |
| All | 22,151 | | | |

The analysis (Table 3-1) indicates the following:

- The median ratings for electricity and fossil-thermal energy use by buildings in the ‘General office’ and ‘Schools and seasonal public buildings’ categories, which together account for nearly 70% of the DEC records, are within 25% of the benchmarks.
- The resultant operational ratings of 3 of the 14 categories analysed were found to be more than 25% away from the benchmarks. The median operational ratings of ‘Entertainment halls’ and ‘Dry sports and leisure facility’ continue to be considerably lower than the benchmarks (Bruhns et al., 2011).
- 6 out of 14 electrical ratings and 12 out of 14 median fossil-thermal ratings are coloured in red. This shows that the focus should be placed on assessing the validity of the benchmarks for each fuel type rather than the resultant operational rating.
- The fact that high electricity consumption is compensated by low fossil-thermal energy use results in an operational rating which requires no immediate action – on these criteria - in the ‘Hospital - clinical and research’, ‘Long term residential’, ‘Emergency services’ and ‘Workshop’ categories.
- 11 of the 25 categories do not have sufficient sample sizes.

While Table 3-1 suggests that only 3 out of 14 benchmarks require immediate attention by the criteria set in the 2011 review, it is important to say that those criteria were rather liberal, specifying as they did that only deviations greater than 25% from benchmarks were sufficient to justify remedial action. The implications of this criterion were therefore examined with a second traffic light analysis, to see what would be the result of taking 10% deviations. Table 3-2 shows the results.

Varying shades of red are used to indicate the different degrees to which ratings deviate from the benchmarks (See the key below). The shades become gradually darker every 10% away from actual performance, with deviations greater than 30% marked by the darkest colour.






| | |
|---|---|
|  | Less than 10% deviation from benchmarks |
|  | 10 - 20% deviation |
|  | 20 - 30% deviation |
|  | More than 30% deviation |
|  | Number of records < 50 |

Table 3-2 Traffic light analysis by benchmark category with 10% deviation criteria

| Benchmark Category | No. of buildings | Electrical Rating Median | Fossil-thermal Rating Median | Operational Rating Median |
|---------------------------------------|------------------|--------------------------|------------------------------|---------------------------|
| General office | 2,911 | 86 | 91 | 91 |
| High street agency | 30 | 57 | . | 79 |
| General retail | 33 | 54 | . | 80 |
| Large non-food shop | 1 | 94 | 8 | 52 |
| Restaurant | 21 | 131 | 67 | 100 |
| Bar, pub or licensed club | 7 | 121 | 27 | 73 |
| Hotel | 16 | 81 | 52 | 69 |
| Cultural activities | 544 | 93 | 59 | 79 |
| Entertainment halls | 203 | 55 | 33 | 46 |
| Swimming pool centre | 261 | 69 | 55 | 63 |
| Fitness and health centre | 42 | 61 | 38 | 53 |
| Dry sports and leisure facility | 606 | 75 | 46 | 65 |
| Public buildings with light usage | 4 | 339 | 127 | 203 |
| Schools and seasonal public buildings | 12,563 | 108 | 82 | 95 |
| University campus | 1,442 | 102 | 50 | 77 |
| Clinic | 728 | 97 | 74 | 89 |
| Hospital - clinical and research | 573 | 136 | 68 | 98 |
| Long term residential | 990 | 131 | 69 | 90 |
| General accommodation | 196 | 89 | 64 | 76 |
| Emergency services | 746 | 154 | 51 | 88 |
| Laboratory or operating theatre | 74 | 108 | 135 | 115 |
| Public waiting or circulation | 5 | 393 | 34 | 174 |
| Terminal | 2 | 257 | 100 | 176 |
| Workshop | 128 | 169 | 64 | 104 |
| Storage facility | 25 | 94 | 42 | 75 |
| All | 22,151 | | | |

Table 3-2 shows the following:

- On these more stringent criteria, 9 out of 14 categories now fall in the range where attention is needed to the benchmarks, compared to the 3 shown in Table 3-1.
- 9 out of 14 electrical ratings and 13 out of 14 fossil-thermal ratings are more than 10% away from the benchmarks.
- The median operational ratings of 5 out of 14 benchmark categories are within 10% of the corresponding benchmarks. This includes two of the largest categories 'General office' and 'Schools and seasonal public buildings'.

3.6 Comparison of the current and the 2011 DEC analyses

Figure 3-10 and Figure 3-11 show comparisons of the current median ratings for electricity and fossil-thermal energy use in each benchmark category with the results from the previous review by Bruhns et al. (2011). Comparisons are made only for those categories that have more than 50 buildings.

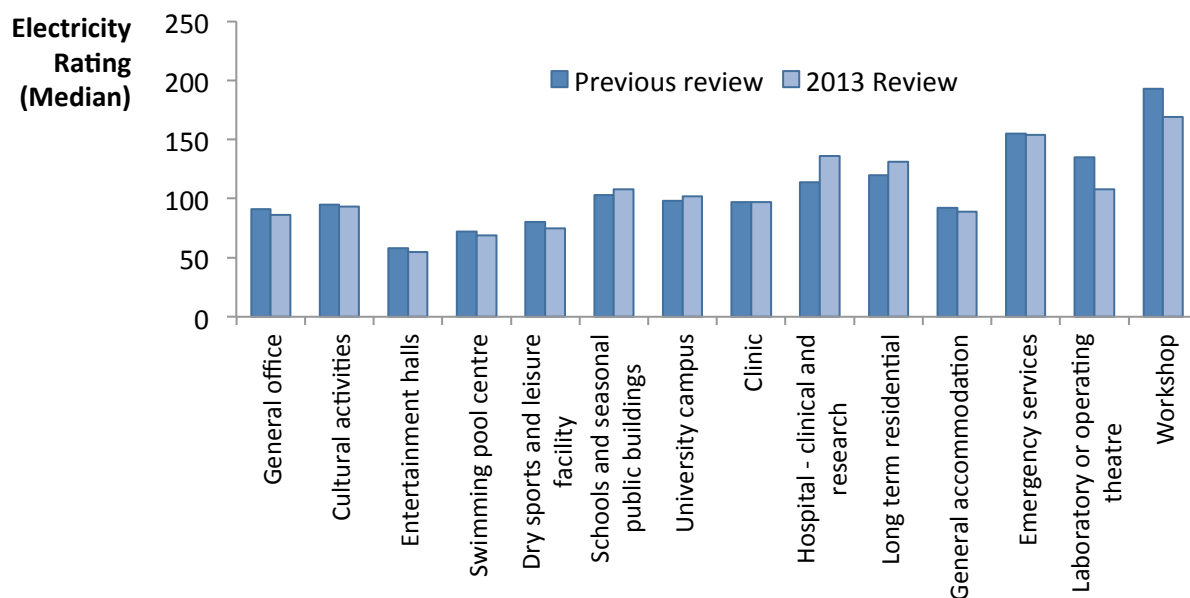


Figure 3-10 Comparison of median electricity ratings between the previous and current reviews

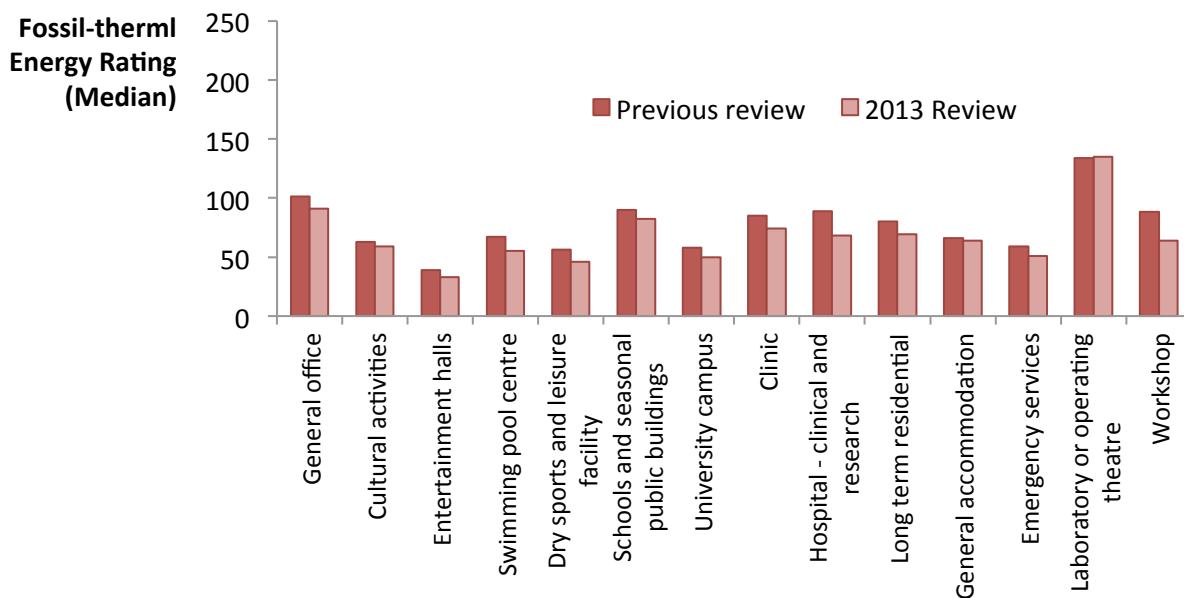


Figure 3-11 Comparison of median fossil-thermal energy ratings between the previous and current reviews

Figure 3-10 shows the following:

- Changes in median values over the period show that electricity consumption has decreased in 9 out of 14 benchmark categories.
- The buildings under the 'Schools and seasonal public buildings', 'University campus', 'Hospital - clinical and research' and 'Long term residential' categories however are more intensive in electrical energy use.

Figure 3-11 shows the following:

- There is a clear decrease in fossil-thermal energy use in 13 out of 14 benchmark categories.
- 'Laboratory or operating theatre' category was the only category that showed an increase in the fossil-thermal rating.

While it is possible to speculate on the factors that may have caused these changes in electricity and fossil-thermal energy use such as increases in fuel price, warmer winters, or more extensive use of ICT and other electronic equipment, further analyses including longitudinal and case studies are required to fully understand these trends.

4 Longitudinal Analyses

This section gives results from the longitudinal study based on the dataset described in section 2.2.2. The analyses show changes in the performance of buildings over the three-year period from 2009 to 2011.

4.1 Changes in energy performances

Figure 4-1 and Figure 4-2 show the changes in median ratings for electricity and fossil-thermal energy uses from 2009 to 2011 from a sample made up of the same buildings in each year. The ratings were plotted for the 6 benchmarking categories.

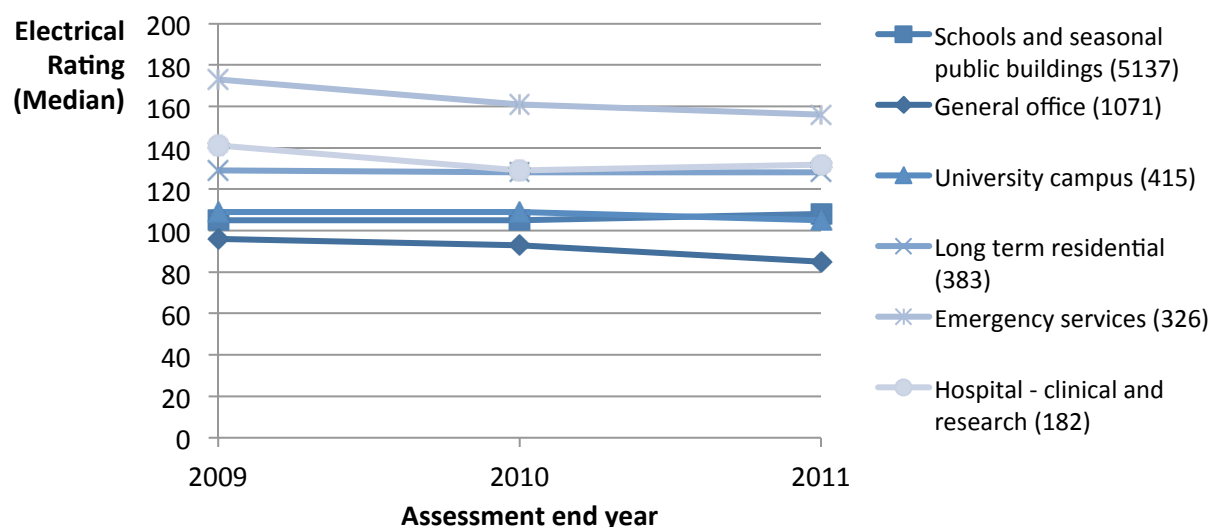


Figure 4-1 Changes in median electricity ratings over three years (numbers of buildings in each year are shown in brackets)

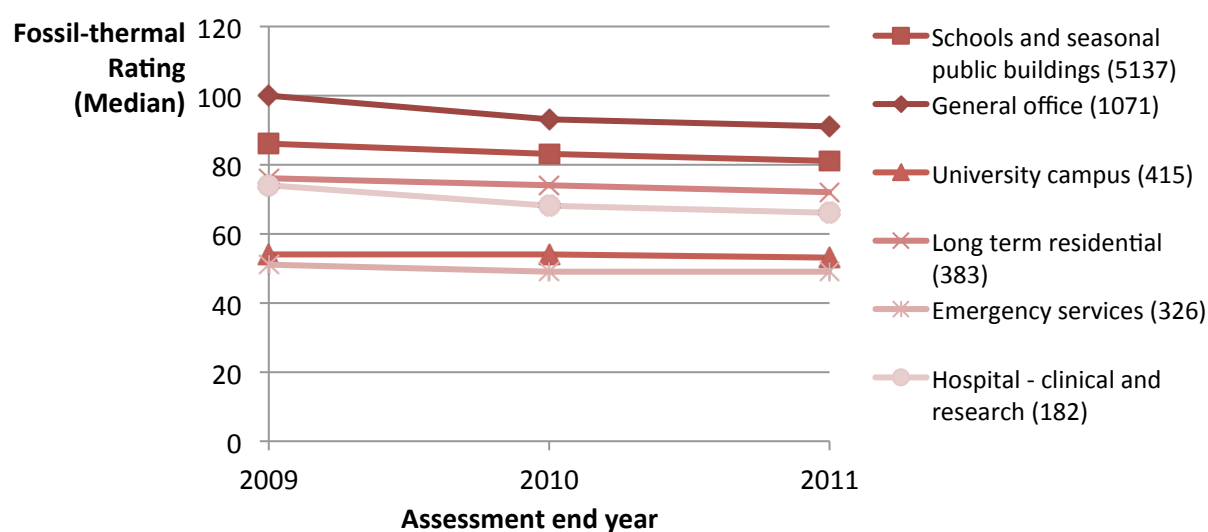


Figure 4-2 Changes in median fossil-thermal ratings over three years (numbers of buildings in each year are shown in brackets)

Figure 4-1 shows the following:

- There is no clear overall trend in electricity consumption by buildings in the 6 categories taken together.
- The buildings under the 'General office' and 'Emergency services' categories were more than 10% less intensive in electricity use by 2011. Similarly, the electrical rating of buildings under the 'University campus', 'Hospital – clinical and research' and 'Long term residential' reduced between 1% and 6% by 2011.
- In contrast with other categories, there was a 3% increase in electrical ratings of buildings in the 'Schools and seasonal public buildings' category.

Figure 4-2 shows the following:

- Buildings under all six benchmark categories show a clear decrease in fossil-thermal energy ratings over the three years.
- The largest reduction in fossil-thermal ratings occurred in buildings under the 'Hospital – clinical and research' and 'General office' categories at 11 and 9% respectively.
- The fossil-thermal performance changed the least in buildings under the 'University campus' with a 2% reduction in the median.

The changes in the pattern of electricity and fossil-thermal energy use are distinctively different, although both show trends towards lower median values for ratings in most of the benchmark groups. These trends may become clearer when more DEC data are lodged in the future.

Moreover, low granularity of the data accumulated from DECs meant that there was not enough information to explain why such trends occurred in these buildings. It would be desirable to make a more detailed analysis, to uncover whether these declines are due to general external factors such as the warming climate or the cutting of staff and budgets, and the extent to which they are attributable to improved efficiency and better management, perhaps encouraged by rising fuel prices.

4.2 Changes in DEC grades by activity type

This section describes changes in the distribution of DEC grades of buildings under the six benchmark categories that were analysed in the previous section. These were ‘General office’, ‘Schools and seasonal public buildings’, ‘University campus’, ‘Long term residential’, ‘Emergency services’, and ‘Hospital - clinical and research’.

The figures below show changes in the number of buildings in each DEC grade band occurring over the three-year period. Note that these trends are again based on the same buildings in each of the three years.

4.2.1 Schools and seasonal public buildings

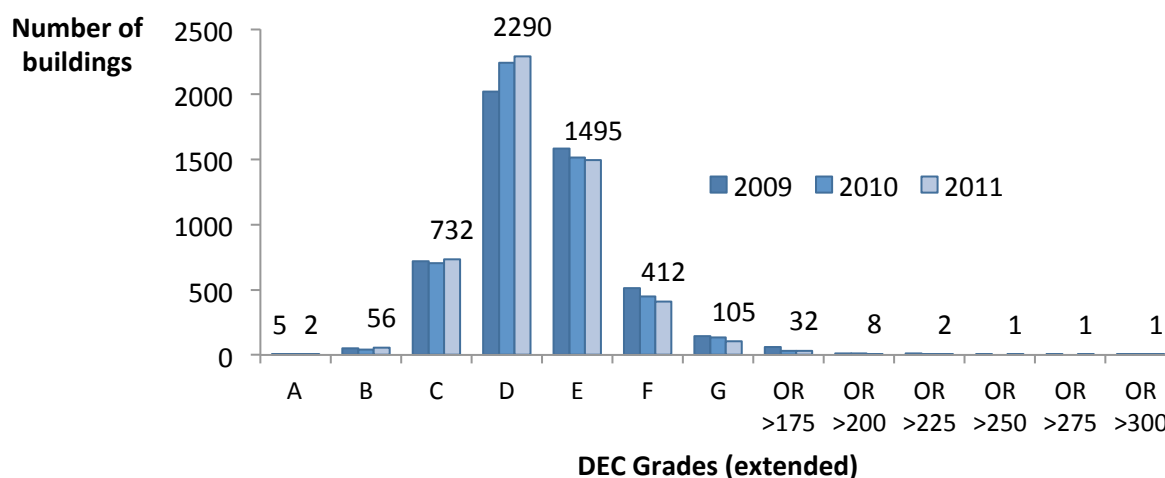


Figure 4-3 Changes in the distribution of DEC grades in the ‘Schools and seasonal public buildings’ category between 2009 and 2011 (numbers on bars are for 2011)

Figure 4-3 shows the following:

- Less than 2% of all buildings had grades A or B by 2011.
- There was a 2% increase in the number of buildings in the C grade band to 732 (14.2%) by the end of the three-year period.
- Numbers of buildings in the D grade band increased by 13% from 2023 (39.4%) to 2290 (44.6%) between 2009 and 2011.
- There were 6% and 20% decreases in the number of buildings in grade bands E and F.
- Approximately 3% of buildings had a G grade or worse performance in 2011. This is a reduction of 39% (95) from the 2009 figure of 245.

An inspection of the data for the top performing school buildings with A grades showed that their energy performance, hence their grades, had changed dramatically over the three-year period. In 2009 there were five schools that achieved A grades. None of the five however retained their grades after three years. By 2011, these schools were to be found at the opposite end of the spectrum, with significantly greater energy use, acquiring grades as a result of either E or F. One school was found to be using more than twice the amount of electricity used in 2009. Despite this significant increase in electricity use however, this school had managed to achieve a B grade due to a low use of fossil-thermal energy.

In contrast, two schools that achieved A grades in 2011 showed dramatic decreases in energy use from 2009. The heating consumption of one of the schools decreased more than 13-fold from 123kWh/m² to 9kWh/m² between 2009 and 2011. The other school showed a 72% decrease in its electrical EUI from 46kWh/m² to 13kWh/m² between the years 2009 and 2010. These are substantial changes in performance and would justify a more detailed investigation of these particular schools. If the changes are real - and these are not errors – there would be an excellent opportunity here for case studies, to determine what these schools have been doing right.

4.2.2 General office

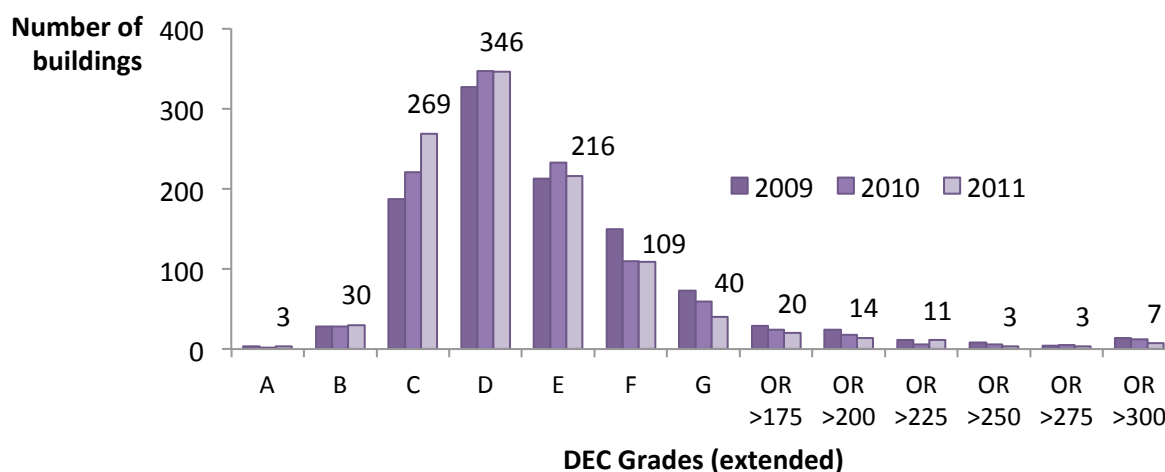


Figure 4-4 Changes in the distribution of DEC grades of buildings under the ‘General office’ category between 2009 and 2011 (numbers on bars are for 2011)

Figure 4-4 shows the following:

- Only 0.3% and 2.8% of office buildings have achieved A or B grades respectively, with no significant changes in numbers over the period.
- The number of buildings with grade C increased by 44% from 187 (17%) to 269 (25%) by 2011.
- Approximately 50% of buildings achieved grades D or E throughout the three-year period, with more than 30% falling in the D grade band.
- A sudden decrease of 20% in the number of buildings in the F grade band occurred between 2009 and 2010.
- There was a 40% reduction in the number of office buildings with G grades or worse, from 163 (15%) to 98 (9%) by 2011.

4.2.3 University campus

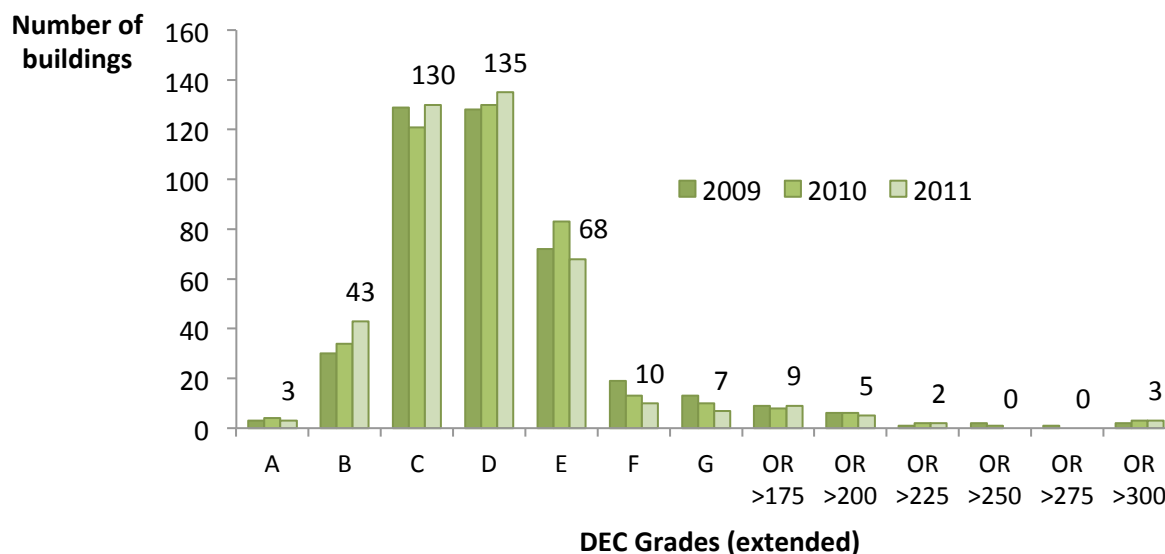


Figure 4-5 Changes in the distribution of DEC grades in the ‘University campus’ category between 2009 and 2011 (numbers on bars are for 2011)

Figure 4-5 shows the following:

- Only 3 buildings (1%) had A grades in 2011.
- There was a 43% increase in the number of buildings with B grades by 2011, from 30 to 43 buildings.
- In each year, more than 60% of buildings are found in grade bands C and D, with approximately 30% in each band.
- A generally decreasing trend occurs in the number of buildings with F and G grades.
- The number of buildings with operational ratings greater than 175, hence worse than a G grade, decreased from 21 to 19 between 2009 and 2011.

4.2.4 Long term residential

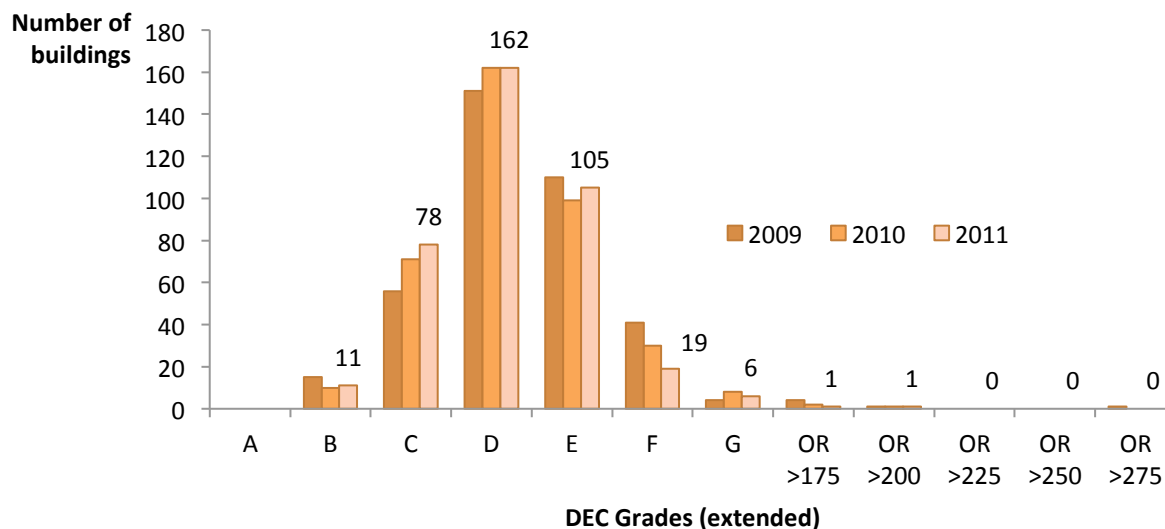


Figure 4-6 Changes in the distribution of DEC grades in the ‘Long term residential’ category between 2009 and 2011 (numbers on bars are for 2011)

Figure 4-6 shows the following:

- No buildings achieved A grades between 2009 and 2011.
- The B grade band accounted in 2011 for approximately 3% of all buildings in the group.
- Approximately 20% of all buildings had C grades by 2011, an increase of 39% from 56 to 78.
- More than 66% of all buildings were performing better than the benchmarks. 42% of all buildings were in the D grade band in 2011.
- Over the three-year period, the number of buildings with F grades reduced considerably.
- Approximately 2% of all buildings had G grades or worse performance at the end of the three-year period.

4.2.5 Emergency services

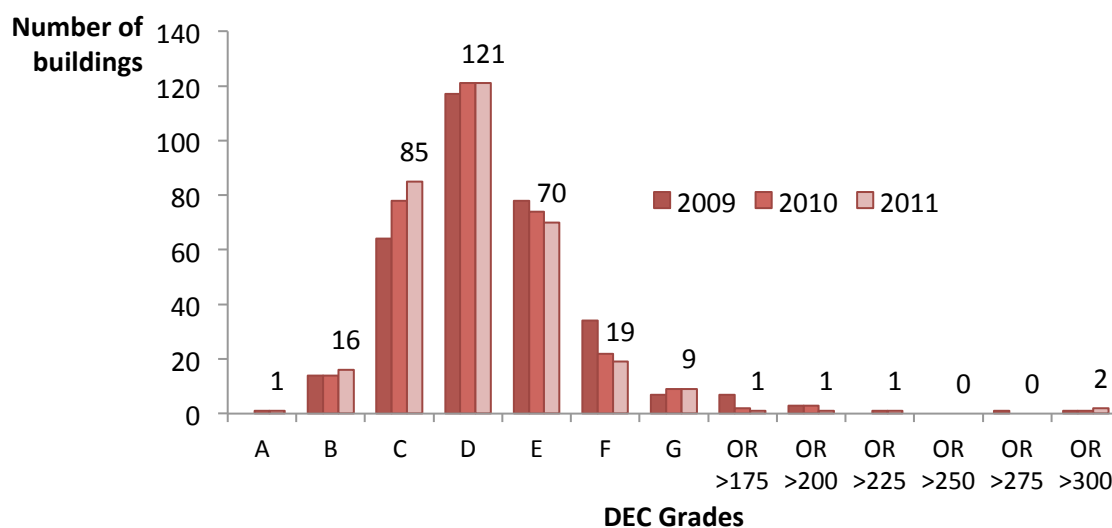


Figure 4-7 Changes in the distribution of DEC grades in the ‘Emergency services’ category between 2009 and 2011 (numbers on bars are for 2011)

Figure 4-7 shows the following:

- Approximately 5% of all buildings had A or B grades in 2011.
- A 6% increase in the number of buildings with C grades took place between 2009 and 2011 from 64 (20%) to 85 (26%).
- 68% of all buildings were performing better than the benchmarks in 2011. 37% of these buildings fell in the D grade band.
- There were 3 to 4% decreases in the number of buildings in grade bands E and F between 2009 and 2011.
- Less than 5% of all buildings had grades worse than G in 2011, a 2% reduction from 2009. There was however a small increase in the number of buildings with operational ratings greater than 300.

4.2.6 Hospital (clinical and research)

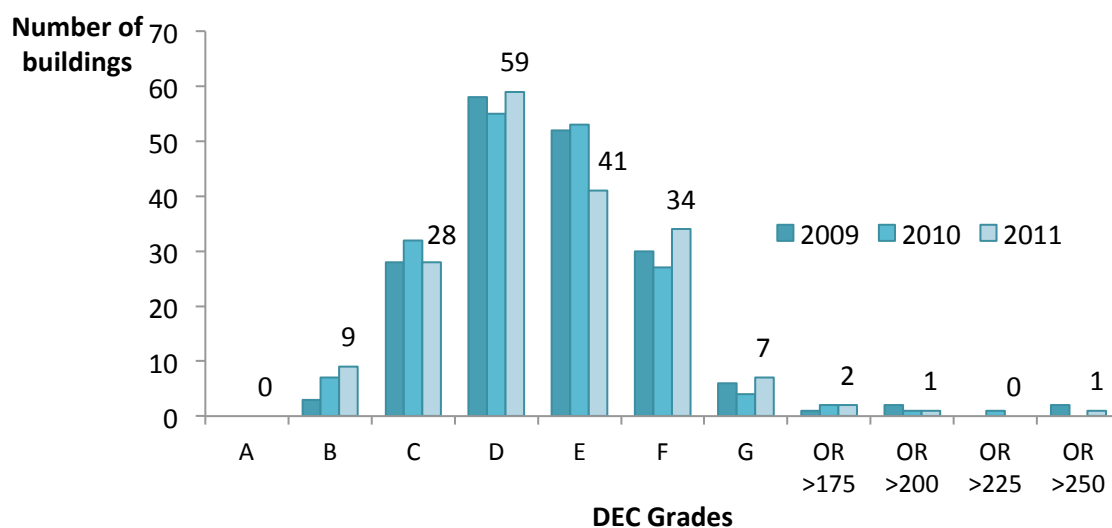


Figure 4-8 Changes in the distribution of DEC grades in the ‘Hospital (clinical and research)’ category between 2009 and 2011 (numbers on bars are for 2011)

Figure 4-8 shows the following:

- No buildings achieved A grades over the three-year period.
- Approximately 5% of buildings were found in the B grade band in 2011, which was an increase of 3% over the 2009.
- 53% of all buildings were found to perform better than the benchmarks.
- The number of buildings in grade bands C and D remained unchanged between 2009 and 2011.
- There was a 6% decrease in the number of buildings with E grades, in contrast to a 2% increase in buildings with F grades.
- Buildings with G grades or worse performance accounted for 6% of all buildings. The changes over the three-year period were negligible.

4.2.7 Summary

Taken together, these statistics for the operational ratings of buildings in the six groups show a number of features.

- The distributions of grades in the six categories indicate that a majority of buildings are placed in the grade D band or above. This indicates that most buildings are performing above the benchmarks in CIBSE *TM46*, as shown in Table 3-1.
- All six activity types have shown notable increases in the number of buildings with D or better grades over the three-year period, meaning that there has been a general improvement in energy performance in these categories.

It should be reiterated that this analysis is based only on buildings that have lodged DEC for three consecutive years. It is, to that extent, biased. These buildings are perhaps more likely to be under

management committed to understanding and improving performance. As discussed in Section 6, the sample of buildings studied in this section accounts for only about a quarter of all buildings with DECs.

5 Additional analyses

5.1 Electrically heated buildings

This section describes the characteristics and energy performance of buildings that use electricity as the main heating fuel (MHF). In all, 3.3% (1,543) of all buildings were separated from the main analyses and processed as described in Section 2.1. Figure 5-1 shows the number of buildings that use electricity as a main source of energy for heating compared to other non-electrically heated buildings.

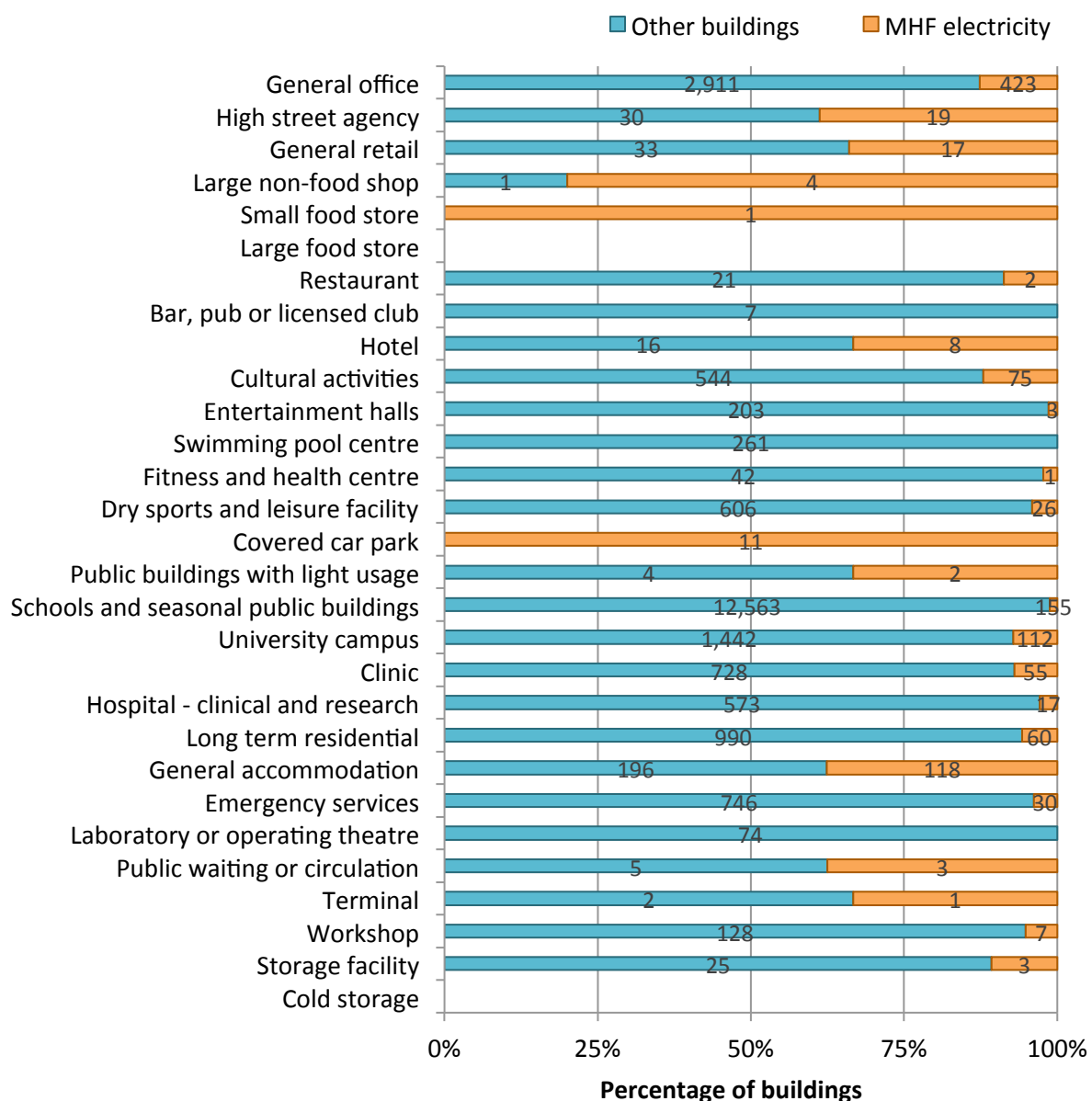


Figure 5-1 comparison of the numbers of electrically heated buildings to the other buildings in the dataset described in section 2.2.1

Table 5-1 Comparisons of the EUI of electrically and non-electrically heated buildings

| Benchmark category | Other buildings | | MHF electricity | |
|--|---|---|---|---|
| | Electrical EUI (kWh/m ²) | Fossil-thermal EUI (kWh/m ²) | Electrical EUI (kWh/m ²) | Fossil-thermal EUI (kWh/m ²) |
| | Median | Median | Median | Median |
| 1 General office | 86 | 116 | 146 | 0 |
| 2 High street agency | 82 | 100 | 138 | 0 |
| 3 General retail | 90 | 97 | 105 | 0 |
| 4 Large non-food shop | 66 | 16 | 93 | 9 |
| 5 Small food store | - | - | 567 | 0 |
| 6 Large food store | - | - | - | - |
| 7 Restaurant | 127 | 246 | 244 | 52 |
| 8 Bar, pub or licensed club | 157 | 107 | - | - |
| 9 Hotel | 85 | 170 | 147 | 77 |
| 10 Cultural activities | 70 | 124 | 104 | 0 |
| 11 Entertainment halls | 87 | 149 | 197 | 12 |
| 12 Swimming pool centre | 192 | 696 | - | - |
| 13 Fitness and health centre | 102 | 178 | 186 | 0 |
| 14 Dry sports and leisure facility | 79 | 167 | 82 | 2 |
| 15 Covered car park | - | - | 34 | 0 |
| 16 Public buildings with light usage | 69 | 146 | 33 | 0 |
| 17 Schools and seasonal public buildings | 45 | 130 | 91 | 3 |
| 18 University campus | 86 | 128 | 108 | 14 |
| 19 Clinic | 75 | 158 | 122 | 0 |
| 20 Hospital - clinical and research | 122 | 301 | 202 | 41 |
| 21 Long term residential | 85 | 301 | 109 | 43 |
| 22 General accommodation | 58 | 202 | 119 | 14 |
| 23 Emergency services | 108 | 209 | 217 | 0 |
| 24 Laboratory or operating theatre | 242 | 238 | - | - |
| 25 Public waiting or circulation | 118 | 43 | 54 | 0 |
| 26 Terminal | 193 | 227 | 392 | 0 |
| 27 Workshop | 62 | 120 | 80 | 45 |
| 28 Storage facility | 37 | 77 | 29 | 0 |
| 29 Cold storage | - | - | - | - |

* Note that these are actual consumption figures and have not been adjusted

Figure 5-1 and Table 5-1 show the following:

- Among the categories with sample sizes greater than 50, the ‘General accommodation’ (38%) and ‘General retail’ (34%) categories had the highest proportions of electrically heated buildings relative to the other buildings. Closer inspection revealed that the majority of these were student housing (95%) and indoor markets (94%) respectively.
- There are notable differences in the pattern of energy use between electrically and non-electrically heated buildings, as would be expected. This suggests that using the current energy benchmarks to evaluate the performance of these buildings is not likely to provide meaningful feedback, although the resulting CO₂ benchmarks may be relevant.

5.2 Composite DECs

This section describes the characteristics of DECs lodged using the composite method. Note that the statistics in the tables below are based on the raw dataset before it was prepared as described in section 2.1.

Table 5-2 shows the numbers and percentages of buildings in each category that have lodged DECs using multiple activity type classifications. The columns under the composite DECs are shaded in two different colours:

- Darker shades of green highlight categories that have relatively large sample sizes.
- Darker shades of blue highlight categories with high proportions of composite DECs.

Table 5-2 Numbers and percentages of composite DECs

| Category | All DECs | Composite DECs | |
|--|----------|----------------|----------|
| | N | N | % of all |
| 1 General office | 16,848 | 3,934 | 23% |
| 2 High street agency | 1,022 | 39 | 4% |
| 3 General retail | 212 | 38 | 18% |
| 4 Large non-food shop | 15 | 3 | 20% |
| 5 Small food store | 3 | 2 | 67% |
| 6 Large food store | 1 | 0 | 0% |
| 7 Restaurant | 958 | 793 | 83% |
| 8 Bar, pub or licensed club | 245 | 215 | 88% |
| 9 Hotel | 112 | 18 | 16% |
| 10 Cultural activities | 3,327 | 886 | 27% |
| 11 Entertainment halls | 1,107 | 358 | 32% |
| 12 Swimming pool centre | 1,150 | 248 | 22% |
| 13 Fitness and health centre | 665 | 455 | 68% |
| 14 Dry sports and leisure facility | 5,160 | 2,338 | 45% |
| 15 Covered car park | 379 | 341 | 90% |
| 16 Public buildings with light usage | 30 | 4 | 13% |
| 17 Schools and seasonal public buildings | 59,668 | 2,213 | 4% |
| 18 University campus | 9,540 | 710 | 7% |
| 19 Clinic | 3,498 | 697 | 20% |
| 20 Hospital - clinical and research | 3,752 | 135 | 4% |
| 21 Long term residential | 5,122 | 240 | 5% |
| 22 General accommodation | 2,020 | 256 | 13% |
| 23 Emergency services | 3,463 | 370 | 11% |
| 24 Laboratory or operating theatre | 553 | 237 | 43% |
| 25 Public waiting or circulation | 61 | 30 | 49% |
| 26 Terminal | 3 | 0 | 0% |
| 27 Workshop | 1,064 | 95 | 9% |
| 28 Storage facility | 227 | 54 | 24% |
| 29 Cold storage | 20 | 20 | 100% |
| All | 120,253 | 14,729 | 12% |

Table 5-2 shows the following:

- Approximately 12% of the records in the raw database were composite DEC.
- In absolute terms, the largest number of composite DEC was lodged under the 'General office' category. A closer look at these records revealed that these buildings consisted mainly of offices combined with ancillary activities such as laboratories, storage spaces or canteens. Similarly composite DEC under the 'Dry sports and leisure facility' and 'Schools and seasonal public buildings' included a range of activities such as restaurants and swimming pools.
- Composite DEC were dominant in the benchmark categories 'Cold storage' and 'Covered car park'. A detailed analysis showed that the order in which multiple benchmark categories were selected was not always reflective of the primary function of a building. Such incidents were particularly prevalent where, for example, small canteens forming parts of schools or offices, which would be classified under the 'Restaurant' category, were used as the first activity. This highlights the difficulties for an analysis of composite DEC based solely on the benchmark categories specified in the database, since these frequently do not correspond to the primary functions of the buildings.

Note that the numbers of composite DEC in each benchmark category were counted based on an assumption that the benchmarks of first choice were indicative of the primary activity of these buildings. As discussed above however, this may not be true in some cases, since the approved OR assessment software does not allow the DEC assessors to designate the "main benchmark category". In such instances, the benchmark category with the largest floor area or the largest contribution to the CO₂ benchmark could be used as a basis for identifying the main category.

5.3 Pro-rated DECs

This section describes the type of buildings (or sites) that have lodged pro-rated DECs based on site-level energy consumption data. Table 5-3 shows the numbers and percentages of pro-rated DECs under each benchmark category. The 'Pro-rated EUI' columns are shaded in the following colours:

- Darker shades of purple highlight categories that have larger numbers of pro-rated DECs.
- Darker shades of blue highlight categories with high proportions of pro-rated DECs.

Table 5-3 Numbers and percentages of DECs lodged using pro-rated EUI

| Benchmark category | All | Pro-rated DECs | |
|--|---------|----------------|----------|
| | N | N | % of all |
| 1 General office | 16,848 | 1,731 | 10 |
| 2 High street agency | 1,022 | 8 | 1 |
| 3 General retail | 212 | 23 | 11 |
| 4 Large non-food shop | 15 | 0 | 0 |
| 5 Small food store | 3 | 2 | 67 |
| 6 Large food store | 1 | 0 | 0 |
| 7 Restaurant | 958 | 275 | 29 |
| 8 Bar, pub or licensed club | 245 | 56 | 23 |
| 9 Hotel | 112 | 25 | 22 |
| 10 Cultural activities | 3,327 | 358 | 11 |
| 11 Entertainment halls | 1,107 | 108 | 10 |
| 12 Swimming pool centre | 1,150 | 41 | 4 |
| 13 Fitness and health centre | 665 | 92 | 14 |
| 14 Dry sports and leisure facility | 5,160 | 1,078 | 21 |
| 15 Covered car park | 379 | 8 | 2 |
| 16 Public buildings with light usage | 30 | 8 | 27 |
| 17 Schools and seasonal public buildings | 59,668 | 9,262 | 16 |
| 18 University campus | 9,540 | 4,031 | 42 |
| 19 Clinic | 3,498 | 398 | 11 |
| 20 Hospital - clinical and research | 3,752 | 1,412 | 38 |
| 21 Long term residential | 5,122 | 709 | 14 |
| 22 General accommodation | 2,020 | 845 | 42 |
| 23 Emergency services | 3,463 | 232 | 7 |
| 24 Laboratory or operating theatre | 553 | 211 | 38 |
| 25 Public waiting or circulation | 61 | 0 | 0 |
| 26 Terminal | 3 | 0 | 0 |
| 27 Workshop | 1,064 | 139 | 13 |
| 28 Storage facility | 227 | 33 | 15 |
| 29 Cold storage | 20 | 2 | 10 |
| Invalid | 28 | 1 | 4 |
| All | 120,253 | 21,088 | 18 |

The largest numbers of pro-rated DEC are found under the ‘Schools and seasonal public buildings’ category. A closer examination of these records revealed that these were predominantly secondary schools (Table 5-4). It was found that pro-rated DEC were lodged for separate buildings accommodating different kinds of teaching facilities.

Table 5-4 Numbers of pro-rated DEC under the ‘Schools and seasonal public buildings’ category by building type

| Building types | N | % of total |
|---|-------|------------|
| Clubhouse | 1 | 0 |
| Community centre | 12 | 0 |
| Community facilities | 22 | 0 |
| Community meeting place | 5 | 0 |
| Creche | 2 | 0 |
| Day centre | 5 | 0 |
| Nursery or kindergarten | 30 | 0 |
| Pre-school facility | 2 | 0 |
| Primary and secondary teaching establishments | 43 | 0 |
| Primary school | 731 | 8 |
| Private school | 17 | 0 |
| School | 397 | 4 |
| Secondary school | 5,875 | 63 |
| Social clubs | 2 | 0 |
| Special school | 68 | 1 |
| Speedway | 7 | 0 |
| State primary school | 374 | 4 |
| State school | 59 | 1 |
| State secondary school | 1,609 | 17 |
| Village hall | 1 | 0 |
| All | 9,262 | 100 |

There was also a large number of pro-rated DEC under the ‘University campus’ category. Table 5-5 below shows that these are not always in fact university buildings. There were significant numbers of pro-rated DEC for separate buildings in sixth form colleges. (These colleges should not properly be included under ‘University campus’, as discussed in section 7.) There were also numerous pro-rated DEC lodged for buildings occupied by central and local government offices, and hospitals.

Table 5-5 Numbers of pro-rated DEC under the ‘University campus’ category by building type

| Building type | N | % of total |
|--------------------|-------|------------|
| Classroom | 376 | 9 |
| Lecture hall | 68 | 2 |
| Sixth form college | 1,286 | 32 |
| University | 2,301 | 57 |
| All | 4,031 | 100 |

Table 5-3 also highlights the benchmark categories with high percentages of DECs based on pro-rated energy uses. Overall, these statistics for pro-rated DECs both by benchmark category and building type show that the vast majority are for parts of schools, universities or hospitals. These are premises that generally have many buildings on one site, where energy use could often be metered centrally but not at the individual building level.

5.4 Buildings with varying occupancy hours

This section analyses those buildings that have claimed extended hours of occupancy. Figure 5-2 shows the percentages of buildings in each benchmark category that have claimed standard or extended occupancy hours respectively. (These are categories that include more than 50 buildings from the dataset described in section 2.2.1.) The total number of buildings in each category is given in brackets.

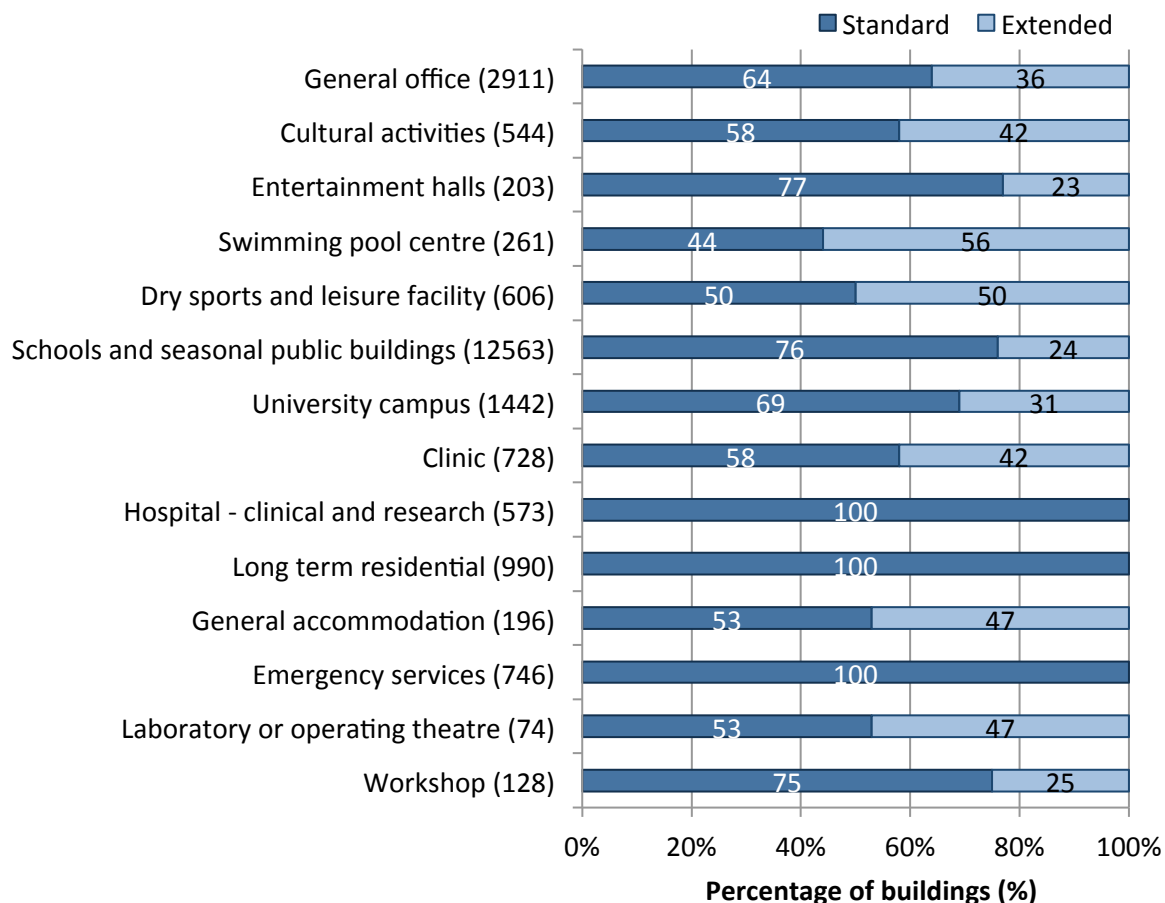


Figure 5-2 Percentages of buildings in each benchmark category which have reported standard or extended occupancy hours

Close examination showed that many buildings in the following categories claimed extended hours:

- ‘Swimming pool centres’ and ‘Dry sports and leisure facilities’ (the highest percentages). These types of building frequently claimed close to the maximum allowed occupancy hours per year.
- Under ‘General accommodation’: numerous halls of residences at universities, and boarding houses.
- Under ‘Laboratory or operating theatre’: laboratories run by the NHS or universities.
- Under ‘Cultural activities’: libraries and museums.
- Under ‘General office’: mostly central or local government offices, with approximately 10% of cases being law courts.

- Under ‘University campus’: university buildings (approximately 70%) and sixth form colleges (20%).
- Under ‘Entertainment halls’: mostly theatres followed by entertainment halls, concert halls and auditoria.

Note that buildings under the ‘Hospital - clinical and research’, ‘Long term residential’ and ‘Emergency services’ categories are not allowed to claim extended hours of occupancy.

We have examined the relationship between extended operating hours and energy use in public sector office buildings. Figure 5-3 and Figure 5-4 give scatter plots of extended occupancy hours against electrical and fossil-thermal EUIs, with the respective regression lines. These results are just for the building types ‘Central government office’ and ‘Local government office’ under the ‘General office’ benchmark category. Note that only those buildings that were identified as being occupied for extended hours were used for the analysis. In total, this included 272 Central government offices and 225 Local government offices.

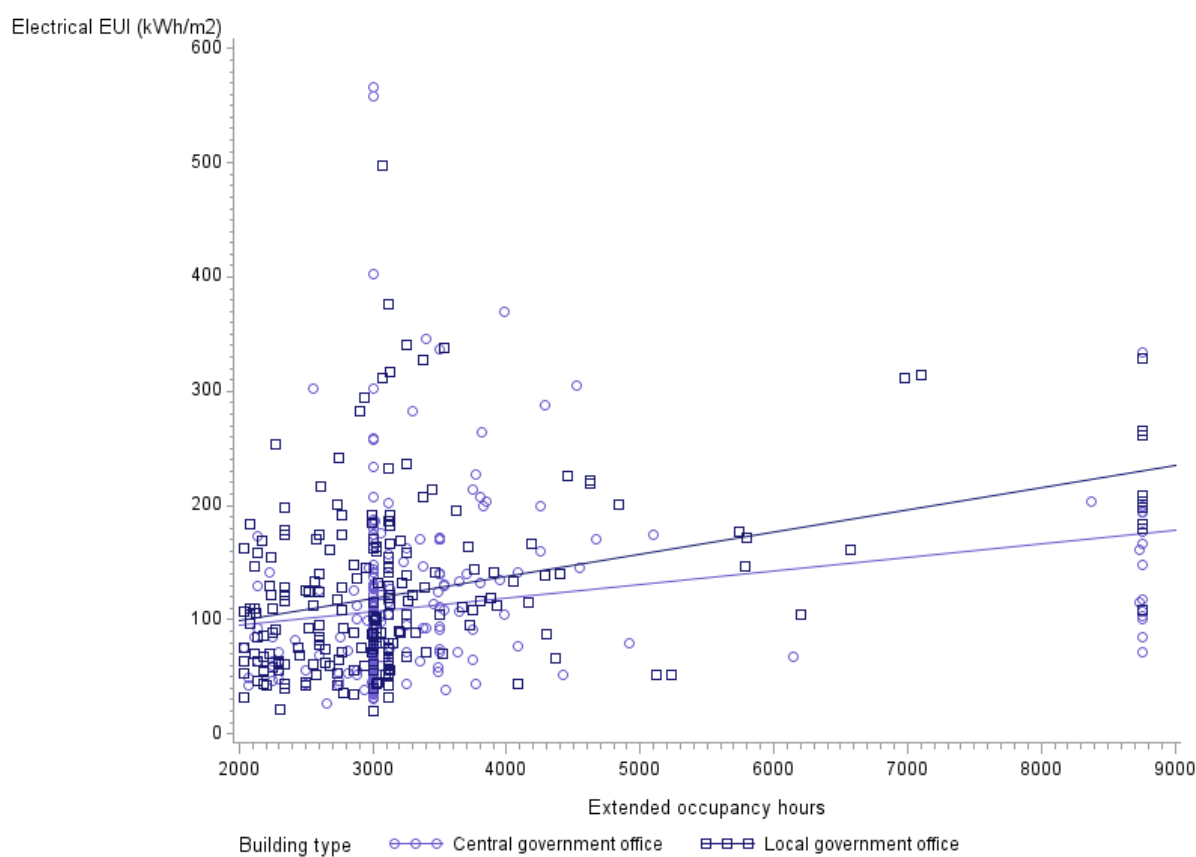


Figure 5-3 Scatter plot of occupancy hours and electrical EUI for Central and Local government office buildings (kWh/m²)

The plot shows considerable variation in electrical EUIs in relation to extended occupancy hours. The line of best-fit shows that there is generally a positive relationship between extended hours and electricity consumption in both Central and Local government offices. This indicates that public sector offices are indeed likely to use more electricity, as their hours of use are extended. The

relationships are however relatively weak. (Pearson correlation coefficients are 0.23 and 0.37 for Central and Local government buildings, respectively.)

The figure also shows a clustering of records around 3000 hours where 50% of the records were found between 2860 and 3350 hours, respectively. Closer examination showed that 116 of 143 (81%) records that claimed precisely 3000 hours belonged to the same single organisation. Further investigation is required to explain the underlying cause. There were, on the other hand, 26 Central and Local government offices (5% of the total) claiming the maximum allowed hours of occupancy.

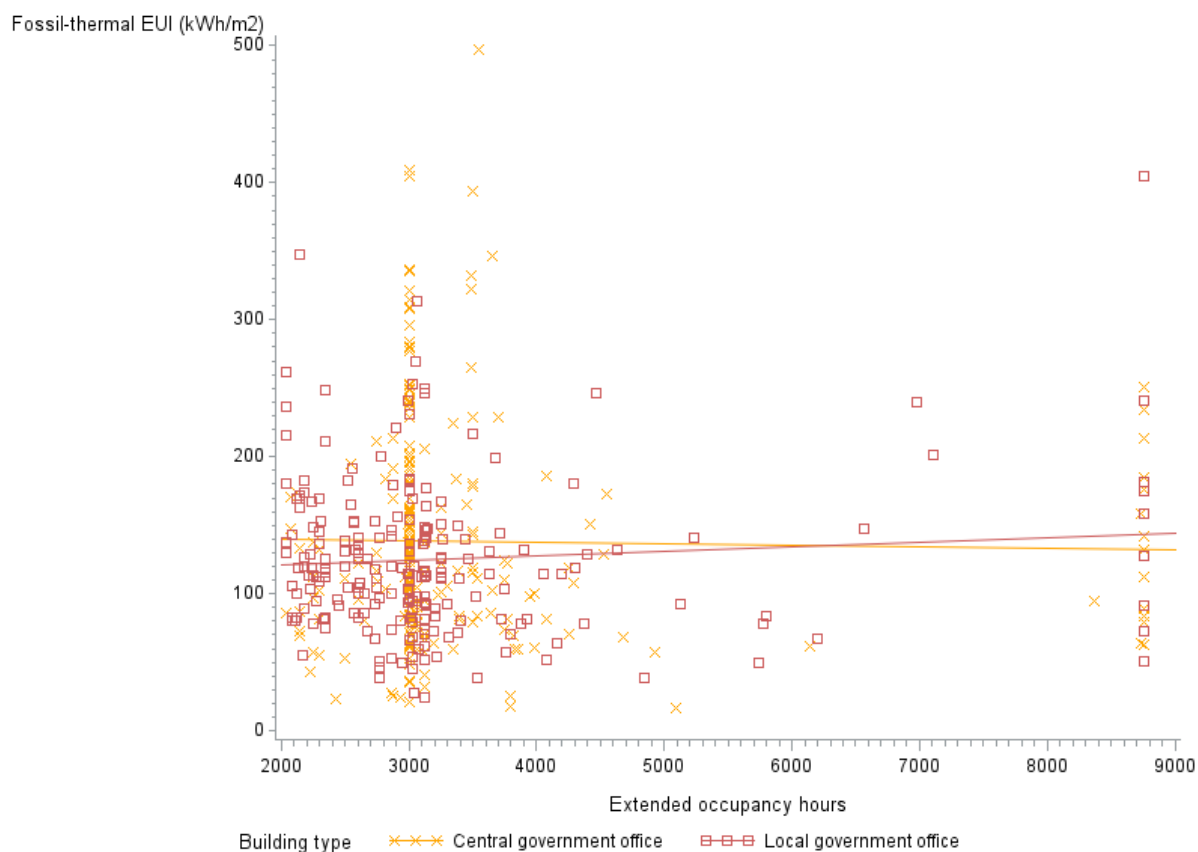


Figure 5-4 Scatter plot of occupancy hours and fossil-thermal EUI for Central and Local government buildings (kWh/m²)

As with the electrical consumption, Figure 5-4 shows a considerable variation in heating energy consumption in relation to occupancy hours. The line of best fit indicates however that there is hardly any systematic relationship between the two variables. (The Pearson correlation coefficients are -0.02 and 0.08 for Central and Local government buildings respectively.) This suggests that the operation of the building services providing space heating and domestic hot water is independent of the hours of occupation. There may be different reasons for such a weak correlation. One cause could be that extended occupancy hours are being claimed inappropriately. Another reason could be that the control systems in these buildings have not been commissioned correctly, and are heating the space and hot water regardless of the pattern of occupation of the building. Both these possible explanations deserve further investigation.

5.5 Separable energy uses

When assessing energy performance of a building to produce DEC, there is an option for surveyors to deduct what are known as *separable* energy uses. These are special types of end use that are uncommon or highly variable in the particular building type (Bruhns et al., 2011).

Table 5-6 shows the number of DEC records where the separable energy uses option was used. These figures were derived from the raw dataset before it was prepared for analysis. Darker shades of blue highlight the activity types with greater numbers of DEC lodged with the separables option.

Table 5-6 Number of DEC records which used the separable energy uses option, by benchmark category

| Benchmark category | Assessment end year | | | | | N | All % |
|---------------------------------------|---------------------|-----------|------------|------------|-----------|------------|-------------|
| | 2008 | 2009 | 2010 | 2011 | 2012 | | |
| | N | N | N | N | N | N | |
| General Office | 25 | 37 | 55 | 66 | 5 | 188 | 44% |
| Restaurant | 1 | 1 | 1 | 1 | . | 4 | 1% |
| Bar, Pub Or Licensed Club | . | . | . | . | 1 | 1 | 0% |
| Cultural Activities | 2 | 3 | 4 | . | . | 9 | 2% |
| Entertainment Halls | . | 1 | 1 | 1 | 1 | 4 | 1% |
| Fitness And Health Centre | . | . | . | 1 | 1 | 2 | 0% |
| Dry Sports And Leisure Facility | 8 | 8 | 12 | 9 | 2 | 39 | 9% |
| Covered Car Park | 2 | 2 | 4 | 4 | 1 | 13 | 3% |
| Schools And Seasonal Public Buildings | . | 1 | 1 | 2 | . | 4 | 1% |
| University Campus | 18 | 23 | 26 | 27 | . | 94 | 22% |
| Clinic | . | 1 | . | . | . | 1 | 0% |
| Hospital - Clinical And Research | . | 6 | 2 | 1 | 3 | 12 | 3% |
| General Accommodation | 10 | 11 | 12 | 11 | . | 44 | 10% |
| Laboratory Or Operating Theatre | 1 | . | . | 2 | . | 3 | 1% |
| Public Waiting Or Circulation | . | 1 | . | . | . | 1 | 0% |
| Workshop | . | 2 | 1 | 4 | . | 7 | 2% |
| Storage Facility | 1 | 1 | 1 | 1 | . | 4 | 1% |
| All | 68 | 98 | 120 | 130 | 14 | 430 | 100% |

Overall, 430 DEC, relating to 220 buildings, were produced using the separable energy uses option. This is approximately 0.36% of the raw dataset (120,253 records). Moreover, Table 5-6 shows that the numbers of records that have used the option have decreased considerably after 2011. There are several possible reasons for such a small number. One cause could be the difficulty of measuring and analysing the energy used by these activities. Another factor could be the rather narrow scope of the list of items eligible for the separable energy uses option. This was highlighted in the previous analysis by Bruhns et al. (2011), which raised the possibility of extending and clarifying the list of separable energy uses. With a revised scope the option could become more useful for DEC assessment.

The table also shows that there are DEC under some benchmark categories for which *TM46* does not allow the use of the separables option (e.g. General Accommodation). These records deserve further investigation.

6 Compliance analysis

There are two ways of investigating the extent to which the owners and occupiers of eligible buildings have complied with the DEC legislation. The first is to look within the DEC database itself, and count the number of certificates lodged for each building. In principle this number should be at least four, for the complete years from 2008 to 2011. Table 6-1 shows, by benchmark categories, the numbers of individual buildings that have lodged one, two, three, four or more DEC's.

Table 6-1 Number of buildings with varying numbers of DEC's by benchmark category

| Benchmark category | Number of DEC's lodged per building | | | | | All N |
|--|-------------------------------------|---------------|---------------|--------------|------------|---------------|
| | 1 | 2 | 3 | 4 | 4+ | |
| 1 General office | 1,788 | 1,458 | 2,444 | 529 | 45 | 6,264 |
| 2 High street agency | 82 | 41 | 40 | 7 | 0 | 170 |
| 3 General retail | 14 | 23 | 26 | 10 | 0 | 73 |
| 4 Large non-food shop | 4 | 2 | 2 | 0 | 0 | 8 |
| 5 Small food store | 0 | 0 | 1 | 0 | 0 | 1 |
| 6 Large food store | 1 | 0 | 0 | 0 | 0 | 1 |
| 7 Restaurant | 79 | 87 | 151 | 62 | 2 | 381 |
| 8 Bar, pub or licensed club | 20 | 15 | 43 | 6 | 0 | 84 |
| 9 Hotel | 17 | 22 | 12 | 1 | 0 | 52 |
| 10 Cultural activities | 256 | 224 | 495 | 130 | 10 | 1,115 |
| 11 Entertainment halls | 76 | 74 | 176 | 34 | 5 | 365 |
| 12 Swimming pool centre | 81 | 83 | 180 | 39 | 2 | 385 |
| 13 Fitness and health centre | 44 | 49 | 89 | 26 | 2 | 210 |
| 14 Dry sports and leisure facility | 430 | 415 | 801 | 187 | 15 | 1,848 |
| 15 Covered car park | 39 | 21 | 82 | 13 | 1 | 156 |
| 16 Public buildings with light usage | 4 | 4 | 4 | 1 | 0 | 13 |
| 17 Schools and seasonal public buildings | 5,340 | 5,286 | 8,281 | 2,702 | 110 | 21,719 |
| 18 University campus | 784 | 809 | 1,461 | 293 | 14 | 3,361 |
| 19 Clinic | 458 | 320 | 495 | 106 | 14 | 1,393 |
| 20 Hospital - clinical and research | 427 | 258 | 607 | 40 | 7 | 1,339 |
| 21 Long term residential | 457 | 471 | 661 | 139 | 4 | 1,732 |
| 22 General accommodation | 296 | 175 | 300 | 48 | 0 | 819 |
| 23 Emergency services | 227 | 249 | 482 | 141 | 27 | 1,126 |
| 24 Laboratory or operating theatre | 35 | 49 | 84 | 25 | 0 | 193 |
| 25 Public waiting or circulation | 1 | 4 | 11 | 2 | 0 | 18 |
| 26 Terminal | 3 | 0 | 0 | 0 | 0 | 3 |
| 27 Workshop | 130 | 75 | 105 | 13 | 1 | 324 |
| 28 Storage facility | 21 | 23 | 24 | 9 | 0 | 77 |
| 29 Cold storage | 3 | 1 | 2 | 0 | 1 | 7 |
| All | 11,117 | 10,238 | 17,059 | 4,563 | 260 | 43,237 |
| % | 26% | 24% | 39% | 11% | 1% | 100% |

*These figures were based on 102,407 of 120,253 records. 17,846 records with the assessment period end date before 1st October 2008 were discounted, since that is the date the DEC scheme was implemented.

They reveal that four DEC's have been registered for just over 10% of all buildings. It is also shown that more than a quarter of buildings have lodged DEC's only once, and a similar number of buildings have lodged DEC's twice.

Table 6-2 shows the numbers of DEC's lodged under each benchmark category for each assessment year.

Table 6-2 Number of DEC lodgements in each category by assessment end year

| Benchmark category | Years when data collection ended | | | | | All N |
|--|----------------------------------|--------|--------|--------|-------|----------|
| | 2008 | 2009 | 2010 | 2011 | 2012 | |
| 1 General office | 583 | 3,750 | 4,289 | 4,368 | 816 | 13,806 |
| 2 High street agency | 19 | 340 | 308 | 24 | 3 | 694 |
| 3 General retail | 11 | 51 | 52 | 53 | 11 | 178 |
| 4 Large non-food shop | . | 5 | 3 | 4 | 1 | 13 |
| 5 Small food store | . | . | 1 | 1 | . | 2 |
| 6 Large food store | . | 1 | . | . | . | 1 |
| 7 Restaurant | 27 | 200 | 229 | 251 | 106 | 813 |
| 8 Bar, pub or licensed club | 8 | 58 | 54 | 60 | 14 | 194 |
| 9 Hotel | 3 | 20 | 33 | 36 | 7 | 99 |
| 10 Cultural activities | 152 | 797 | 846 | 796 | 169 | 2,760 |
| 11 Entertainment halls | 41 | 276 | 273 | 270 | 52 | 912 |
| 12 Swimming pool centre | 55 | 280 | 323 | 280 | 37 | 975 |
| 13 Fitness and health centre | 21 | 133 | 161 | 170 | 39 | 524 |
| 14 Dry sports and leisure facility | 207 | 1,260 | 1,364 | 1,363 | 245 | 4,439 |
| 15 Covered car park | 4 | 47 | 113 | 126 | 38 | 328 |
| 16 Public buildings with light usage | 1 | 7 | 8 | 8 | 2 | 26 |
| 17 Schools and seasonal public buildings | 3,502 | 15,066 | 15,941 | 14,819 | 3,035 | 52,363 |
| 18 University campus | 351 | 2,260 | 2,455 | 2,557 | 309 | 7,932 |
| 19 Clinic | 157 | 839 | 961 | 945 | 185 | 3,087 |
| 20 Hospital - clinical and research | 35 | 870 | 949 | 946 | 152 | 2,952 |
| 21 Long term residential | 163 | 1,139 | 1,265 | 1,222 | 177 | 3,966 |
| 22 General accommodation | 36 | 439 | 554 | 637 | 78 | 1,744 |
| 23 Emergency services | 237 | 783 | 844 | 910 | 132 | 2,906 |
| 24 Laboratory or operating theatre | 19 | 133 | 151 | 141 | 29 | 473 |
| 25 Public waiting or circulation | 3 | 18 | 10 | 14 | 9 | 54 |
| 26 Terminal | . | . | 1 | 1 | 1 | 3 |
| 27 Workshop | 21 | 515 | 214 | 166 | 30 | 946 |
| 28 Storage facility | 44 | 53 | 49 | 42 | 12 | 200 |
| 29 Cold storage | 1 | 5 | 5 | 5 | 1 | 17 |
| All | 5,701 | 29,345 | 31,456 | 30,215 | 5,690 | 102,407 |
| % | 6% | 29% | 31% | 30% | 6% | 100% |

This shows that overall participation in the scheme grew up until 2010 (31,456 lodgements), but dropped off slightly in 2011 (30,215 lodgements). (The figures for 2012 are for only part of the year.)

This is not however a universal trend. The numbers of office DECs have for example continued to increase year-on-year throughout, as have those for universities and some sports and leisure facilities. (Note that these are number of DECs not buildings.)

Comparison of numbers of DECs with other data sources

However these figures fail of course to reveal the numbers of eligible buildings for which no DECs have ever been lodged. It is not easy to make estimates of those numbers. To do so, we need to find comprehensive listings of public buildings elsewhere in other data sets, preferably with their floor areas so that those with areas less than 1000 m² can be discounted. Two such sources exist. The first is the e-PIMS (electronic Property Information Mapping Service) database, which covers all Crown properties (Civil Service 2013). These include central government offices, law courts, prisons and several other types. The e-PIMS database also in principle records whether Crown properties have DECs – although it becomes clear on close examination that the relevant DEC fields in the database are not always filled, even when properties have Certificates. The second source is the Valuation Office Agency (VOA) who maintain the Summary Valuation (SMV) database and the Rating List for the purposes of levying commercial rates (Valuation Office Agency 2013). These cover most non-domestic building types, although the SMV does not have floor areas in all cases. The VOA databases do not cover central government. Comparison of the DECs database with the e-PIMS database is however complicated by the fact that the DECs scheme applies to England and Wales and e-PIMS is for the UK.

There is a general problem that bedevils all statistical work on the non-domestic stock, and that is the question of the spatial units to which data refer. The standard unit for DECs is in principle the building; but as we have seen, single DECs can sometimes refer to groups of buildings sharing the same site (site DECs), typically in universities, hospitals and large schools. VOA data by contrast relate in all cases to ‘hereditaments’ or premises with single occupiers. A hereditament can be a part of a shared building, a whole building, or a group of separate buildings on one site. It seems that e-PIMS has entries relating to both whole buildings and parts of buildings. This all makes further difficulties for the comparison of numbers in the different sources.

One more problem in making comparisons arises from the activity classifications used in *TM46*, VOA data and e-PIMS. These are not consistent, as discussed further in Part 7. To take the example of offices: under the benchmark category ‘General office’, *TM46* includes – among others – the building types ‘Central government office’, ‘Local government office’, ‘Town Hall’, ‘Public sector office’, ‘Office’ and various categories of ‘Office’ distinguished by their ventilation systems and whether their plans are cellular or open. ‘Central government offices’ can be compared with the Crown offices in e-PIMS, and ‘Local government office’ and ‘Town Hall’ with equivalent VOA categories. But the classification ‘Public sector offices’ can clearly apply to either central or local government. And the various other *TM46* ‘Office’ types could apply to both public and commercial offices – although we would expect the majority of offices with DECs to be in the public sector. Equivalent problems arise in other benchmark categories (see Part 7).

With all these caveats, Table 6-3 attempts to compare total numbers of buildings/ sites with DECs in selected groups of *TM46* building types, with numbers of premises/ building/ sites under broadly equivalent activity classifications in e-PIMS, VOA data, or combinations of these. (Allowance has *not* been made for the different geographical coverage of the different databases.) The classifications have been aggregated such that all relevant cases are hopefully captured on both sides. The numbers of DECs are from the post-2010 cross-section. The e-PIMS data are for 2011, and the VOA data for 2010. Mean floor areas (m²) are given for the e-PIMS and VOA premises/ buildings.

Numbers of state schools are from the Department for Education (2011) and numbers of hospitals from the Department of Health (Information Centre 2013).

Table 6-3 comparisons of numbers of DEC's with other databases

| DECs | | e-PIMS and/or VOA data | | |
|--|-------------|-------------------------------|-------------|----------------------------------|
| <i>TM46 activity type</i> | <i>N</i> | <i>Activity type</i> | <i>N</i> | <i>Mean area (m²)</i> |
| Offices | | | | |
| Central government office | 387 | <i>e-PIMS:</i> | | |
| Local government office | 668 | Central government office | 3170 | 1983 |
| Town Hall | 113 | <i>VOA:</i> | | |
| Public sector office | 453 | Local government office + | | |
| Office | 274 | Town Hall | 2277 | 1448 |
| Office, cellular, nat. vent. | 91 | | | |
| Office, mech. vent. or A/C | 234 | | | |
| Office, open plan, nat. vent. | 111 | | | |
| Totals: | 2331 | | 5477 | |
| Law courts | | | | |
| Court | 255 | <i>VOA:</i> | | |
| Crown and county court | 71 | Law court* | 513 | 1073 |
| Crown court | 11 | <i>e-PIMS:</i> | | |
| | | Magistrates court, tribunal* | 408 | 1964 |
| | | Crown court | 45 | 4680 |
| | | County court | 148 | 1149 |
| Totals: | 337 | | 1114 | |
| * It is possible that there may be overlap between VOA and e-PIMS here | | | | |
| Museums | | | | |
| Museum | 195 | <i>ePIMS:</i> | | |
| Art gallery | 42 | Museum | 17 | 8737 |
| Arts centre | 32 | <i>VOA:</i> | | |
| | | Museum, art gallery/ centre | 1717 | 361 |
| Totals: | 269 | | 1734 | |
| Libraries | | | | |
| Library | 275 | <i>VOA: Library</i> | 3095 | 403 |
| Cont'd | | | | |

| DECs | | e-PIMS and/or VOA data | | |
|---|--------------|-----------------------------------|--------------|----------------------------------|
| <i>TM46 activity type</i> | <i>N</i> | <i>Activity type</i> | <i>N</i> | <i>Mean area (m²)</i> |
| Schools | | | | |
| Primary, secondary teaching | 111 | <i>Department for Education:</i> | | |
| Primary school | 6631 | State primary school | 18433 | |
| State primary school | 2496 | State secondary school | 3556 | |
| Secondary school | 1300 | Special school | 1549 | |
| State secondary school | 403 | <i>VOA:</i> | | |
| Special school | 419 | Private school | 2616 | 611 |
| State school | 160 | | | |
| Private school | 22 | | | |
| School | 462 | | | |
| Totals: | 12004 | | 26154 | |
| Universities | | | | |
| University | 944 | <i>VOA: University</i> | 1020 | |
| Surgeries, clinics, health centres | | | | |
| Dentist's surgery | 4 | <i>VOA:</i> | | |
| Doctor's surgery | 16 | Surgery, clinic, health centre | 23016 | 172 |
| Surgery or clinic | 7 | Health centre | 3538 | 485 |
| Clinic, health centre | 232 | | | |
| Health centre, clinic | 229 | | | |
| Medical/ dental centre | 16 | | | |
| Medical centre | 28 | | | |
| Occupational health centre | 17 | | | |
| Out-patient treatment | 48 | | | |
| Primary healthcare building | 131 | | | |
| Totals: | 728 | | 26554 | |
| Hospitals | | | | |
| General acute hospital | 423 | <i>VOA, Department of Health:</i> | | |
| Teaching/ specialist hospital | 150 | NHS Hospital | 1392 | |
| Community/ mental hospital | 257 | Private hospital | 535 | |
| Hospital | 35 | | | |
| Totals: | 865 | | 1927 | |
| Prisons | | | | |
| Prison | 100 | <i>e-PIMs and other sources:</i> | | |
| Remand centre | 4 | Prison, remand centre | 115 | 33272 |
| Young offenders' institution | 9 | Young offenders' institution | 25 | 20128 |
| Totals: | 113 | | 140 | |

The figures in Table 6-3, for what they are worth, suggest very different levels of compliance in different sectors – although there are many complications and uncertainties. There are types or groups of types where compliance is high, as with prisons (80%), where the classifications in the data sources are directly compatible. We also know that all prisons have floor areas greater than 1000 m². Compliance is also good, on the face of it, in universities (92%), for which in many cases both DEC and VOA records will be for sites with many buildings. The number of universities in England and Wales is 140, in the UK 161. However according to the University Directors of Estates the number of university buildings in England and Wales is 14,233 (including residential buildings) (UDE 2013). This compares with just 944 DECs. We do not know how many of these certificates relate to sites and how many to individual buildings.

In other activity groups, compliance seems to be much poorer. For example in law courts it is only 30% - although it is possible that there is some double counting here in e-PIMS and the VOA. A problem for many of these comparisons is that the numbers from e-PIMS and VOA data are for all premises/ sites irrespective of floor area. It would be desirable, and feasible, to count in those sources only cases where floor area is greater than 1000 m², but we have not done this. The mean floor areas given instead in Table 6-3 are indicative, but of course can conceal wide distributions around the means. For the various types of law court in e-PIMS nevertheless the mean sizes are all well over 1000 m². This is also true for the offices in e-PIMS and VOA, where compliance is 43%.

The comparisons for museums, libraries and surgeries/ health centres are not very meaningful, since it is clear that many of these are well below the 1000 m² threshold. The comparison of schools (where compliance on the basis of the figures here is 46%) may similarly be affected by rural primary schools having floor areas less than 1000 m². This seems unlikely however to account for the whole of the difference between the DECs and Department for Education totals. There are possible further complications arising from the use of site DECs for large schools.

Most of these comparisons are problematic for the reasons explained. The specific figures should not be taken as precise or definitive. One way of making more accurate estimates of compliance would be to match DECs one-by-one to VOA and e-PIMS buildings/ sites by their addresses; however that would be a major task, which we have not attempted. We can nevertheless draw the broad conclusion from Table 6-3 that compliance with the DECs scheme as a whole is patchy, and in several large groups of activities is well below 50%. It is worth emphasising, what is more, that this is a very liberal interpretation of 'compliance', to include buildings and sites for which *any* number of DECs – perhaps just one - have been lodged over the life of the scheme. A recent survey of DEC users and non-users for the Department of Energy has explored some of the reasons for non-compliance, and the apparent ineffectiveness of sanctions for late renewals or for ignoring the system altogether (DECC 2013b).

7 Classification of benchmark categories and building types

The benchmarks in *TM46* were based originally on selected examples of buildings of each given type (CIBSE 2008). The classifications of types were derived from the variety of sources from which these data were drawn. Benchmark categories were then defined to combine building types that it was believed would have comparable patterns of consumption. Thus several types with intermittent patterns of occupancy were grouped under ‘Schools and seasonal public buildings’, and others occupied continuously day and night and every day of the year, under ‘Long term residential’. This resulted, in some instances, in the inclusion within the same benchmark of some otherwise quite diverse activities.

The fact that the benchmarks and building type classifications have now been in use for five years means that they can be reassessed against the accumulated DEC data, and any problems identified. We have seen in the previous sections how actual mean electricity and fossil thermal energy use in several categories departs widely from the *TM46* benchmarks. In this section we present some further analyses and data, to throw light on differences in patterns of energy consumption within the same benchmark category. There are inconsistencies and other issues with the *TM46* building type classifications that could arguably be cleared up in order to give sharper pictures of comparative performance, and provide greater comparability with other databases of energy use in buildings.

It is true that there are political and technical arguments in favour of staying with the *TM46* classifications and benchmark values. To change them could result in building operators and energy managers complaining of ‘goal posts being moved’. It could make it more difficult to compare new ratings with old, and to carry out longitudinal analyses as in Part 4. On the other hand it was certainly envisaged at the start of the scheme that the benchmarks would be revised at some point in the future, possibly on a five-year cycle. This section presents arguments in favour of revisions, some minor, some more substantial.

7.1 Minor problems with building type classifications

7.1.1 Unused codes

Analysis of the numbers of buildings classified by each building type code shows that out of 237 codes, 78 have never been used. A further 27 codes are used only once, and 10 codes are used just twice. Many of these are for building types that do not yet in principle require DEC, as in the retail and hospitality sectors, but might come into use if and when the scheme is extended to commercial buildings. Others relate to building types that would rarely if ever exceed 500 m² in area such as ‘Beach huts’, ‘Public lavatories’ or ‘Scout huts’.

There remain however other codes that are unused and might reasonably be suppressed or amalgamated with other building types. These include such specialised activities as ‘Simulator’, ‘Gas/decontamination chamber’, ‘Helicopter repair’ and ‘Helicopter storage’, whose numbers nationally would be small. None would seem to warrant special codes. Some of these are in any case likely to be just parts of buildings. Other clear cases of codes for part-buildings are ‘Guardroom’, ‘Classroom’, ‘Lecture hall’ and ‘Operating theatre’ (although the last has no building type code as such and is included only as a benchmarking category). The statistics show that the code 153 ‘Classroom’ has been used 122 times and 154 ‘Lecture hall’ 31 times. Many of these cases must however be blocks in schools, colleges or universities containing numbers of teaching rooms. (There could indeed be freestanding individual classrooms and single large lecture theatres, but the detached classrooms

would certainly fall under the 1000 m² threshold, as perhaps would some detached lecture halls.) Small changes in the naming of types could take care of these problems.

At the same time there are many frequently occurring building types in the building stock for which there are no *TM46* categories, notably in the industrial and warehouse sectors, which together account for more than half of the non-domestic stock. These omissions will need to be rectified if the DEC scheme is extended to commercial buildings. This issue is taken up again below.

7.1.2 Repeated codes

Some building types are repeated. ‘Petrol filling stations’ have two codes, 51 in ‘General retail’ and 221 in ‘Workshop’. (Neither is used so far by any DEC.) There are separate codes 216 and 232 for ‘Garage’ and ‘Garages’, both within the ‘Workshop’ benchmark, plus a further type 236 ‘Vehicle storage’ within ‘Storage facility’. The term ‘Garage’ is admittedly somewhat slippery, since it can mean a building for storing vehicles, a workshop for mending vehicles, a petrol station, a vehicle salesroom, or any combination of these. But this only emphasises the necessity for clarity in the various building type descriptions, especially since there could be significant variations in energy use involved. In some cases what would appear to be the same building type has two codes under the same benchmark, as for example 172 ‘Detention’ and 173 ‘Detention centre’ under ‘Long term residential’; or 157 ‘Clinic or health centre’ and 160 ‘Health centres and clinics’, both under ‘Clinic’. The codes 115 ‘Covered parking’ and 121 ‘Parking building’ (under different benchmarks) would also seem to describe one and the same building type. All these problems could be easily solved by deletions and redefinitions.

More serious is the fact that hospitals are found under two benchmark categories, ‘Hospital (clinical and research)’ and ‘Long term residential’. The intention in putting building type 171 ‘Community and mental health hospital’ into the second benchmark is presumably to separate long-term residential care (and perhaps its presumed high level of fossil thermal use) from the short-term treatment and special facilities in the clinical and research hospitals. But the DEC analysis shows that mean fossil thermal use is actually *lower* in the community and mental health hospitals than in the general acute hospitals. What is more, there is a further and very general building type 175 ‘Hospital’ (without further qualification) also under ‘Long term residential’. Why is this not grouped with the clinical and research hospitals? The buildings with this code have a comparable level of consumption for fossil-thermal (although somewhat lower use of electricity). It is surely misleading to have a benchmark category for hospitals from which many hospitals are excluded. There is strong case here for a reassignment of building types between benchmarks. The building type name ‘Hospital’ also raises a more general issue to do with the level of specificity of type classifications. This is discussed further below.

7.1.3 Ambiguity and vagueness in classifications

Some building types are vaguely described and it is unclear what exactly they comprise. What is a ‘Sacred place’ (code 125) if it is not a church or other place of worship, both of which have their own codes? What are ‘Law facilities’ (code 16)? Are they lawyers’ offices? Are they law courts? (But these have their own codes.) What is a ‘Warehouse office (code 31)? Is it an office in a converted former warehouse? If so, this is irrelevant to the activity as such, and the building should be classified as an office. Such cases could be clarified by using sharper, less ambiguous descriptions.

7.1.4 Effects of inadequate building type codes

Where the building type codes within a benchmark category are inadequate through being too broad or too vague, surveyors will reach to find possible alternatives elsewhere in the classification. This happens for example with 'University campus', where there are only two codes suitable for individual university buildings, 'Lecture hall' and 'University'. Given this limited choice, surveyors in many instances have elected to use building type codes under other benchmark categories, such as 'Laboratory' or some of the various Office types. They have classified university halls of residence under 'School boarding house' in the 'General accommodation' benchmark. This is understandable. But it means of course that inappropriate benchmark values may be being applied; and that analysis of DEC statistics for the 'University campus' benchmark category as a whole becomes highly problematic.

7.1.5 Building types under inappropriate benchmark categories

There are certain cases where the allocation of building types to benchmark categories is, on the face of it, surprising or perplexing. Perhaps the original buildings by which the benchmarks were set had similar levels of energy use? However this possible explanation does not seem to account for some of the anomalies. For example type 109 'Sports centre with pool' is placed under 'Dry sports and leisure facility' despite the fact that 'Dry' in this context means, precisely, *without* swimming pools. That it is very definitely misplaced is evident from this type's mean fossil-thermal consumption, which is 457kWh/m², compared with the mean of 245kWh/m² for the benchmark category as a whole.

Another such misplaced type is 214 'Crematorium' under the 'Workshop' benchmark. The intrinsic nature of the crematorium's activity means that it has an extremely high level of fossil fuel use, at 713kWh/m² (the mean for 11 buildings). Allowance is made in *TM46* for furnaces to be treated as separable uses, but this does not seem to have happened here. Otherwise crematoria might in the future be grouped with comparably high industrial users.

Yet another anomaly is the inclusion of 'Community centres' and 'Day centres' within the 'Schools and seasonal public buildings' benchmark. In fact both types are typically in use year-round, not just seasonally as with schools. Analysis of fossil thermal EUIs shows that these are significantly higher for the two types of centre than for the schools and other buildings under this benchmark. There is a strong argument for moving them elsewhere.

In other cases it is more difficult to say that building types are in the wrong benchmark categories on the grounds of their consumption levels, since the numbers are small. But for example why are 'Armouries' under 'Terminals'? Why are 'Docks and wharfs' under 'Public waiting or circulation'? (Is there a confusion here with ferry passenger terminals?) Why is 'Mortuary' under 'Clinic'? And why is 'Sixth form college' under 'University campus', when it should be included with schools or colleges of further education, whose energy use would be likely to be more comparable? (FE colleges are however missing as a type from *TM46*.)

7.2 Varying levels of aggregation and specificity in building type codes

A more serious problem with the *TM46* activity type codes is that, within several benchmark categories, there are different building type codes that describe the same activities at different levels of specificity or aggregation. This occurs with schools. At the highest level of generality are codes 143 'School' and 139 'Primary and secondary teaching establishments'. At a level below this come 148 'State primary school' and 150 'State secondary school'. Confusing the issue still further

are codes 140 'Primary school' and 144 'Secondary school', which do not specify whether these are state or private. The consequence is that the surveyor of a particular state school can choose to place it in any of four different categories. It means that it is not possible to make a clean separation in the DEC's data between primary/ secondary or public/ private schools, which makes comparisons with other data sources difficult, as we saw in Part 5. All could be solved with a reduced set of codes distinguishing:

- State primary school
- State secondary school
- Private primary school
- Private secondary school

A further type could be added for special schools, and state secondaries might be divided between academies and other schools. Surveyors would then have no difficulty in picking the relevant type.

This issue is important because our analysis shows that electricity consumption patterns differ significantly between primary and secondary schools. Figure 7-1 gives cumulative frequency distribution curves for electricity and fossil thermal EUIs in primary and secondary schools in England. We have included only schools for which the DEC types are unambiguous. These were all DEC's under building types 'Primary school', 'Secondary school', 'State primary school', and 'State secondary school'. In order to compare consumption on an equivalent basis, the fossil thermal EUIs in all cases were normalised to 2021 heating degree-days based on the assumption that 80% of the heating consumption was for space heating. Buildings that were identified as operating extended hours were discounted, in order to prevent these from skewing the results.

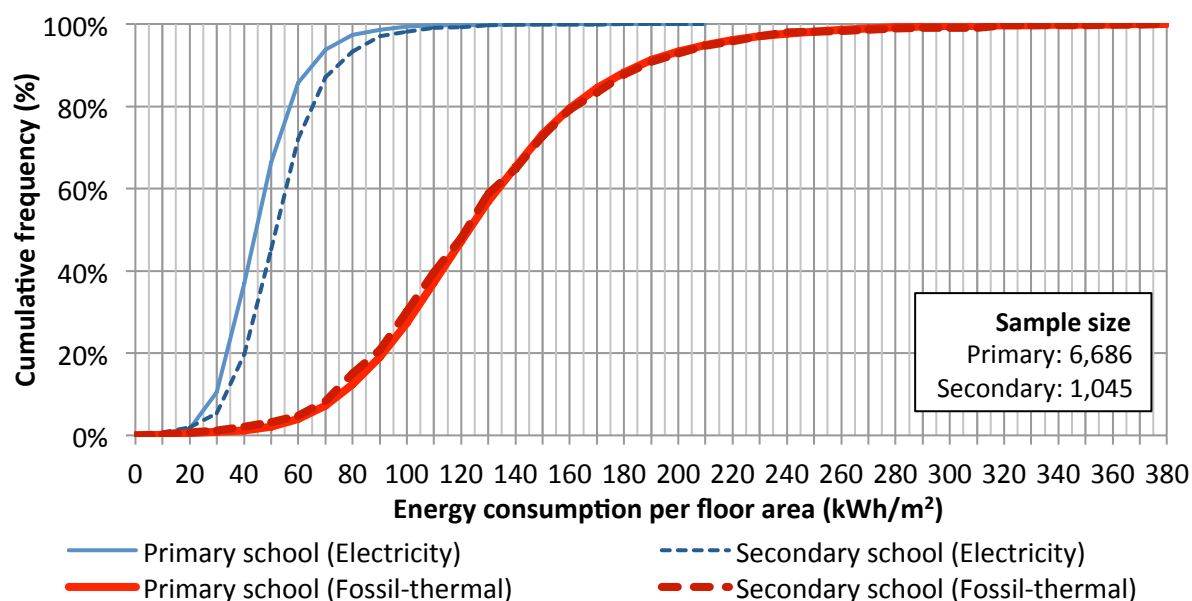


Figure 7-1 Cumulative frequency distribution of the electrical and fossil-thermal EUIs of primary and secondary schools (Hong et al., 2013)

The distributions for electricity EUI show a clear difference between primary and secondary schools, while there is little difference between the distributions for fossil thermal. A series of hypothesis tests comparing these distributions have shown that the difference for electricity is statistically significant, but that there is no significant difference for fossil thermal. These results suggest the

possibility of primary and secondary schools being separately benchmarked in the future, especially given that the numbers of buildings involved are so large. There is some evidence furthermore to suggest that academies are higher energy users than other secondary schools; and the DEC data themselves indicate that private schools are higher users on average than state schools, presumably in part because those that include boarding houses are occupied 24 hours, seven days a week during term-time. These differences could be worth exploring.

A second benchmark category where similar problems arise is 'General office'. As we saw in Part 6, there are again building types at varying levels of generality, including 'Offices' without further qualification; beneath this 'Commercial office' and 'Public sector office'; and further subdividing the public sector, codes for 'Central government office', 'Local government office' and 'Town hall'. Similar arguments apply as with schools. The situation could be clarified here by reducing these codes to just four:

- Commercial office
- Central government office
- Local government office
- Town hall

It would then be possible to carry out similar analyses to those for schools in Figure 7-1. The mean DEC consumption figures for 'Central government office' and 'Local government office' suggest that consumption differs between these. But many offices of both types are presently classified as 'Public sector offices'.

A second issue with the *TM46* 'General office' types is the inclusion of three 'Office' building types (22, 23 and 24) distinguished only by their ventilation systems and whether they are cellular or open plan. (There will be both central and local government offices included under these types, but not distinguishable as such.) It is surprising that these distinctions are made, since *TM46* is quite clear that benchmarks are not to be differentiated on the basis of servicing systems, and specifically that "a fully air conditioned office shares the same benchmark as a naturally ventilated office" (CIBSE, 2008 p.1). To make a more generous allowance for air conditioning would be to create a perverse incentive.

Since servicing systems are nevertheless distinguished for office in types 22, 23 and 24, we have made a cross-tabulation of the data recorded in each case for the internal environment of the buildings (Table 7-1). This shows, as percentages, the extent to which the building type classifications match the specified internal environments. The coloured cells show the mismatches. On this evidence it would seem to be more satisfactory to drop these different 'Office' types, especially since this could help clarify the differences between commercial, central government and local government offices as described. The DEC data at least hint that local government offices differ significantly in both electricity and fossil thermal use from both central government and commercial offices.

Table 7-1 Comparison of building type category specified with internal environment specified

| Building Type | Internal Environment | | | | | | All | |
|--|----------------------|------------------------------------|---------------------------------|-----------------------------|--|-------------------------------------|-----|---|
| | Air Conditioning | Heating and Mechanical Ventilation | Heating and Natural Ventilation | Mechanical Ventilation Only | Mixed-mode with Mechanical Ventilation | Mixed-mode with Natural Ventilation | % | % |
| | % | % | % | % | % | % | % | % |
| Offices - cellular, naturally ventilated | 1 | 3 | 89 | . | 2 | 4 | 100 | |
| Offices - mechanically ventilated and/or air conditioned | 37 | 24 | 18 | 0 | 12 | 9 | 100 | |
| Offices – open plan, naturally ventilated | 7 | 3 | 76 | . | 4 | 11 | 100 | |

As a final example of variations in performance within benchmark categories we can take ‘Entertainment halls’, for which the traffic light analysis of Figure 3.6 showed one of the largest differences between benchmark values and actual performance. Members of Julie’s Bicycle, an activist group in the entertainment industry, have set their own rival benchmarks for performing arts buildings (Heathfield and Bottrill, 2012). They have collected data on more than 100 buildings, and obtained means of 110kWh/m² for electricity use and 140kWh/m² for gas. These compare with the *TM46* benchmarks for ‘Entertainment halls’- the closest category - of 180 and 420kWh/m² respectively. The Julie’s Bicycle buildings are classified into ‘Theatres’ and ‘Other’, and it is clear that patterns of energy use are different between these groups, although the authors give no separate figures. Interestingly they also present data to indicate that numbers of seats may be a more useful unit for measuring energy use than floor area. This initiative by Julie’s Bicycle is very laudable. It also demonstrates dangers for the DEC scheme, where the *TM46* benchmark values are seen to differ so widely from typical current consumption that professional and commercial organisations lose confidence in them.

7.3 Incompatibility between *TM46* building types and other classifications of non-domestic buildings

One large question remains: the incompatibility of the *TM46* categorisation of building types with other activity classifications for non-domestic buildings used elsewhere. The *TM46* types could certainly be adjusted and revised to deal with many of the problems outlined above. The grouping of types within benchmark categories could also be rearranged to ensure more homogeneity in patterns of energy use. Categories could be amalgamated or split up as appropriate. But differences would still remain from other classification systems.

A serious general weakness of *TM46* as it stands is that, as mentioned, there are very few building types in the manufacturing and warehouse sectors. These account for a very large fraction of the stock. More types would certainly have to be introduced should the DEC scheme be extended to commercial buildings. At present there is just one portmanteau code 219 for all ‘Manufacturing premises’. There are codes for ‘Cold store’ and ‘Storage depot’, but no code for ‘Warehouse’ as such.

Further education colleges are missing. More types would be also needed in some other commercial sectors, especially for sports buildings and retail. Recent research for DECC, as well as work carried out by Sheffield Hallam University in the 1990s, has shown that there are large differences in energy use between different types of shop (and not just between large and small shops) (Nicholls 2013, Mortimer, Elsayed and Grant 2000). This would suggest a need for more retail types than are at present distinguished in *TM46*.

The most comprehensive and arguably most useful system of classification of non-domestic building types is that developed over many years by the Valuation Office Agency. This is employed in the Rating List and SMV databases mentioned in Part 6. The system is not complete, since it excludes building types that are exempt from rates, including Crown properties, agricultural buildings and places of worship. Certain of the VOA categorisations can be criticised. Nevertheless the system is certainly workable and well tested, and combinations of the VOA's so-called 'primary descriptions' and 'special category' (SCAT) codes can be combined to cover the greater part of the stock. Extra codes can be added to cope with the exclusions.

There are two potential attractions for using an extended VOA classification in connection with DECs. First the VOA has already classified all rateable hereditaments (premises) in England and Wales. They also hold accurate floor area data for the majority of premises. Should DEC assessments start from the data held by the VOA - which are in the public domain - and use the VOA's typology, then consistency could be assured. The second attraction is that the Department for Energy and Climate Change (DECC) is in the process of building a database that will contain information on all non-domestic buildings in England and Wales (DECC 2013a). This Non-Domestic Energy Efficiency Data Framework (NEED) takes floor area data from the VOA (and other sources). These are being matched at the level of individual premises/ buildings to electricity and gas consumption data from the energy supply companies. The activity classification will be an extended version of that developed by the VOA.

If and when NEED becomes operational – and there are many obstacles – it will clearly transform our picture of energy use in, and carbon emissions from, the entire non-domestic stock. The question will arise, what distinctive function can the DECs system then play, when consumption data are available from NEED for every single building? That is to say, how can DECs and NEED be made compatible and work together? Certainly there would seem to be an extremely strong case, in relation to DECs, either for making the existing *TM46* types compatible with the VOA classifications so far as possible, or else for replacing *TM46* wholesale with an extended VOA typology.

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Appendices

Appendix A – Description of information in the DEC dataset

Appendix B – Energy and floor area statistics by building type category

Appendix C – Distribution of DEC's by main heating fuel type

Appendix D – Distribution of DEC's by internal environment type

Appendix A - Description of information in the DEC dataset

| Variable | Description |
|---|---|
| RRN | DEC Report Reference Number unique to each certificate |
| UPRN | Unique Property Reference Number (a site or building) |
| OR assessment end date | End date for the 365 day assessment period of energy consumption |
| Issue date | Date that a DEC was produced with ORCalc software |
| Reason type | Explains why a DEC was lodged (voluntary, mandatory etc.) |
| Report status | Identifies the status of the DEC (entered, appeal or cancelled) |
| DEC status | Identifies whether a DEC is standard, default or asset rating only (only for those lodged after 7th March 2010). |
| Description of a building | Name of the occupier, address lines, postcode and town |
| Benchmark category | Activity type(s) of a building (or site) |
| Building type category | Sub-classification(s) of the activity in a building (or site) |
| Total floor area (m ²) | Total useful floor area of a zone (or zones) in a building (or site) |
| Area metric | Measures of floor area used (e.g. Gross Internal Area (GIA), Net lettable area (NLA), Sales Floor Area (SFA)) |
| Total unheated floor area (m ²) | |
| Occupancy level | Identifies whether a building (or site) is occupied for standard or extended occupancy hours |
| Total equivalent | Hours of use if a building (or site) is occupied for more than the reference hours stated in CIBSE <i>TM46</i> |
| HVAC system | Type of heating, ventilation and air conditioning system (radiators, centralised, convectors etc.) |
| Internal environment | Type of servicing (natural ventilation, mechanical ventilation or air conditioning etc.) |
| Main heating fuel | Type of fuel mainly used for heating (gas, electricity etc.) |
| Annual energy use electrical (kWh/m ²) | Annual electricity consumption collected over 365 days. Does not include on-site renewables. |
| Annual energy use fuel thermal (kWh/m ²) | Annual fossil-thermal consumption collected over 365 days. Does not include on-site renewables. |
| Typical electrical use (kWh/m ²) | Electrical benchmark adjusted for weather and occupancy |
| Typical thermal use (kWh/m ²) | Fossil-thermal benchmark adjusted for weather and occupancy |
| Energy consumption by fuel type (kWh/yr) | Anthracite, gas, oil etc. |
| Electricity CO ₂ (tonnesCO ₂ /yr) | Total carbon emission from electricity consumption (kWh/yr). |
| Heating CO ₂ (tonnesCO ₂ /yr) | Total carbon emission from fossil-thermal consumption (kWh/yr). |
| Operational rating | |
| Previous operational rating | |
| Information on renewables | Description of the technology, delivered energy, CO ₂ contribution, % of the electricity and fossil-thermal consumption delivered by on-site |
| Separable energy uses by fuel type | |
| Floor areas for the separable energy uses (m ²) | |

Table A1 Description of variables in the DEC data

Appendix B – Energy and floor area statistics by building type category

| Benchmark Category / Building Type | | N | EUI Elec. (kWh/m ²) Median | EUI Heating (kWh/m ²) Median | DEC Rating Median | Floor Area Median |
|------------------------------------|--|-----|--|--|-------------------------|-------------------------|
| General office | Adult education centre | 83 | 59 | 182 | 85 | 1,477 |
| | Air traffic control | 1 | 174 | 105 | 155 | 2,947 |
| | Building society office | 3 | 14 | 152 | 68 | 1,616 |
| | Business units | 17 | 76 | 96 | 77 | 2,217 |
| | Call centre | 34 | 145 | 115 | 115 | 3,073 |
| | Central government office | 387 | 93 | 122 | 93 | 2,853 |
| | Commercial office | 19 | 94 | 122 | 112 | 1,388 |
| | Conference centre | 37 | 85 | 146 | 100 | 2,037 |
| | Courts | 255 | 80 | 132 | 90 | 2,576 |
| | Crown and county courts | 71 | 86 | 127 | 88 | 4,025 |
| | Crown court | 11 | 84 | 94 | 91 | 8,625 |
| | Financial service office | 3 | 130 | 118 | 113 | 3,787 |
| | Law facilities | 10 | 107 | 150 | 105 | 2,392 |
| | Legal/financial services | 13 | 81 | 94 | 80 | 1,588 |
| | Local government office | 668 | 89 | 112 | 91 | 2,930 |
| | Office showroom | 1 | 63 | 112 | 75 | 1,305 |
| | Office with industry | 5 | 123 | 112 | 157 | 4,100 |
| | Offices | 274 | 86 | 123 | 91 | 1,830 |
| | Offices - cellular, naturally ventilated | 91 | 72 | 127 | 85 | 1,609 |
| | Offices - mechanically ventilated and/or air conditioned | 234 | 128 | 113 | 116 | 2,653 |
| | Offices - open plan, naturally ventilated | 111 | 84 | 103 | 88 | 1,669 |
| | Professional / design | 2 | 134 | 61 | 101 | 2,801 |
| | Professional services off street | 1 | 55 | 55 | 55 | 1,521 |
| | Public sector offices | 453 | 80 | 100 | 83 | 2,374 |
| | Studio office | 1 | 123 | 117 | 95 | 2,126 |
| | Town hall | 113 | 85 | 139 | 88 | 4,043 |
| Warehouse office | 13 | 53 | 129 | 75 | 2,400 | |
| High street agency | Post Office | 5 | 96 | 89 | 85 | 324 |
| | Public services | 25 | 78 | 100 | 77 | 2,468 |
| General retail | Beauty salon | 1 | 9 | 167 | 34 | 1,659 |
| | Garden centres | 2 | 21 | 247 | 59 | 3,986 |
| | Indoor markets | 30 | 108 | 92 | 83 | 2,899 |
| Large non-food shop | Retail-warehouse | 1 | 66 | 16 | 52 | 3,666 |

Cont'd

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| Benchmark Category / Building Type | | N | EUI Elec. (kWh/m ²) Median | EUI Heating (kWh/m ²) Median | DEC Rating Median | Floor Area Median |
|------------------------------------|--|-----|--|--|-------------------------|-------------------------|
| Restaurant | Cafe | 1 | 32 | 91 | 29 | 1,375 |
| | Canteen | 8 | 128 | 266 | 97 | 1,312 |
| | Eating place | 3 | 145 | 232 | 103 | 1,420 |
| | Mess - junior ranks - accommodation only | 1 | 67 | 192 | 63 | 10,283 |
| | Mess - junior ranks - catering only | 1 | 92 | 169 | 72 | 2,717 |
| | Mess - officers - catering only | 1 | 64 | 132 | 53 | 2,724 |
| | Restaurant | 6 | 272 | 319 | 160 | 1,158 |
| Bar, pub or licensed club | Night club | 5 | 145 | 107 | 73 | 1,980 |
| | Public house | 2 | 180 | 97 | 78 | 3,809 |
| Hotel | Hotel | 16 | 85 | 170 | 69 | 4,928 |
| Cultural activities | Art Gallery | 42 | 79 | 163 | 98 | 2,578 |
| | Arts centre | 32 | 77 | 140 | 98 | 2,202 |
| | Library | 275 | 76 | 118 | 79 | 1,830 |
| | Museum | 195 | 55 | 125 | 73 | 2,166 |
| Entertainment halls | Auditorium | 14 | 91 | 169 | 48 | 2,686 |
| | Cinema | 8 | 100 | 178 | 54 | 2,570 |
| | Concert hall | 19 | 84 | 137 | 41 | 3,721 |
| | Dancing school | 2 | 180 | 342 | 102 | 2,578 |
| | Entertainment hall | 69 | 87 | 157 | 46 | 1,833 |
| | Theatre | 91 | 86 | 148 | 45 | 2,532 |
| Swimming pool centre | Swimming pool | 261 | 192 | 696 | 63 | 2,187 |
| Fitness and health centre | Fitness centre | 30 | 102 | 152 | 52 | 2,688 |
| | Gymnasium | 11 | 100 | 237 | 58 | 1,890 |
| | Health club | 1 | 122 | 202 | 46 | 3,011 |
| Dry sports and leisure facility | Ice skating rinks | 8 | 289 | 216 | 132 | 5,232 |
| | Indoor bowling | 15 | 60 | 167 | 57 | 2,403 |
| | Leisure centre | 207 | 88 | 143 | 61 | 1,990 |
| | Pavilion/sports clubhouse | 15 | 128 | 220 | 92 | 1,142 |
| | Sports centre with pool | 145 | 108 | 427 | 101 | 4,159 |
| | Sports ground | 7 | 77 | 127 | 64 | 1,900 |
| | Sports ground buildings | 18 | 63 | 206 | 63 | 1,643 |
| | Sports hall | 174 | 61 | 131 | 49 | 1,509 |
| | Squash club | 1 | 31 | 113 | 32 | 1,197 |
| | Tennis courts etc | 16 | 60 | 89 | 35 | 3,642 |
| Public buildings with light usage | Church | 1 | 100 | 207 | 312 | 1,562 |
| | Place of worship | 1 | 127 | 112 | 235 | 1,025 |
| | Places of religious worship | 1 | 13 | 96 | 83 | 675 |
| | Sacred place | 1 | 38 | 180 | 170 | 3,445 |

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| Benchmark Category / Building Type | | N | EUI Elec. (kWh/m ²) Median | EUI Heating (kWh/m ²) Median | DEC Rating Median | Floor Area Median |
|---------------------------------------|---|-------|--|--|-------------------------|-------------------------|
| Schools and seasonal public buildings | Community centre | 168 | 43 | 150 | 93 | 1,250 |
| | Community facilities | 74 | 53 | 153 | 96 | 1,525 |
| | Community meeting place | 5 | 70 | 121 | 119 | 1,261 |
| | Creche | 1 | 62 | 223 | 137 | 1,769 |
| | Creche/childcare facility | 20 | 56 | 183 | 106 | 1,201 |
| | Day centre | 170 | 46 | 193 | 112 | 1,347 |
| | Nursery or kindergarten | 85 | 49 | 128 | 97 | 1,219 |
| | Pre-school facility | 25 | 59 | 130 | 111 | 1,051 |
| | Primary and secondary teaching establishments | 111 | 50 | 143 | 106 | 1,567 |
| | Primary school | 6,631 | 43 | 128 | 94 | 1,512 |
| | Private school | 22 | 48 | 143 | 104 | 2,266 |
| | Reserves centre | 5 | 39 | 100 | 87 | 2,054 |
| | School | 462 | 45 | 138 | 98 | 1,933 |
| | Secondary school | 1,300 | 51 | 119 | 96 | 5,516 |
| | Social clubs | 1 | 57 | 87 | 96 | 1,243 |
| | Special school | 419 | 51 | 162 | 112 | 1,691 |
| | Speedway | 3 | 44 | 159 | 121 | 1,148 |
| | State primary school | 2,496 | 44 | 132 | 94 | 1,617 |
| | State school | 160 | 44 | 135 | 96 | 1,519 |
| | State secondary school | 403 | 52 | 114 | 94 | 6,082 |
| Village hall | 2 | 46 | 159 | 90 | 1,229 | |
| University campus | Classroom | 76 | 77 | 111 | 72 | 2,763 |
| | Lecture hall | 27 | 85 | 151 | 81 | 2,771 |
| | Sixth form college | 395 | 82 | 128 | 76 | 3,430 |
| | University | 944 | 88 | 129 | 79 | 3,893 |
| Clinic | Clinic or health centre | 232 | 75 | 157 | 89 | 1,317 |
| | Dentist's surgery | 4 | 122 | 155 | 122 | 2,107 |
| | Doctor's surgery | 16 | 77 | 120 | 78 | 1,037 |
| | Health Centres and Clinics | 229 | 77 | 145 | 86 | 1,472 |
| | Medical and dental centre combined | 16 | 72 | 180 | 85 | 1,483 |
| | Medical centre | 28 | 63 | 117 | 65 | 2,080 |
| | Occupational health centre | 17 | 51 | 213 | 91 | 1,482 |
| | Out patient treatment establishments | 48 | 66 | 169 | 90 | 1,711 |
| | Primary health care buildings | 131 | 82 | 174 | 95 | 1,565 |
| Surgery or clinic | 7 | 68 | 156 | 88 | 684 | |
| Hospital - clinical and research | General Acute Hospital | 423 | 118 | 311 | 97 | 5,038 |
| | Teaching/Specialist Hospital | 150 | 132 | 265 | 101 | 3,244 |

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CIBSE Display Energy Certificate (DEC) Review – Final Report
 Prepared by UCL Energy Institute

| Benchmark Category / Building Type | | N | EUI Elec. (kWh/m ²) Median | EUI Heating (kWh/m ²) Median | DEC Rating Median | Floor Area Median | |
|------------------------------------|---|-------------------|--|--|-------------------------|-------------------------|--------|
| Long term residential | Community and Mental Health Hospitals | 257 | 91 | 287 | 90 | 2,530 | |
| | Detention | 1 | 110 | 395 | 105 | 888 | |
| | Detention centre | 3 | 58 | 210 | 59 | 6,333 | |
| | Home | 131 | 81 | 341 | 93 | 1,399 | |
| | Hospital | 35 | 86 | 308 | 93 | 2,412 | |
| | Hostel | 78 | 67 | 247 | 72 | 1,789 | |
| | Nursing home | 207 | 83 | 337 | 91 | 1,500 | |
| | Nursing residential homes and hostels | 165 | 84 | 318 | 91 | 1,510 | |
| | Prison | 100 | 94 | 256 | 85 | 23,414 | |
| | Remand centre | 4 | 142 | 241 | 115 | 3,461 | |
| | Young offenders instit'n | 9 | 141 | 264 | 124 | 4,817 | |
| General accommodation | Boarding/guesthouse | 45 | 66 | 228 | 87 | 2,655 | |
| | Holiday centre | 2 | 50 | 188 | 79 | 1,897 | |
| | Junior ranks accommodation | 8 | 59 | 190 | 68 | 4,435 | |
| | Mess - wos & sgts - catering & accommodation | 1 | 60 | 208 | 68 | 10,460 | |
| | Official service residence | 3 | 36 | 149 | 38 | 1,753 | |
| | School boarding house | 135 | 55 | 194 | 75 | 2,207 | |
| | Service families accommodation - officers - type 1 | 1 | 77 | 176 | 82 | 1,145 | |
| | Transient accommodation - other ranks | 1 | 109 | 123 | 87 | 6,172 | |
| Emergency services | Ambulance station | 13 | 83 | 156 | 78 | 2,330 | |
| | Emergency services | 18 | 89 | 203 | 74 | 1,547 | |
| | Fire station | 259 | 69 | 228 | 76 | 1,145 | |
| | Police station | 456 | 134 | 200 | 96 | 2,454 | |
| Laboratory or operating theatre | Laboratory | 74 | 242 | 238 | 115 | 3,050 | |
| Public waiting or circulation | Bus station/train station/seaport terminal | 5 | 118 | 43 | 174 | 2,276 | |
| | Terminal | Airport terminals | 1 | 117 | 221 | 127 | 13,112 |
| | | Railway mixed use | 1 | 269 | 232 | 224 | 4,452 |
| Workshop | Contractors sheds etc | 2 | 99 | 244 | 186 | 2,789 | |
| | Crematorium | 7 | 112 | 196 | 218 | 816 | |
| | Fixed wing aircraft - repair | 2 | 52 | 83 | 80 | 3,423 | |
| | Manufacturing premises excluding process energy use | 11 | 79 | 114 | 123 | 2,136 | |
| | Recording studios | 3 | 52 | 72 | 78 | 1,642 | |
| | Sorting office | 10 | 67 | 172 | 122 | 853 | |
| | Vehicle repair workshop | 12 | 73 | 118 | 110 | 2,585 | |
| | Vehicle services | 4 | 63 | 121 | 98 | 1,581 | |
| | Workshop | 48 | 46 | 105 | 87 | 1,796 | |
| Workshops/maintenance depot | 29 | 62 | 145 | 109 | 1,684 | | |
| Storage facility | Storage depot | 25 | 37 | 77 | 75 | 2,091 | |
| All | | 22,151 | | | | | |

Table B1 Statistics by building type (based on data described in Section 2.2.1)

Appendix C – Distribution of DECs by main heating fuel type

| Benchmark Category | N | Main heating fuel | | | | | | | | | | | | |
|---------------------------------------|--------|-------------------|--------|---------|------|------------------|----------------------------|---------------------------|------|-------------|-------|-------|---------------------------|-----|
| | | - Anthracite | Biogas | Biomass | Coal | District Heating | Grid Displaced Electricity | Grid Supplied Electricity | LPG | Natural Gas | Oil | Other | Smokeless Fuel (inc Coke) | |
| | | % | % | % | % | % | % | % | % | % | % | % | % | % |
| General office | 16,848 | . | 0.0 | 0.0 | 0.2 | 0.1 | 1.7 | 0.0 | 6.9 | 0.1 | 87.5 | 3.2 | 0.2 | . |
| High street agency | 1,022 | . | . | . | . | . | . | . | 4.8 | . | 92.6 | 2.6 | . | . |
| General retail | 212 | . | . | . | . | . | 1.4 | . | 25.0 | . | 69.8 | 3.8 | . | . |
| Large non-food shop | 15 | . | . | . | . | . | . | . | 46.7 | . | 53.3 | . | . | . |
| Small food store | 3 | . | . | . | . | . | . | . | 33.3 | . | 66.7 | . | . | . |
| Large food store | 1 | . | . | . | . | . | . | . | . | . | 100.0 | . | . | . |
| Restaurant | 958 | . | . | . | 0.8 | 1.6 | 1.8 | . | 1.6 | 0.3 | 80.7 | 12.1 | 1.1 | . |
| Bar, pub or licensed club | 245 | . | . | . | . | . | 11.4 | . | 5.7 | . | 78.4 | 2.9 | 1.6 | . |
| Hotel | 112 | . | . | . | . | . | 6.3 | . | 19.6 | 1.8 | 59.8 | 12.5 | . | . |
| Cultural activities | 3,327 | . | . | . | 0.3 | 0.4 | 2.9 | . | 7.7 | 0.5 | 83.2 | 4.6 | 0.5 | . |
| Entertainment halls | 1,107 | . | . | . | 0.6 | . | 5.1 | . | 1.4 | 0.1 | 88.9 | 3.0 | 0.9 | . |
| Swimming pool centre | 1,150 | . | . | . | 0.1 | 1.0 | 1.2 | . | . | . | 95.5 | 2.3 | . | . |
| Fitness and health centre | 665 | . | . | . | . | 0.2 | 1.5 | . | 0.9 | . | 94.9 | 2.6 | . | . |
| Dry sports and leisure facility | 5,160 | . | 0.0 | . | 0.4 | 0.5 | 0.8 | . | 1.7 | 0.2 | 92.8 | 3.7 | . | . |
| Covered car park | 379 | . | . | . | . | . | 3.4 | . | 10.0 | . | 86.0 | 0.5 | . | . |
| Public buildings with light usage | 30 | . | . | . | . | . | . | . | 13.3 | . | 86.7 | . | . | . |
| Schools and seasonal public buildings | 59,668 | 0.0 | 0.0 | 0.0 | 0.4 | 0.7 | 0.1 | . | 0.7 | 0.2 | 87.6 | 10.2 | 0.0 | 0.0 |
| University campus | 9,540 | 0.0 | 0.0 | . | 0.1 | 0.2 | 6.7 | . | 3.1 | 0.2 | 85.8 | 3.0 | 0.9 | . |
| Clinic | 3,498 | . | . | . | 0.3 | 0.6 | 1.1 | 0.1 | 3.2 | 0.1 | 93.7 | 0.9 | . | . |
| Hospital - clinical and research | 3,752 | . | . | . | 0.1 | 1.3 | 3.5 | 0.2 | 0.6 | 0.0 | 90.9 | 3.3 | 0.1 | . |
| Long term residential | 5,122 | . | . | . | 0.1 | 0.4 | 0.8 | 0.3 | 3.0 | 0.3 | 90.6 | 4.5 | . | . |
| General accommodation | 2,020 | . | . | . | 0.1 | 0.1 | 5.5 | . | 20.1 | 0.3 | 68.2 | 5.5 | . | . |

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| Benchmark Category | N | Main heating fuel | | | | | | | | | | | Smokeless Fuel (inc Coke) | |
|---------------------------------|---------|-------------------|--------|---------|------|------------------|----------------------------|---------------------------|------|-------------|-------|-------|------------------------------|-----|
| | | - Anthracite | Biogas | Biomass | Coal | District Heating | Grid Displaced Electricity | Grid Supplied Electricity | LPG | Natural Gas | Oil | Other | | |
| | | % | % | % | % | % | % | % | % | % | % | % | % | % |
| Emergency services | 3,463 | 0.0 | . | . | 0.2 | 0.1 | 0.2 | . | 2.3 | 0.1 | 91.7 | 5.3 | . | . |
| Laboratory or operating theatre | 553 | . | . | . | . | 0.5 | 22.6 | . | 0.5 | . | 70.5 | 2.9 | 2.9 | . |
| Public waiting or circulation | 61 | . | . | . | . | . | 3.3 | . | 19.7 | . | 77.0 | . | . | . |
| Terminal | 3 | . | . | . | . | . | . | . | 33.3 | . | 66.7 | . | . | . |
| Workshop | 1,064 | . | . | . | . | . | 0.5 | . | 1.1 | 1.7 | 92.6 | 4.1 | . | . |
| Storage facility | 227 | . | . | . | . | . | 1.3 | . | 2.6 | 0.4 | 89.0 | 6.6 | . | . |
| Cold storage | 20 | . | . | . | . | . | . | . | 5.0 | . | 95.0 | . | . | . |
| Invalid | 28 | . | . | . | . | . | . | . | . | . | 100.0 | . | . | . |
| All | 120,253 | 0.0 | 0.0 | 0.0 | 0.3 | 0.5 | 1.4 | 0.0 | 2.7 | 0.2 | 87.7 | 6.9 | 0.2 | 0.0 |

Table C1 Distribution of DEC data by main heating fuel type (based on unfiltered raw data prior to the steps described in Section 2.1)

Appendix D – Distribution of DEC by internal environment type

| Benchmark Category | N | Servicing type | | | | | | | |
|---------------------------------------|-------|------------------|------------------------------------|---------------------------------|-----------------------------|--|-------------------------------------|--------------------------|--|
| | | Air Conditioning | Heating and Mechanical Ventilation | Heating and Natural Ventilation | Mechanical Ventilation Only | Mixed-mode With Mechanical Ventilation | Mixed-mode with Natural Ventilation | Natural Ventilation Only | |
| | | % | % | % | % | % | % | % | |
| General office | 2911 | 20 | 15 | 52 | 0 | 6 | 7 | 0 | |
| High street agency | 30 | 47 | 10 | 37 | . | | 7 | | |
| General retail | 33 | 3 | 21 | 58 | | 9 | 9 | | |
| Large non-food shop | 1 | . | | 100 | . | | . | | |
| Restaurant | 21 | . | 38 | 57 | | 5 | . | | |
| Bar, pub or licensed club | 7 | . | 43 | . | | 43 | 14 | | |
| Hotel | 16 | . | 19 | 63 | | 13 | 6 | | |
| Cultural activities | 544 | 10 | 20 | 57 | | 8 | 6 | | |
| Entertainment halls | 203 | 11 | 34 | 32 | | 19 | 4 | | |
| Swimming pool centre | 261 | 4 | 68 | 9 | | 17 | 2 | | |
| Fitness and health centre | 42 | 5 | 43 | 36 | | 12 | 2 | 2 | |
| Dry sports and leisure facility | 606 | 2 | 43 | 38 | 0 | 13 | 3 | | |
| Public buildings with light usage | 4 | . | 25 | 75 | . | | . | | |
| Schools and seasonal public buildings | 12563 | 0 | 3 | 93 | | 1 | 3 | 0 | |
| University campus | 1442 | 6 | 21 | 50 | | 14 | 9 | | |
| Clinic | 728 | 2 | 25 | 61 | | 6 | 5 | 0 | |
| Hospital - clinical and research | 573 | 7 | 28 | 31 | | 21 | 12 | 1 | |
| Long term residential | 990 | 1 | 21 | 73 | | 2 | 4 | 0 | |
| General accommodation | 196 | . | 4 | 94 | | 1 | 1 | 1 | |
| Emergency services | 746 | 4 | 12 | 70 | | 6 | 8 | | |
| Laboratory or operating theatre | 74 | 32 | 35 | 5 | | 19 | 8 | | |
| Cont'd | | | | | | | | | |

| Benchmark Category | N | Servicing type | | | | | | |
|-------------------------------|-------|------------------|------------------------------------|---------------------------------|-----------------------------|--|-------------------------------------|--------------------------|
| | | Air Conditioning | Heating and Mechanical Ventilation | Heating and Natural Ventilation | Mechanical Ventilation Only | Mixed-mode With Mechanical Ventilation | Mixed-mode with Natural Ventilation | Natural Ventilation Only |
| | | % | % | % | % | % | % | % |
| Public waiting or circulation | 5 | 20 | 40 | 40 | . | . | . | . |
| Terminal | 2 | 50 | 50 | . | . | . | . | . |
| Workshop | 128 | 1 | 20 | 72 | . | 4 | 4 | . |
| Storage facility | 25 | 8 | 24 | 64 | . | 4 | . | . |
| All | 22151 | 4 | 11 | 76 | 0 | 4 | 4 | 0 |

Table D1 Distribution of buildings in each category by internal environment (based on data described in Section 2.2.1)