Department for Business, Energy & Industrial Strategy

Building Energy Efficiency Survey: Education sector, 2014–15

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Contents

Notes on statistical conventions

1. All estimates for energy consumption and greenhouse gas emissions are presented on an annual basis.
2. All results presented relate to 2014–15.
3. All estimates shown in all reports are point estimates and subject to uncertainty as they are based on survey findings. Confidence intervals are shown in Appendix A at sub-sector level for energy intensity for electrical and non-electrical uses.
4. Rounding conventions:
    - All energy values presented in this report are quoted in units of gigawatt-hours (GWh) and rounded to the nearest multiple of 10 with the exception of values below 10, which are presented as integers. For example, a quantity of 316 GWh would be presented in this report as 320 GWh;
    - All greenhouse gas emission values are quoted either in units of kilotonnes of carbon dioxide equivalent ($ktCO_2e$) rounded to the nearest multiple of 10 with the exception of values below 10, which are presented as integers, or in megatonnes of carbon dioxide equivalent ($MtCO_2e$) and rounded to one decimal place. For example, a quantity of 316 $ktCO_2e$ would be presented in this report as 320 $ktCO_2e$, or as 0.3 $MtCO_2e$;
    - All electrical and non-electrical energy intensity values (for example, tables C.5 and C.6) are quoted in units of kilowatt-hours per square meter GIA per year (kWh/m^2), rounded to the nearest integer;
    - All financial figures presented in tabular form in this report are quoted in thousands of pounds (£) and rounded to the nearest multiple of £100,000 unless stated otherwise. For example, a quantity of £65,340,000 would be presented in this report as 65,300 (in units of £ thousands);
    - All figures for total floor areas across the sector are quoted in units of millions of square meters and rounded to the nearest multiple of 1. For example, a floor area of 16,385,312 m^2 would be presented as 16 million m^2;
    - All percentage values are quoted to the nearest integer;
    - Abatement potential payback[1] estimates are shown to the nearest year.
5. Table conventions:
    - For data presented in tabular form, zero values are represented by a ‘dash’ symbol i.e. ‘-’;
    - For data presented in tabular form, the final row shows the total of all individual values. Where such a total is not applicable, a ‘double apostrophe’ symbol is presented i.e. ‘’.
6. All floor area figures are presented in units of Gross Internal Area (GIA). This is the floor area of a building measured to the internal face of the perimeter walls at each floor level. Further information can be found in “Code of measuring practice: definitions for rating purposes”, available at: www.gov.uk/government/publications/measuring-practice-for-voa-property-valuations/code-of-measuring-practice-definitions-for-rating-purposes.

[1] Payback is a measure of the time required for the cumulative savings associated with an energy saving measure to match the cost of installation. It is calculated by dividing the capital installation cost associated with a measure by the annual financial savings achieved based on energy cost reductions accounting for any annual operational costs.

Executive summary

Introduction

The Building Energy Efficiency Survey (BEES) was designed to meet the following research objectives:

- To update the Department's understanding of how energy is used, for a snap-shot in time, across the non-domestic building stock in more detail than is available at present;[2]
- To update the Department's understanding of how energy use can be abated across the non-domestic building stock in more detail than is available at present;
- To understand the barriers and enablers of energy abatement.

The first two objectives are addressed in this and other sector reports. The third objective is addressed in the BEES overarching report.

Overview of project method

The BEES study reports on the non-domestic building stock for England and Wales. Within this overall scope the stock is split into 10 sectors. These are in turn made up of 38 sub-sectors, each of which were analysed separately. This report provides the detailed study findings for the education sector.

The study collected data through a large sample of telephone surveys (3,690) across all sectors. Each survey record is a premises which may represent a whole building or a part of a building. This information was obtained from a single organisation in a premises[3]. A smaller subset of site surveys (214) across all sectors were sampled from within the telephone survey sample. The telephone survey respondents were randomly selected from national level datasets for England and Wales.

The telephone surveys were used as the primary input into two models. One model calculated the records' energy use (the energy use model) and the other calculated the energy saving potential (the abatement model). The energy use model estimated the energy consumption of each premises record at an end use level. The abatement model determined the abatement potential of energy efficiency measures which could be applied to that premises, their capital cost and the amount of energy these measures could save.

The detailed findings from site surveys and a database of matched energy and activity data were used to calibrate the two models. The site surveys were also used to validate the telephone survey responses, and collect information on barriers and facilitators from the site contacts.

Overall, the model calibration process has shown that at a sub-sector level the energy use consumption is reliable but that at a single record level the accuracy has a higher level of uncertainty.

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[2] The current non-domestic stock model (Pout, C (2000) NDEEM: the national non-domestic buildings energy and emissions model) is underpinned by field research conducted by Sheffield Hallam University in the 1990s.

[3] For all telephone surveys, the person responsible for managing energy on site was sought to complete the survey.

The overall project method had weaknesses in two key areas:

- Data inputs were obtained through telephone surveys, which were highly simplified. The telephone survey was designed to ensure it was easy to understand for non-energy experts so this meant questions could not be particularly technical and this further limited the sophistication of the input data to the model;
- The majority of the inputs were self-reported, which meant it was prone to a range of biases, such as differences in interpretation or understanding of a question by the respondent.

Following analysis of the data on the individual premises, the record results were weighted in order to produce results representative of all non-domestic buildings in England and Wales in each sector.

Education sector overview

The education sector consisted of nurseries, primary schools, secondary schools and higher education (HE) teaching & research and student residential accommodation. For the purpose of this study, it did not include education premises that were present in other building types, for example sports centres. The education sector had a total floor area of 80 million m^2 (10 per cent of the total non-domestic stock) across 47,500 premises (3 per cent of the total non-domestic stock). The education sector's total energy consumption was 15,020 GWh. The sector's electrical energy consumption was 4,930 GWh (6 per cent of the total non-domestic stock) and non-electrical consumption was 10,100 GWh (13 per cent of total non-domestic stock).

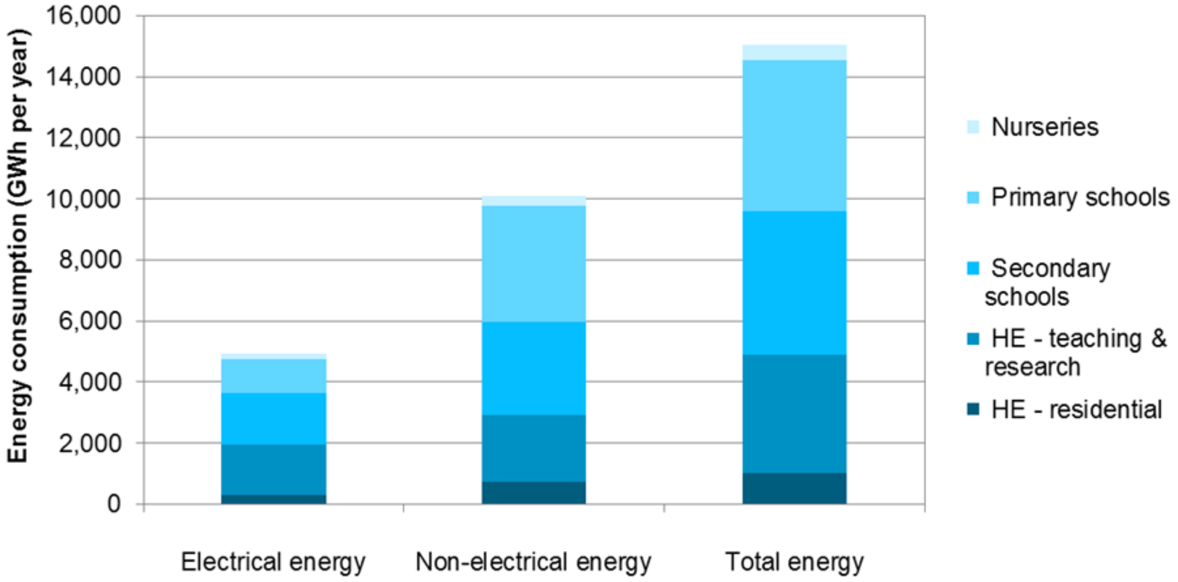
The findings in this report are based on data collected through 165 telephone surveys used in the energy use and abatement models and 18 site surveys in 2014–15.

Key findings

Energy consumption in the education sector, 2014–15

- According to modelled data based on telephone survey responses, the sector consumed 15,020 GWh of energy. This included 4,930 GWh of electrical energy and 10,100 GWh of non-electrical energy per year (Figure 0.1).
- The largest energy consumer in this sector was primary schools, with 4,930 GWh total energy consumption (33 per cent of sector total): Secondary schools were the second largest consumer, with 4,700 GWh of total energy consumption (31 per cent of sector total).
- The difference in absolute consumption between the sub-sectors matched to some extent with their overall size. Primary and secondary schools were the largest sub-sectors in terms of energy consumption, while also representing 68 per cent of the sector's overall floor area. In contrast, nurseries represented 3 per cent of the sector's floor area (the smallest of the five sub-sectors) as well as only 3 per cent of the overall energy consumption.
- Whilst all of the of the education sector had similar total energy intensities, higher education – teaching & reserach premises had the highest median total energy intensity (192 kWh/m^2), followed by primary schools (191 kWh/m^2).
- Higher education – teaching & research premises typically displayed the highest median electrical energy intensity (78 kWh/m^2). Higher education – residential premises displayed the highest median non-electrical energy intensity of 144 kWh/m^2, followed by primary schools (140 kWh/m^2) and nurseries (133 kWh/m^2).
- The energy consumption of the education was broken down into specific 'end uses'. The most significant end use was space heating (8,420 GWh, 56 per cent of total energy consumption), followed by hot water (1,470 GWh, 10 per cent of total energy consumption).

Figure 0.1: Energy consumption by energy type and education sub-sector, 2014–15



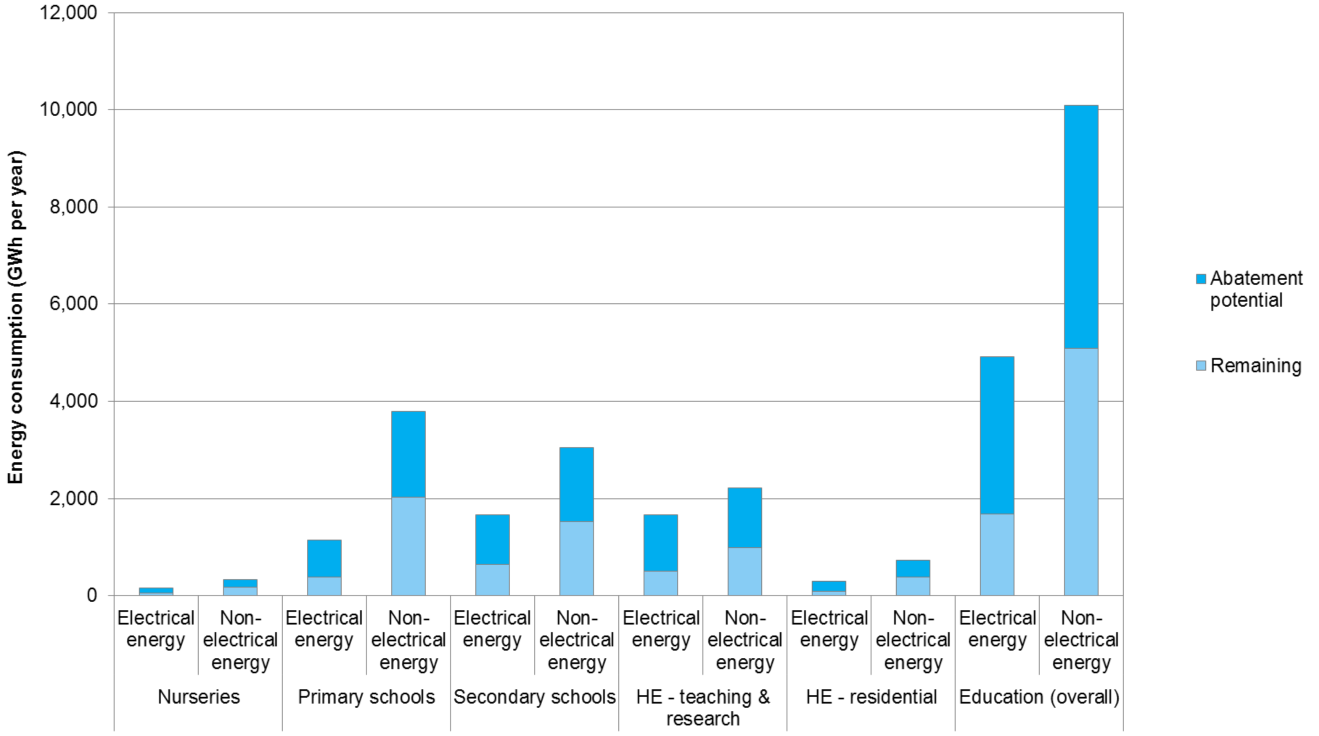
Source: Energy use model results for the sector covering England and Wales

Abatement potential in the education sector, 2014–15

- According to modelled data based on telephone survey responses, Figure 0.2 shows abatement potential for the sector, broken down by sub-sector and fuel type. This represents the total abatement potential that is technically available, which relates to the possible reductions in energy consumption following implementation of all applicable measures. The results include measures that are not cost-effective and the model applies a simple assessment of measure suitability. Building specific installation requirements that may impose additional costs are not accounted for.
- The total abatement potential in the education sector was 6,760 GWh of total energy consumption (45 per cent reduction on consumption). This comprised 1,670 GWh of electrical energy (a 34 per cent reduction) and 5,090 GWh of non-electrical energy (a 50 per cent reduction).
- This could be achieved at a capital cost of £2.1 billion. The socially cost effective potential was 4,000 GWh of total energy consumption, which consisted of 1,250 GWh of electrical energy consumption and 2,750 GWh of non-electrical energy consumption. Companies are more likely to be influenced by the payback period for improvement: overall there were 1,700 GWh of total energy savings with a private payback period[4] of 3 years or less (410 GWh electrical energy abatement and 1,290 non-electrical energy abatement).
- The sub-sector with the largest relative and absolute abatement potential was primary schools, with 370 GWh of electrical energy (33 per cent reduction on consumption) and 2,030 GWh of non-electrical energy (54 per cent reduction on consumption).

[4] Payback is calculated by dividing the total cost associated with a measure (the capital cost installation cost and annual operational costs) and dividing these by the annual financial savings achieved based on energy cost reductions.

Figure 0.2: Abatement potential by energy type and education sub-sector, 2014–15



Source: Abatement model results by sub-sector, England and Wales

Table 0.1 shows the abatement potential by measure type. Definitions of measure type are included in Appendix C. The largest group of savings for the education sector – in terms of reductions in energy consumption – relate to the implementation of building instrumentation & control measures, carbon & energy management and space heating measures. The largest group of savings – in terms of the potential energy bill savings - relate to the implementation of carbon and energy management programmes.

Table 0.1: Abatement potential in the education sector by measure type, 2014–15

Measure type	Savings					
	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**
Air conditioning and cooling	4,200	10	40	-	40	52,300
Building fabric	26,500	180	20	960	980	486,800
Building instrumentation and control	34,500	220	70	1,100	1,170	172,900
Building services distribution systems	5,800	20	60	-	60	57,900
Carbon and energy management	73,400	370	410	1,290	1,700	81,700
Hot water	13,400	80	40	360	400	63,000
Humidification	-	-	-	-	-	-
Lighting	72,700	210	730	-	730	410,800
Cooled storage	2,700	8	30	-	30	12,400
Small appliances	3,400	10	30	20	50	64,000
Space heating	37,700	280	30	1,360	1,390	436,500
Swimming pools	300	2	1	7	8	2,600
Ventilation	20,700	60	210	-	210	223,900
Total	**295,400**	**1,430**	**1,670**	**5,090**	**6,760**	**2,064,900**

Source: Abatement model results for the sector, England and Wales

1. Education sector

This report relates to the education sector (one of ten sectors covered in the Building Energy Efficiency Survey (BEES)). This section provides definitions for the five education sub-sectors (nurseries, primary schools, secondary schools, higher education – teaching & research and higher education – residential). It then sets the education sector in the wider non-domestic stock context in terms of both the number of premises and floor area it represents.

Table 1.1 sets out the definitions for each of the sub-sectors reported in the education sector.

Table 1.1: Table of education sub-sector definitions[5]

Sub-sector	Definition
Nurseries	Refers to premises used for educational programmes or daytime supervision/recreation for young children before they attend primary school. Gross internal floor area should include all space within the premises, including classrooms, administrative space, conference rooms, kitchens used by staff, lobbies, cafeterias, gymnasiums, auditoriums, stairways, lift shafts, and storage areas.
State and private primary schools (referred to as 'primary schools')	Refers to premises used for the education of children up to Year 6 (ages 10 and 11) prior to secondary prior to secondary school. Gross internal floor area should include all space within the premises, including classrooms, administrative space, conference rooms, kitchens used by staff, lobbies, cafeterias, gymnasiums, auditoriums, laboratory classrooms, portable classrooms, greenhouses, stairways, atriums, lift shafts, small landscaping sheds, and storage areas.
State and private secondary schools (referred to as 'secondary schools')	Refers to premises used for providing children with part or all of their secondary education, typically between the ages of 11-18 Gross internal floor area should include all space within the premises, including classrooms, administrative space, conference rooms, kitchens used by staff, lobbies, cafeterias, gymnasiums, auditoriums, laboratory classrooms, portable classrooms, greenhouses, stairways, atriums, lift shafts, small landscaping sheds, and storage areas.[6] State and Private colleges (6th form and other forms of Further Education) have been included within this sub-sector.[7]
Higher education teaching & research (referred	Refers to premises used for the purposes of higher education. This includes public and private colleges and universities, but excludes residential buildings. Gross internal floor area should include all space

[5] These definitions were originally based on those used for US Energy Star scheme and then were adapted for the UK context.

[6] In order to qualify for the telephone survey premises needed to include teaching space. Residential areas were excluded from analysis. A building within the premises of a school which was dedicated to accommodation would be screened out in the telephone survey.

[7] Sampling was based on DEC categories - secondary schools with integrated 6th form facilities would in most cases be part of 'secondary schools', while 6th form colleges in independent premises would be categorised as 'higher education'.

Sub-sector	Definition
to as ‘higher education – teaching & research’)[8]	within the premises, including classrooms, laboratories, offices, cafeterias, maintenance facilities, arts facilities, athletic facilities, storage rooms, toilets, lift shafts, and stairways.
Higher education residential (referred to as ‘higher education – residential’)	Refers to premises used for the provision of accommodation for students studying for higher education.

Education sector in the context of the wider non domestic stock

The education sector accounts for 3 per cent of the non-domestic stock in terms of premises count (47,500) and 10 per cent in terms of floor area (80 million m^2 GIA[9]).[10]

In terms of energy consumption the sector consumed 15,020 GWh of total energy per year. This comprised 4,930 GWh of electrical energy and 10,100 GWh of non-electrical energy per year, which is equivalent to 6 per cent and 13 per cent of non-domestic stock totals respectively. This information is set out in Figure 1.1 to Figure 1.3.

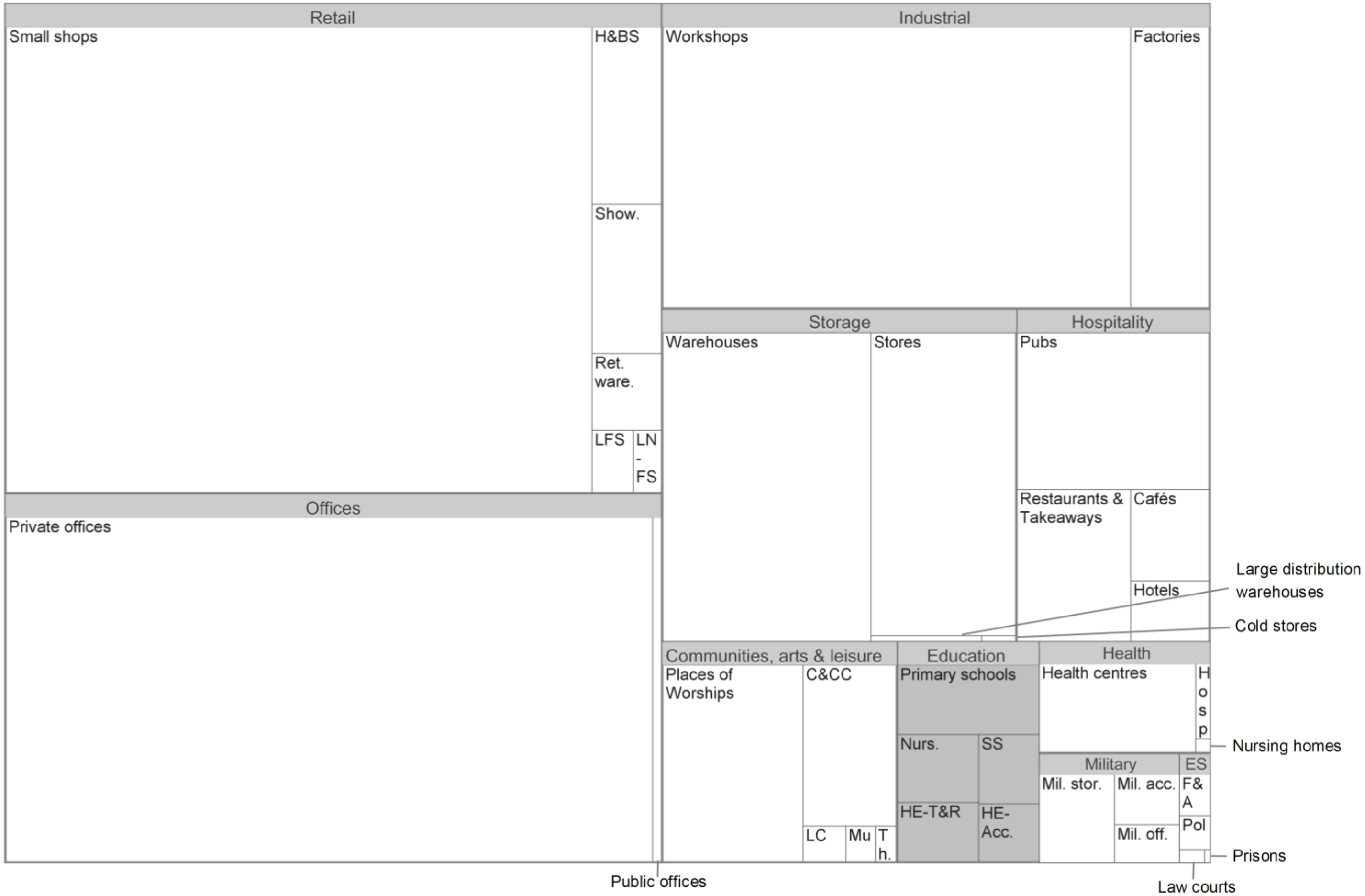
[8] As part of BEES analysis, in order to create a homogenous sub-sector, it has been assumed that 100% of higher education – teaching & research premises floor area is used for teaching facilities. In practise it is understood that typically only 78% of floor area is in activities that would be classified in this way with the remaining floor area being in activities split across other uses.

[9] GIA stands for Gross Internal Area: the area of a building measured to the internal face of the perimeter walls at each floor level.

[10] The sources for these statistics can be found in the technical annex (and are referred to collectively as the Population table).

Figure 1.1: Premises frequency by sub-sector for the non-domestic stock, 2014–15

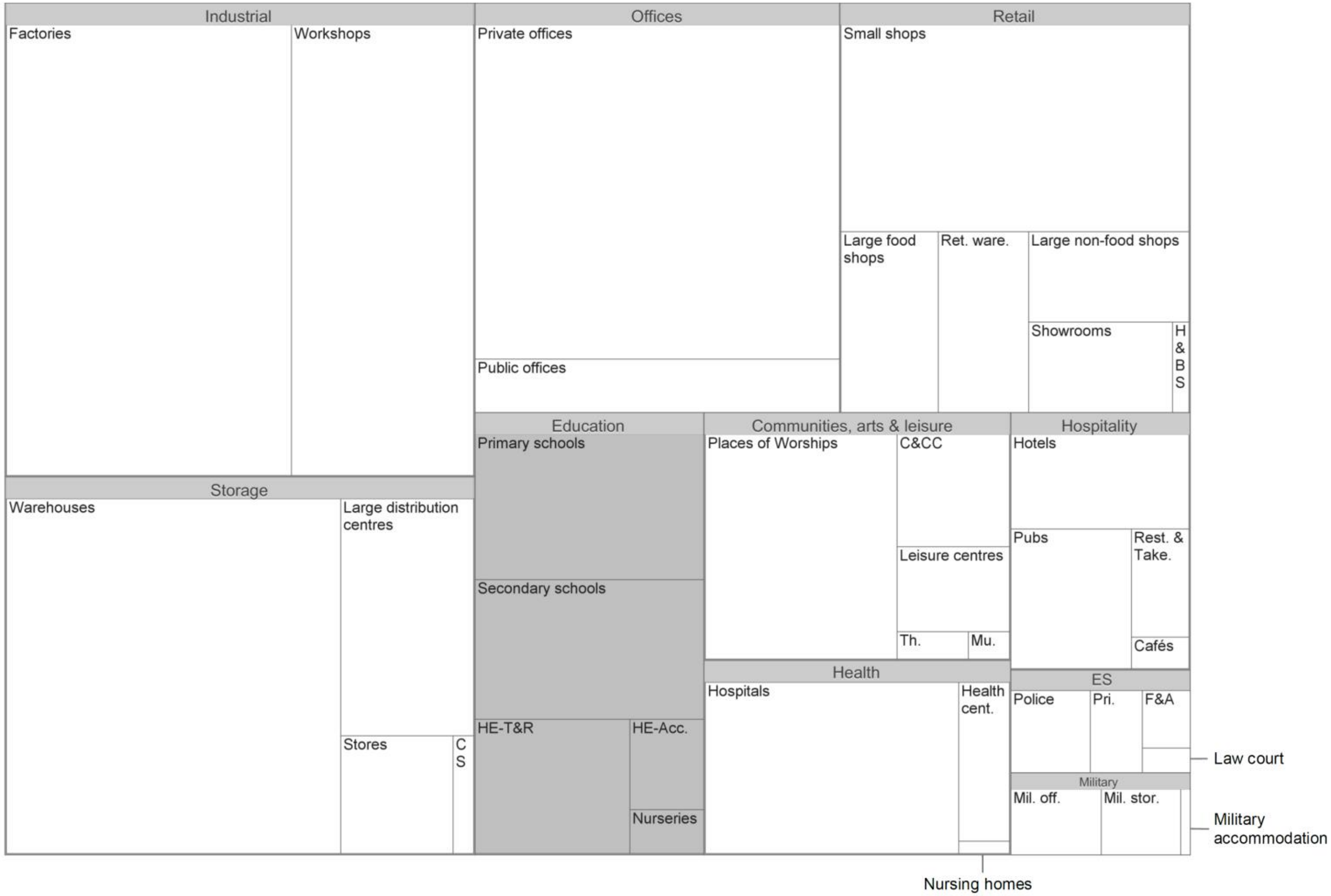
ID	Sub-sector
H&BS	Hairdressing & beauty salons
Show.	Showrooms
Ret. ware.	Retail warehouses
LFS	Large food shops
LN-FS	Large non-food shops
C&CC	Clubs & community centres
LC	Leisure centres
Mu.	Museums, Art galleries and Libraries
Th.	Theatres, cinemas and concert halls
Nurs.	Nurseries
SS	Secondary schools
HE-T&R	HE—Teaching and research
HE-Acc.	HE — Accommodation
Hosp.	Hospitals
Mil. stor.	Military storage
Mil. acc.	Military accommodation
Mil. off.	Military offices
F&A	Fire & ambulance stations
Pol.	Police stations



Source: Population table

Figure 1.2: Floor area by sub-sector for the non-domestic stock, 2014–15

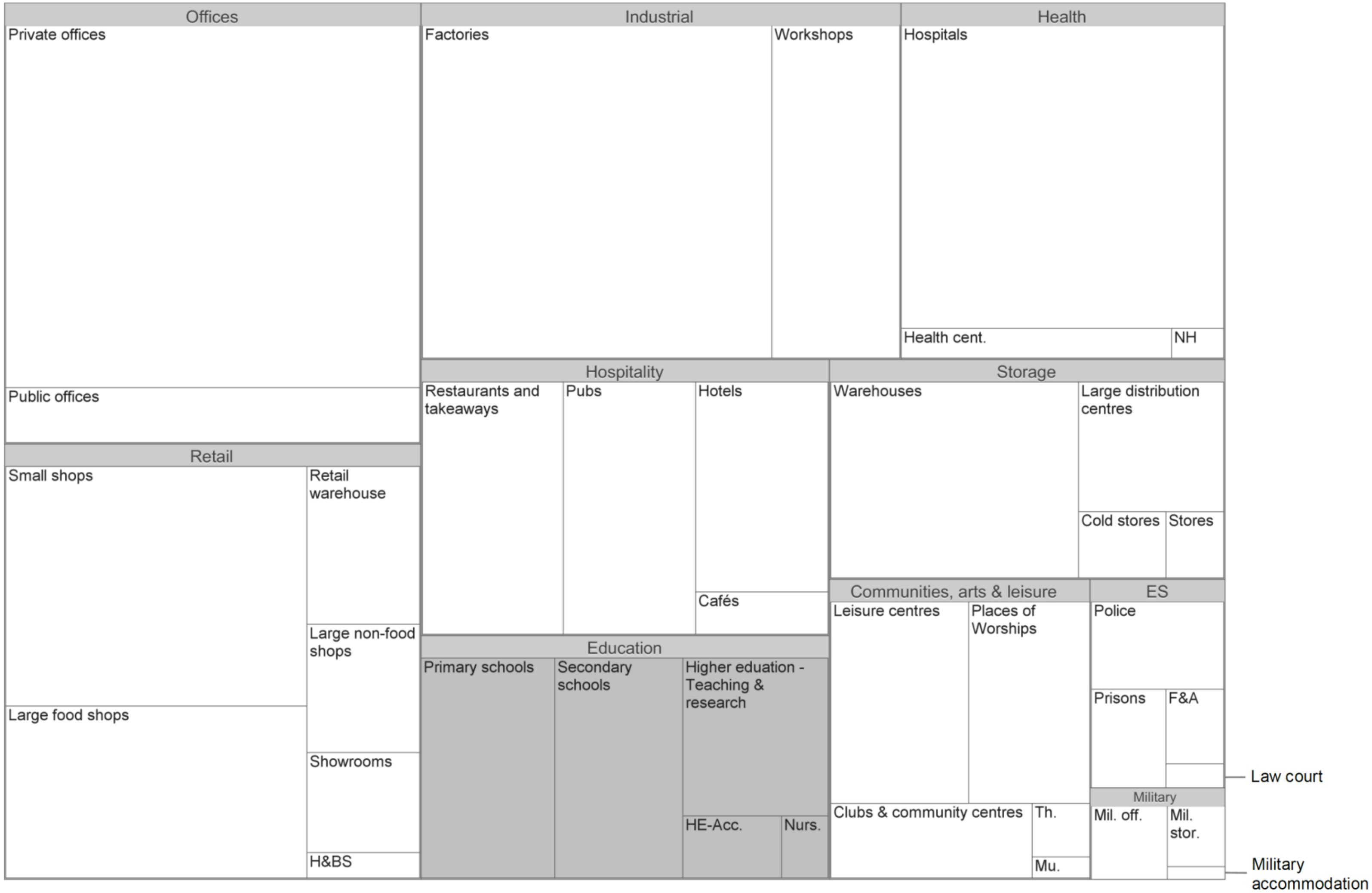
ID	Sub-sector
Ret. ware.	Retail warehouse
H&BS	Hairdressing & beauty salons
CS	Cold stores
HE-T&R	HE—Teaching and research
HE-Acc.	HE — Accommodation
C&CC	Clubs & community centres
LC	Leisure centres
Th.	Theatres, cinemas and concert halls
Mu.	Museums, Art galleries and Libraries
Health cent.	Health centre
Rest. & Take.	Restaurants & takeaways
Pri.	Prisons
F&A	Fire & ambulance stations
Mil. off.	Military office
Mil. Stor.	Military storage



Source: Population table

Figure 1.3: Energy consumption by sub-sector for the non-domestic stock, 2014–15

ID	Sub-sector
Health cent.	Health centre
NH	Nursing homes
H&BS	Hairdressing & beauty salons
HE-Acc.	HE — Accommodation
Nurs.	Nurseries
Th.	Theatres, cinemas and concert halls
Mu.	Museums, Art galleries and Libraries
F&A	Fire & ambulance stations
Mil. off.	Military office
Mil. Stor.	Military storage



Source: Energy use model results by sub-sector, England and Wales

General characteristics of the education sector

The survey records relate to a single premises within buildings predominantly classified as education activities. In some cases the premises will be the whole building, in other cases just the area occupied by a single organisation.

Education premises varied greatly in size and complexity from small nurseries forming part of an otherwise domestic property, to large university research facilities with extensive mechanical ventilation and air conditioning, leisure and conference facilities. Individual premises ranged in organisational structure from independent nurseries, local authority managed and privately run schools up to the largest universities in England and Wales.

Within the sector there are clear differences in energy uses between nurseries, schools and higher education establishments, and furthermore residential and non-residential facilities in higher education as a result of the different activities undertaken.

In nursery and school-level facilities, the dominant activity was teaching, and classrooms made up the largest part of the floor space. Other common activities included catering provision, staff areas and outdoor spaces for play. As the age of the students increases energy intensive activities such as computer rooms, server rooms, theatres/drama studios, and swimming pools became more common.

In higher education - residential premises, facilities were dominated by bedrooms; kitchens, living space and washing facilities made up much of the remainder. Catering facilities, laundrettes, retail and educational space was also found in these premises, especially when they were part of a larger campus. Higher education – teaching & research premises were dominated by teaching spaces (lecture halls, seminar rooms, teaching laboratories etc.), offices (either for teaching, research or support staff), common areas and rest facilities. Exceptional additional energy intensive uses included research laboratories, computer rooms for students, sports facilities or swimming pools, catering facilities and server rooms.

Summary statistics for the education sector

A number of standard characteristics for the education sector are set out in Table 1.3, Figure 1.4 and Figure 1.5; from premises and organisation size through to operating hours and premises tenure. These key characteristics for the education sector and how these vary across the education sub-sectors themselves are described.

Analysis of BEES has primarily been done to give a fair representation of floor area within sub-groups. Floor area has a strong association with energy use.

Based on the floor area weighted records, premises in the education sector had broadly common characteristics with the exception of nurseries:

- Universities and schools tended to occupy a whole building which they owned. The buildings were often built before 1985 and typically had peak occupancy hours for fewer than 8 hours a day;
- In contrast, nurseries were split evenly between owner occupied and leased premises and often occupied only part of a building. They tended to be based in buildings constructed after 1991 and had peak occupancy hours between 9 to 15 hours a day.

The education sector organisation sizes were tailored by sub-sector to improve their relevance. The organisation size bandings are shown in Table 1.2.

Table 1.2: Organisation size tailoring by sub-sector

Sub-sector	**Nurseries**	**Primary schools**	**Secondary schools**	**Higher education**
Organisation size	Number of children	Number of pupils	Number of pupils	Number of students
Micro	1-9	1-49	1-499	Not used
Small	10-49	50-199	500-999	1-9,999
Medium	50-249	200-299	1,000-1,499	10,000-19,999
Large	250 or more	300 or more	1,500 or more	20,000 or more

This means it is difficult to compare the findings for organisation sizes across sub-sectors directly. In broad terms though there was a tendency for the medium organisation size banding across sub-sectors to be the most prevalent. The greatest variance in organisation sizes occurred in secondary schools where there were premises of all organisational sizes.

Schools and higher education premises typically occupied premises with a floor area of greater than 1,000 m^2. This contrasted with nurseries which were most likely to have a floor area between 250 m^2 and 499 m^2. The lack of smaller premises i.e. those below 1,000 m^2, in schools and higher education premises, is likely to be exaggerated due to sampling biases as described in more detail in the method challenges section later in this report.

With regards to tenure, the majority of school and higher education premises were owner occupied. Higher education – teaching & research, primary schools, secondary schools and higher education – residential premises had 100 per cent, 84 per cent, 79 per cent and 79 per cent of floor area that was owner occupied, respectively. In comparison, for nurseries the prevalence of owner occupied premises was substantially lower at only 57 per cent of floor area.

There was a range of approaches towards energy management across sub-sectors. In general terms, the larger the organisation the more proactive they were on energy management. Respondents in higher education premises, for instance, typically described themselves as ‘actively seeking new ways to reduce energy use’ (between 70–90 per cent were). In all other sub-sectors energy management was less of a priority[11] with 18 per cent of nurseries, 12 per cent of secondary schools and 9 per cent of primary schools admitting that they had not ‘considered ways of reducing energy use’.

In terms of building age, higher education - teaching & research and nursery premises tended to be based in newer buildings (54 per cent and 42 per cent of floor area is in buildings constructed after 1991, respectively). Primary schools, secondary schools and higher education - residential premises tended toward being constructed between 1940 and 1985 (55 per cent, 43 per cent and 36 per cent respectively).

Typically premises across all the sub-sectors occupied a whole building. Although 14 per cent of nurseries were premises occupying only part of the building). In the other education sub-sectors it was also not uncommon for the premises to be based on a site with multiple buildings that were all operated by the same organisation. For instance this was the case for 40 per cent of secondary schools, 36 per cent of higher education – teaching & research premises, 27 per cent of primary schools but only 3 per cent of higher education – residential premises.

[11] This means the respondent chose the option ‘We try to reduce energy use when we can but it is not an area of high importance” in response to the energy management attitudes question in the telephone survey.

As with organisation size, the peak operating hours questions in the telephone survey were tailored by sub-sector. It was defined as the period for which the premises were fully occupied, where full occupancy was the period where at least 50 per cent of the typical maximum number of users were present. The user types by sub-sector were: primary schools – staff and pupils; secondary schools – staff and pupils; nurseries – staff; higher education teaching and research – staff and students; higher education residential – students.

Overall, the usage pattern within nurseries differed substantially from other sub-sectors, with 89 per cent of premises having peak operating hours of between 9 and 15 hours per day. In primary schools, secondary schools, higher education - residential and higher education - teaching & research premises peak operating hours were typically less than 8 hours a day (90 per cent, 86 per cent, 83 per cent and 62 per cent, respectively).

The peak operating hours for higher education - residential premises were lower than had been anticipated. It would have been reasonable to assume these hours should have been higher due to the constant need for these premises to be operational. This raises concerns about the reliability of data for this sub-sector and whether the question had been consistently understood.

Table 1.3: Range of building and premises characteristics by education sub-sector by percentage of floor area, 2014–15

Column percentages

	Education sub-sector					
	Nurseries (%)	Primary schools (%)	Secondary schools (%)	Higher education – teaching & research (%)	Higher education – residential (%)	**Education sector (%)**
Organisation size[12]						
Micro	-	3	21	2	7	8
Small	15	26	26	50	40	19
Medium	81	31	33	44	54	38
Large	3	40	19	4	-	34
Don’t know	-	-	-	-	-	1
Total floor area (m^2)						
Less than 50	-	-	-	-	-	0
50-99	3	-	-	-	-	1
100-249	15	-	-	-	-	4
250-499	61	5	-	-	-	6
500-999	16	8	6	-	8	46
1,000-4,999	5	85	20	34	41	22
5,000-9,999	-	2	37	24	51	22
10,000 or more	-	-	37	42	-	0
Don’t know	-	-	-	-	-	-

[12] See table 1.2 above for sub-sector specific definitions of organisation size.

Table 1.3 continued.

	Education sub-sector					
	Nurseries (%)	Primary schools (%)	Secondary schools (%)	Higher education – teaching & research (%)	Higher education – residential (%)	**Education sector (%)**
Tenure						
Owned	57	84	79	100	79	84
Leased	43	16	18	-	21	15
Don't know	-	-	2	-	-	1
Energy management ambition[13]						
Active	26	32	29	70	96	44
Passive	56	59	59	30	4	49
None	18	9	12	-	-	8
Do not know	-	-	-	-	-	-
Age of building						
Pre-1900	19	21	7	15	12	14
1900-1939	6	13	12	11	12	12
1940-1985	8	55	43	16	36	40
1986-1990	6	7	2	4	3	4
1991-2006	37	-	16	32	23	15
2007 or later	5	5	19	22	12	14
Don't know	19	-	-	-	3	1
Building structure						
Part of building	14	-	-	-	-	0
Whole building	86	73	60	64	97	69
Multiple buildings	-	27	40	36	3	31
Peak operating hours[14]						
8 or less	11	90	86	62	83	80
9-15	89	10	14	38	-	19
16-23	-	-	-	-	8	0
24	-	-	-	-	6	0
Don't know	-	-	-	-	3	0

[13] 'Active' relates to respondents who indicated that they "actively seek new ways to reduce energy use"; 'Passive' relates to respondents who indicated that they "try to reduce energy use where possible, but it's not a priority", 'None' relates to respondents who indicated that they "have not considered ways to reduce energy use".

[14] Respondents were asked "How many hours in a typical working day is the premises reasonably fully occupied by your employees (at least 50% of staff present)?".

Table 1.3 continued.

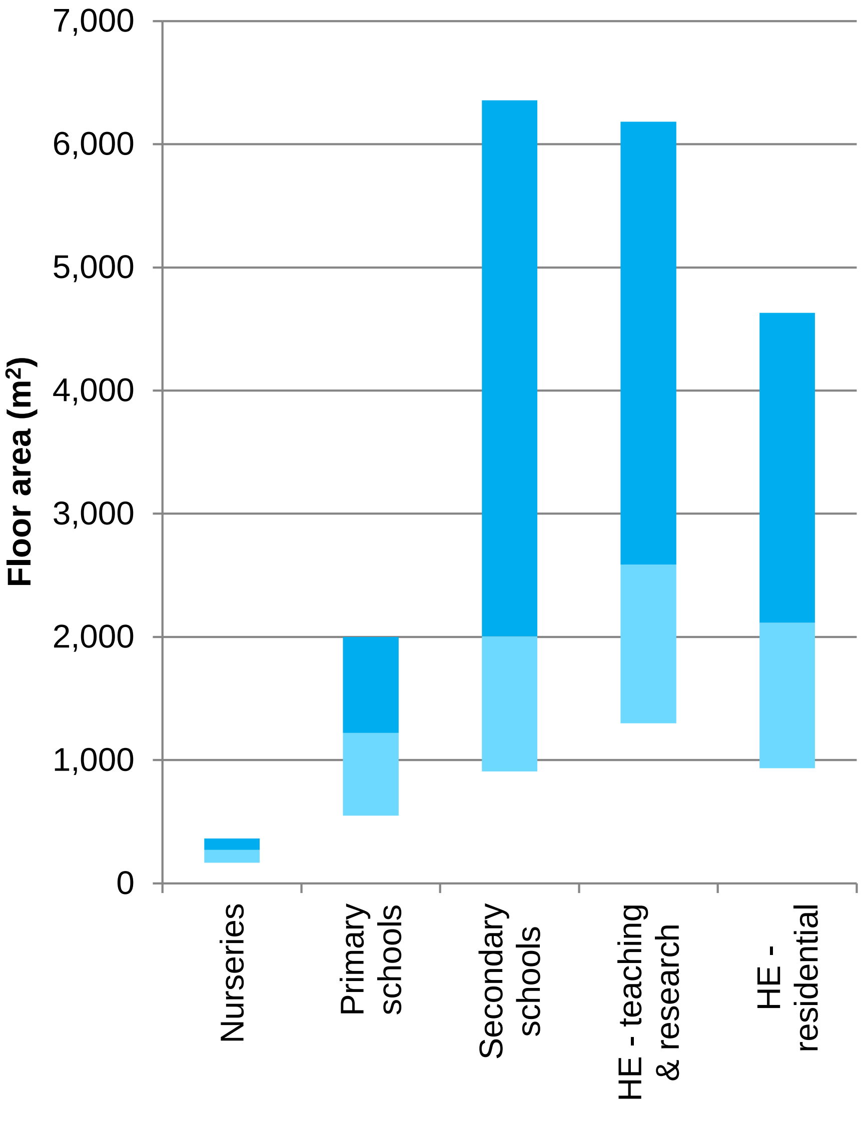
	Education sub-sector					
	Nurseries (%)	Primary schools (%)	Secondary schools (%)	Higher education – teaching & research (%)	Higher education – residential (%)	**Education sector (%)**
Opening hours[15]						
8 or less	8	8	14	-	-	8
9-15	92	92	69	92	-	78
16-23	-	-	15	-	-	5
24	-	-	2	8	97	9
Don't know	-	-	-	-	3	-
Unweighted base	*35*	*41*	*42*	*24*	*25*	*167*

Source: Telephone survey or equivalent records for the sector, England and Wales

[15] This was defined as the total number of hours that the premises were at least partially occupied by staff (when at least 20 per cent of the maximum number of staff -on a typical working day- were present).

Figure 1.4 shows the distribution of premises sizes, in terms of floor area, by sub-sector. The plot shows that higher education – teaching & research premises had the largest median floor area in the education sector at 2,560 m^2, followed by higher education – residential (2,120 m^2), secondary schools (2,000 m^2), primary schools (1,220 m^2) and nurseries (270 m^2). The distribution of floor area sizes for secondary schools was the largest across the five sub-sectors, with the central 50 per cent of premises having floor areas between 910 m^2 and 6,360$m^{2;}$ compared with a range of 1,300 m^2 to 6,180 m^2 in higher education – teaching & research premises and 930 m^2 to 4,630 m^2 in higher education – residential premises.

Figure 1.4: Premises size by education sub-sector, 2014–15

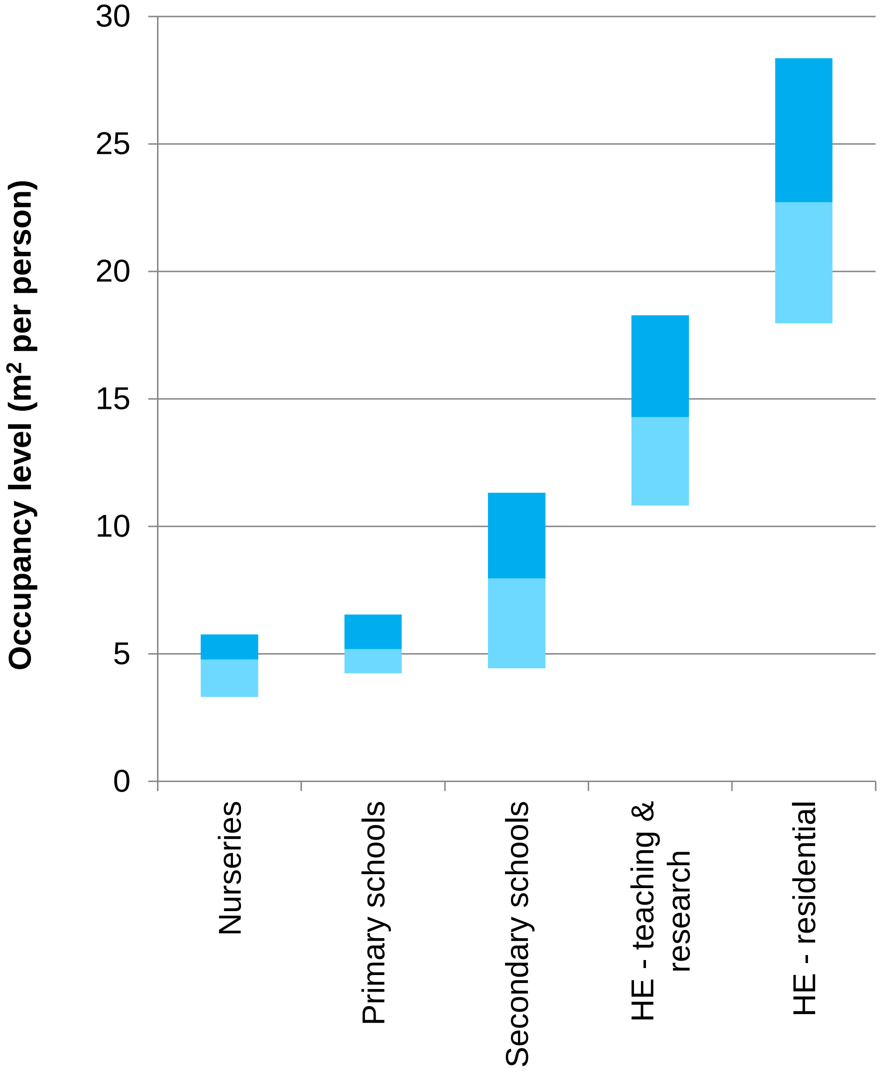


Note: In box plots, the blue columns, when combined, indicate the range of floor areas covered by the interquartile range of results (the middle 50 per cent of data points). For series with fewer than 50 data points no percentiles outside the interquartile range can be shown.

Source: Telephone survey or equivalent records for the sector, England and Wales

Figure 1.5 shows the distribution of occupancy level (the floor area per staff and visitor number) based on the number of staff and visitors present over a typical working day.[16] Higher education – residential premises showed the lowest median occupancy level of 23 m^2 per person.[17] This compares with a median of 14 m^2 per person in higher education – teaching & research premises, 8 m^2 per person in secondary schools and 5 m^2 per person in both primary schools and nurseries.

Figure 1.5: Occupancy level (floor area per staff and visitor number) by education sub-sector, 2014–15



Note: In box plots, the blue columns, when combined, indicate the range of floor areas covered by the interquartile range of results (the middle 50 per cent of data points). For series with fewer than 50 data points no percentiles outside the interquartile range can be shown.

Source: Telephone survey or equivalent records for the sector, England and Wales

[16] The definition of 'visitor' varies by subsector – in the case of primary and secondary schools this refers to pupils, in the case of nurseries this refers to children, and in the case of HE – teaching and research and HE – residential this refers to students.

[17] Commonly, in sectors where this metric is reported, staff density would be based on Net Lettable Floor Area (NLA). This is the area of a building that is let to tenants and excludes common areas e.g. walkways. A typical ratio from GIA to NLA is 0.7.

2. Methods

This section provides a summary of the Building Energy Efficiency Survey (BEES) methodology describing the research objectives of this study, the standard approach to data collection, data screening and data processing; as well as the methodological challenges for the education sector.

Greater detail on the BEES methodology in relation to the education sector is presented in Appendices A, B and C, which cover statistics on the methodological quality and an explanation of how the approach was tailored for the education sector.

A detailed technical annex for BEES has also been published alongside this report, which provides detailed coverage on sampling approaches, the study method and the models used. This can be found at www.gov.uk.

Research objectives

The Building Energy Efficiency Survey (BEES) was designed to meet the following research objectives:

- To update the Department's understanding of how energy is used, for a snap-shot in time, across the non-domestic building stock in more detail than is available at present;[18]
- To update the Department's understanding of how energy use can be abated across the non-domestic building stock in more detail than is available at present;
- To understand the barriers and enablers of energy abatement.[19]

The first two objectives are addressed in this and other sectors reports. The third objective is addressed in the BEES overarching report.

Standard approach

A standard overall approach was designed to gather information on energy use in premises relying on telephone surveys and a limited number of site surveys. The non-domestic stock was broken down into 10 sectors and 38 sub-sectors.

The analysis for BEES is performed at sub-sector level with bespoke questionnaires and modelling assumptions used at this level.

The study has generated a database of 3,690 records. Each record may represent an entire building or a premises within a larger building. The findings in this report are based on data collected for the education sector through 165 telephone surveys and 18 site surveys during 2015.

The records include data on energy usage, information on the building itself (fabric, age etc.) and the occupant's organisation.

The survey asked respondents about the energy used within or associated with buildings e.g. sports floodlighting, external security and car park lighting. Energy use activities which were not within the scope of the study included industrial process loads. It was not possible to capture all energy end uses that may be present in a premises.

[18] The current non-domestic stock model (Pout, C (2000) NDEEM: the national non-domestic buildings energy and emissions model) is underpinned by field research conducted by Sheffield Hallam University in the 1990s.

[19] The detail on the barriers and facilitators of energy abatement are addressed in the overarching report.

The standard method is summarised in Figure 2.1 and set out in the bullet points below:

1. **Sample design** - BEES has been sampled and grossed primarily based on data from the Non-domestic National Energy Efficiency Data-framework (ND-NEED). This dataset uses the Valuation Office Agency's (VOA) property rating list. Where a sector was out of scope of the VOA database, alternative data sources were used. This gives a base record of address, floor area, building type, and energy use[20]. Using the Experian references in ND-NEED it was possible to add a contact telephone number. Analysis shows that the scope of BEES includes 89 per cent of building floor area in England & Wales. The number of surveys per sub-sector was determined based on their overall size with a minimum of 50 surveys sought where possible. Overall 1 per cent of floor area has been surveyed based on the sub-sectors in scope.
2. **Data collection** – A sub-sector tailored telephone survey, supplemented with data from a more detailed site survey in a subset of cases, was used to gather the information required to model the energy end uses within these premises.
    - The telephone survey involved a single stage and took around 25 minutes to complete. It gathered basic information on the premises, its servicing and usage. It also included sub-sector specific key questions to gather further data on the most significant energy end uses. These questions were designed with input from expert interviewers and, if necessary, trial site surveys at the design stage of the research programme. The survey was conducted with the person responsible for energy management, building management or another suitable manager.
    - A limited number of site surveys were undertaken on the telephone survey sample. The candidates were selected based on a range of characteristics such as energy intensity, location and floor area size. The site surveys gathered detailed information on the energy end use consumption, activities (extent and intensity), abatement potential and the barriers and facilitators to implementing energy efficiency measures in the premises. The outputs were used to test the energy use and abatement models. Data collected on site was also used to correct and overwrite findings from the initial telephone survey. The data on barriers was collected via semi-structured face to face interviews.
3. **Data cleansing** - Prior to modelling, the data were cleansed firstly through record exclusion. Records were screened for outliers, then they were reviewed for quality. The outlier analysis was based on typical operating metrics, such as occupancy level (the number of square metres per person in a premises). Where extreme values were identified the record would be removed. The quality assurance process identified the proportion of questions for which a response was required to model energy use. Any records which failed to meet the minimum data quality thresholds, measured by the percentage of 'Don't know' responses were excluded. Exclusion of these records was deemed necessary on the grounds that a significant prevalence of 'Don't know' responses was considered indicative of a respondent who lacked engagement or had a poor understanding of their building's core services and equipment. Within the education sector, a total of 220 telephone survey or equivalent records were collected – following the record exclusion process a total of 167 records were retained for analysis. In this sector the share of records excluded was high (25 per cent of total), as many of the records in the available sample yielded a high proportion of 'Don't know' responses, considered to indicate poor record reliability.
4. Secondly, record amendment was conducted on the remaining data. The remaining

[20] The BEES sector and sub-sector classifications were based on a bespoke classification developed from VOA data of Special Category Code (SCAT) and Property Description.

records were reviewed and in some cases data amended to overcome isolated yet important instances of ‘Don’t know’. These amendments were applied to the telephone survey dataset. Where telephone survey records contained a ‘Don’t know’, the response was estimated where possible based on the most likely response based on what was typical for the premises, or was proxied based on other question responses[21].

5. **Data processing** – Two models were used to process the cleaned telephone survey outputs. The **energy use model** was used to estimate the energy use in each premises, and the **abatement model** was used to estimate the cost and abatement potential of different abatement measures if they were to be installed in that premises. These models are outlined below, for more details see the technical annex. It should be noted that all processed outputs relate to the time when the original data was collected.[22]
    - The energy use model used an energy calculator to estimate a premises energy consumption, split by end use and fuel type, based on the cleaned telephone survey responses. A calibration process was carried out for each sub-sector to map telephone survey responses to different values of parameters in the energy calculator. This calibration was based on alternative data sources, previous knowledge of the sub-sector and the site surveys. The energy use mode did not take dynamic effects or building geometry into account, given the nature of the telephone survey data.
    - The abatement model used the cleaned telephone survey outputs and a set of relatively simplistic measure applicability rules to assess whether or not different abatement measures were applicable to a particular premises. The effect of applicable measures was estimated by changing relevant parameters in the energy calculator and recalculating the energy consumption of the premises.
6. **Weighting** – All the data generated was weighted upwards to represent the sub-sector population, based on the likelihood the premises was selected and on the overall share of floor area in the achieved sample.

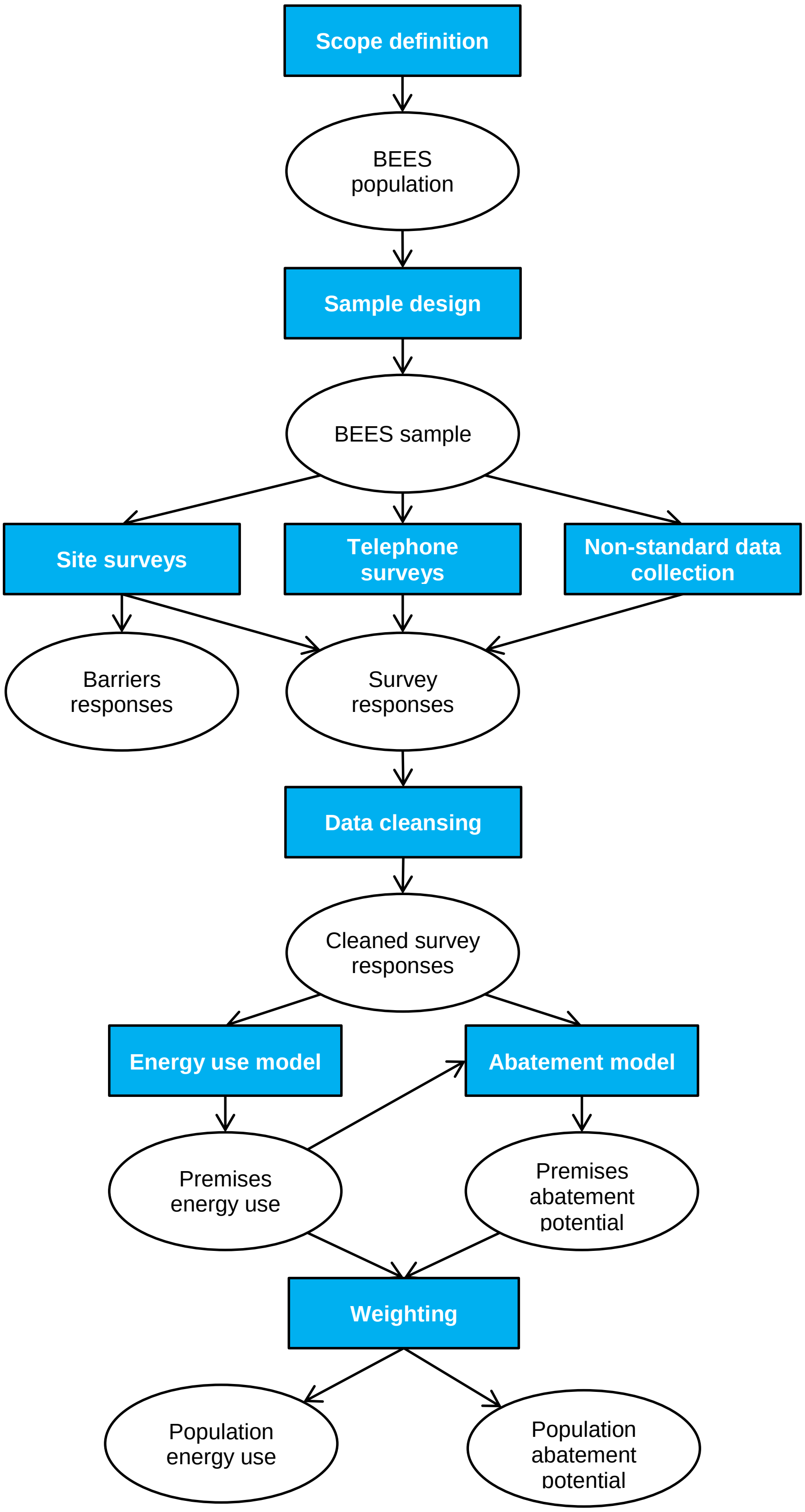
This approach was then tailored by sector. The impact of the change to the methodology within the education sector is covered in “Methodology challenges in the education sector”, which follows in this section, and in more detail in Appendix B.

All estimates shown in this report are point estimates and subject to uncertainty as they are based on survey findings. Confidence intervals are shown in Appendix A at sub-sector level for energy intensity for electrical and non-electrical uses.

[21] For example, in one sub-sector a small number of respondents gave a ‘Don’t know’ response to the question “Do you use electricity to heat tap water and/or showers and if so how much?”. The vast majority of responses to within the sub-sector were ‘None’, so this was used as a proxy as it was deemed to be suitably representative of the sample. The energy consumption for these sites was also checked in each instance for any evidence that water was heated with non-electrical fuel.

[22] Data collection for the Building Energy Efficiency Survey in its entirety occurred over 18 months from late 2013 to mid-2015.

Figure 2.1: Methodology flowchart



Methodology challenges in the education sector

For education sub-sectors the BEES methodology was implemented as envisaged. There were however overarching complications, which needed to be accounted for during planning. In particular, university campuses required a careful approach to ensure the telephone survey respondent provided a response for a distinct premises which matched the target scope for the BEES study.

A summary of the major issues encountered is set out below and a full description is included in Appendix B along with a list of additional more minor issues:

- **Sample design** Schools and higher education (HE) premises were sampled from datasets with a known floor area bias towards larger buildings. These records were sampled predominantly from the Display Energy Certificate database and these certificates were only required where premises exceeded floor area thresholds. The original minimum floor area threshold was 1,000 m^2. The sample data was based on records up to 2012. Since 2012 there have been subsequent reductions in the floor area thresholds for Display Energy Certificates. Because the sample was biased towards larger premises the energy characteristics and abatement potential may not be reflective of the stock as a whole. For instance, larger premises are more likely to use mechanical ventilation, have a greater range of activities within them and, for some abatement measures, be more cost effective because many measures have minimum costs associated with them.
- **Data collection** The uptake for telephone surveys in the higher education sub-sectors was limited. In order to obtain an adequate sample, certain universities were contacted through a non-standard approach, and asked to contribute multiple surveys to the study. This introduced a degree of bias in sample selection, especially where a single contact contributed a significant share of the records for a sub-sector. This could affect the representativeness of answers on energy management and other organisational factors compared to the whole sub-sector.
- **Data processing** In higher education premises, there were an exceptionally broad range of activities undertaken and mixed uses within the same building were very common; this was particularly the case in non-residential buildings. There were also a wide range of complex specialised activities such as highly customised research facilities. It was not possible to collect sufficient data using a telephone survey approach to describe and model a number of complex uses such as laboratories to a similar level achieved with more common end uses such as lighting or small power, and simple default estimates had to be employed in these cases. As a result, findings related to these more complex end uses are subject to a lower level of certainty.

3. Energy consumption

This section presents a series of summary charts and tables detailing the results of the energy use modelling undertaken during the analysis of the education sector.

Energy consumption and greenhouse gas emissions in the education sector

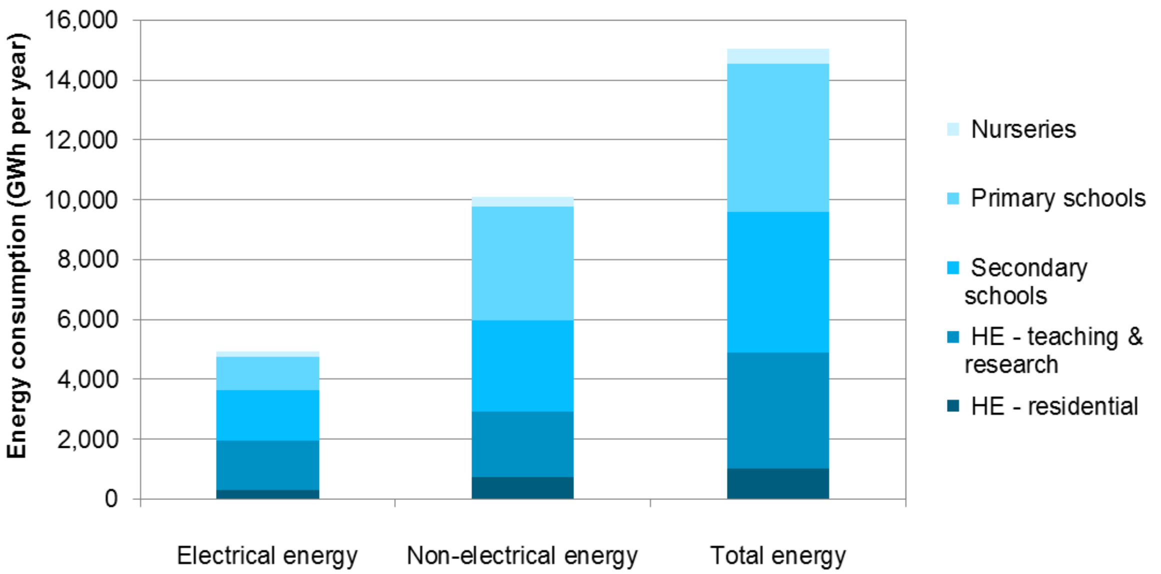
The electrical and non-electrical energy consumption of the education sector is presented in Figure 3.1, broken down by the five education sub-sectors (covering: nurseries, primary schools, secondary schools, higher education (HE) – teaching & research and higher education (HE) – residential).

The education sector consumed 15,020 GWh of energy. This consisted of 4,930 GWh of electrical energy and 10,100 GWh of non-electrical energy per year (Figure 3.1).

The largest energy consumer in this sector was primary schools with a consumption of 4,930 GWh of energy (33 per cent of sector total). This was split between 1,140 GWh of electrical energy (23 per cent of sector total) and 3,790 GWh of non-electrical energy (38 per cent of sector total). The sub-sector is the largest consumer primarily because it had the largest floor area in the education sector and therefore was the most extensive (28 million m^2 for primary schools compared with 27 million m^2 for secondary schools and 17 million m^2 for higher education – teaching & research).

Secondary schools were the second largest consumer in the sector with a consumption of 4,700 GWh of energy (31 per cent of sector total). This consisted of 1,660 GWh of electrical energy consumption (34 per cent of sector total) and 3,040 GWh of non-electrical energy consumption (30 per cent of sector total). Nurseries were the smallest consumer in the sector with 490 GWh of energy consumption, which was split into 160 GWh of electrical energy (3 per cent of sector total) and 330 GWh of non-electrical energy (3 per cent of sector total).

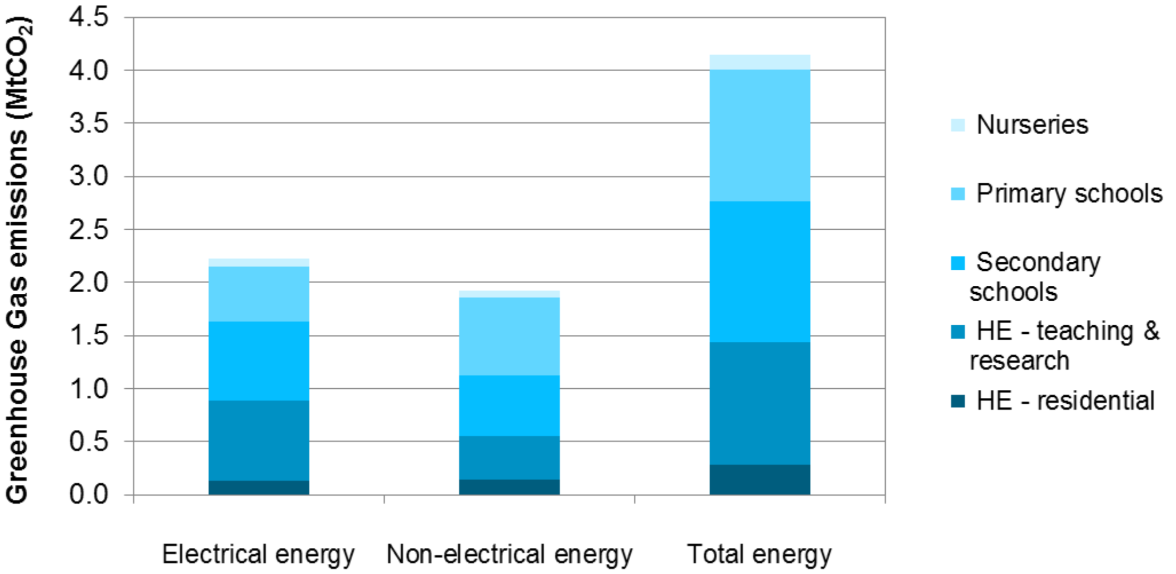
Figure 3.1: Electrical and non-electrical energy consumption by energy type and education sub-sector, 2014–15



Source: Energy use model results for the sector, England and Wales

The greenhouse gas emissions for the education sector are presented in Figure 3.2.[23] The total greenhouse gas emissions from the education sector were estimated to be 4.1 MtCO_2e per year. The annual greenhouse gas emissions from electrical energy consumption were 2.2 MtCO_2e and those from non-electrical energy consumption were 1.9 MtCO_2e.

Figure 3.2: Greenhouse gas emissions by energy type and by education sub-sector, 2014–15



Source: Energy use model results by sub-sector, England and Wales

[23] Greenhouse gas emissions were estimated using energy consumption figures from the energy use model and grid average electricity and fuel emission factors from IAG guidance on valuing greenhouse gas emissions published by DECC, updated on 10 December 2015. See https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal for further information.

Energy consumption by end use

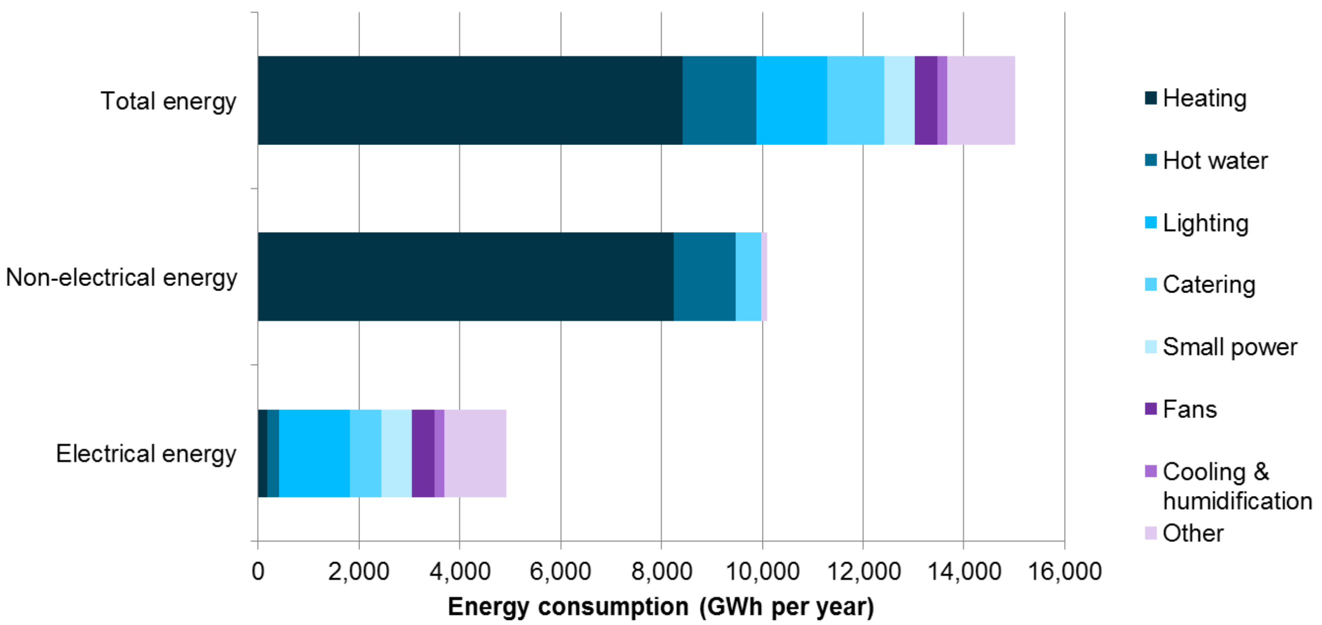
The total energy consumption by end use is presented in Figure 3.3 and Table 3.1.

The energy use model defines 23 separate energy end uses in its analysis. These are derived by modelling the telephone survey inputs and calibrated using site survey data. For the purposes of presentation in Figure 3.1, the 23 uses have been simplified to six categories covering key building services end uses (heating, hot water, lighting, fans, cooling & humidification and other) and two custom categories relevant to the sector (Catering and Small power). The simplified classification is shown against the more detailed classification results in Table 3.1.

Further detail can be found in Appendix C on the 23 end uses and how these are re-categorised to the eight categories used in this sector report.

The total energy consumption for the education sector was 15,020 GWh. The most significant end use was space heating (8,420 GWh, 58 per cent of total), followed by hot water (1,470 GWh, 10 per cent). The most common end uses of electrical energy were internal lighting at 1,380 GWh (28 per cent of total), followed by small power and catering (each 610 GWh, 11 per cent). The most significant non-electrical energy end uses were space heating at 8,240 GWh (82 per cent) followed by hot water (1,230 GWh, 12 per cent). Non-electrical energy consumption for heating was much higher than electrical energy consumption (8,240 GWh compared with 180 GWh).

Figure 3.3: Energy consumption by simplified end use breakdown for the education sector, 2014–15



Source: Energy use model results for the sector, England and Wales

Table 3.1: Energy consumption by energy type and energy end use for the education sector, 2014–15

Energy end use category (Simplified)	BEES end use category[24]	Electrical energy consumption (GWh/year)	Non-electrical energy consumption (GWh/year)	Total energy consumption (GWh/year)
Heating	Space heating	180	8,240	8,420
Hot water	Hot water	240	1,230	1,470
Cooling & humidification	Space cooling	190	-	190
Fans	Fans	450	-	450
Lighting	Lighting - internal	1,370	-	1,370
Catering	Catering	620	510	1,120
Small power	Small power	620	-	620
Other	Pumps	130	-	130
	Controls	90	-	90
	Lighting - external	70	-	70
	ICT Equipment	260	-	260
	Vertical transport	20	-	20
	Cooled storage	50	-	50
	Entertainment equipment	120	-	120
	Pool/leisure	30	120	150
	Lighting - display	30	-	30
	Laundry	50	-	50
	Lab equipment	210	-	210
	Other	210	-	210
Total		**4,930**	**10,100**	**15,020**
Unweighted base		*165*	*162*	*165*

Source: Energy use model results by sub-sector, England and Wales

Education sector energy intensity distributions

Energy intensity (energy use per m^2 floor area) enables activities across sectors to be compared, and is used for benchmarking in the building services industry.[25] Figure 3.4 to 3.6 present the distribution of energy intensity for all modelled records in each sub-sector within the education sector, in terms of total energy intensity, electrical energy intensity and non-electrical energy intensity respectively.[26] In this report all intensity figures (excluding box plots) have been

[24] The end uses are defined in Appendix C.

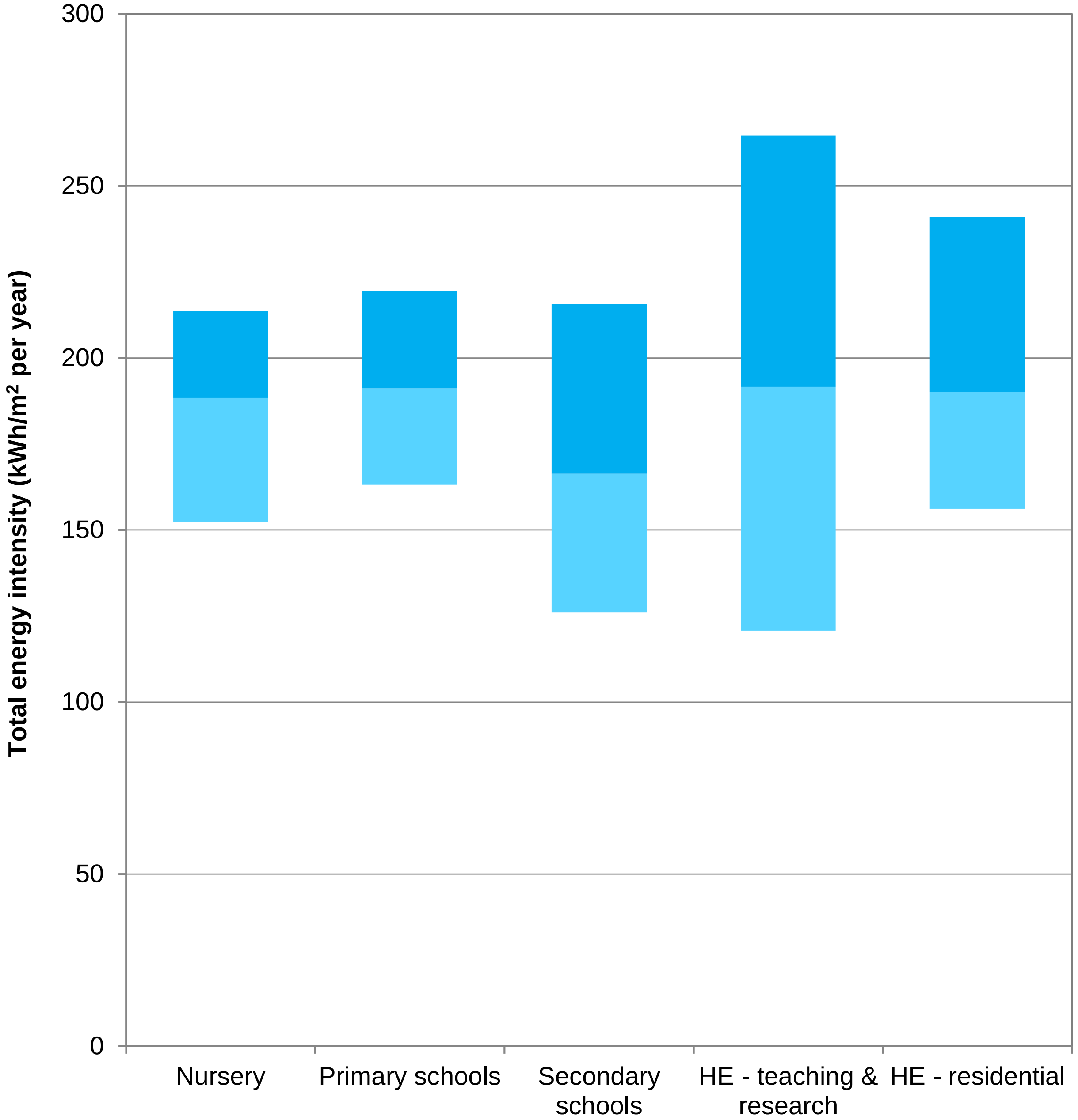
[25] As employed in CIBSE TM46 Energy Benchmarks (available at: http://www.cibse.org/knowledge/cibse-tm/tm46-energy-benchmarks), and others.

[26] Please note mean energy intensities are calculated by summing the total consumption associated with an end use and dividing it by the sub-sectors total floor area. The energy intensities for non-electrical uses are therefore based on the total population and do not make an allowance for where the main heating fuel is electricity.

calculated using the total sector or sub-sector floor area regardless or whether they have a particular energy source or end-use.

Figure 3.4 shows that whilst all of the sub-sectors had similar total energy intensities, higher education – teaching & reserach premises had the highest median total energy intensity (192 kWh/m^2). Figure 3.5 and Figure 3.6 show that higher education – teaching & research premises typically displayed the highest median electrical energy intensity (78 kWh/m^2). Higher education – residential premises displayed the highest median non-electrical energy intensity of 144 kWh/m^2, followed by primary schools (140 kWh/m^2) and nurseries (133 kWh/m^2).

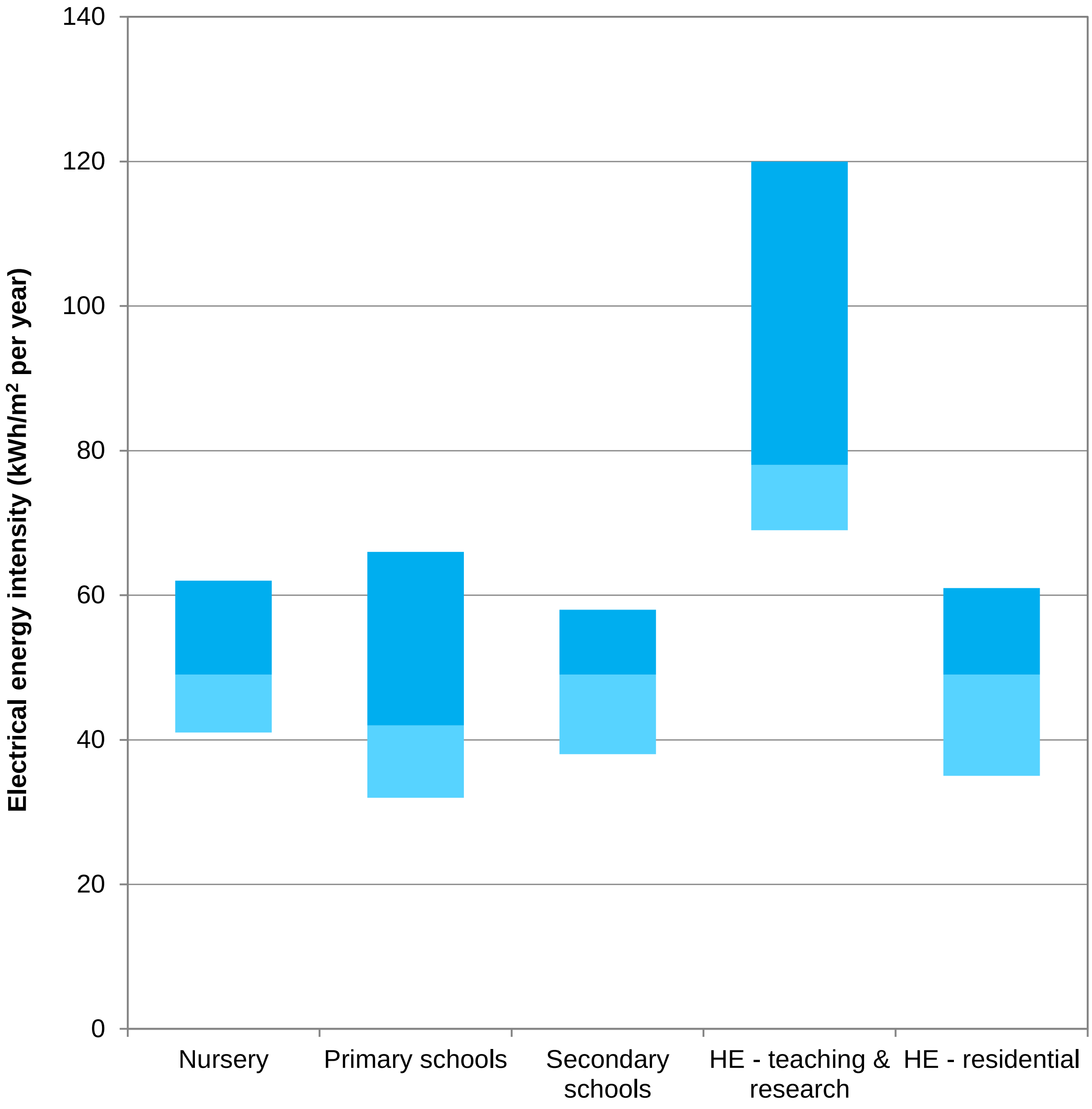
Figure 3.4: Distribution of total energy intensity by education sub-sector, 2014–15



Note: In box plots, the blue columns, when combined, indicate the range of floor areas covered by the interquartile range of results (the middle 50 per cent of data points). For series with fewer than 50 data points no percentiles outside the interquartile range can be shown.

Source: Energy use model results by sub-sector, England and Wales

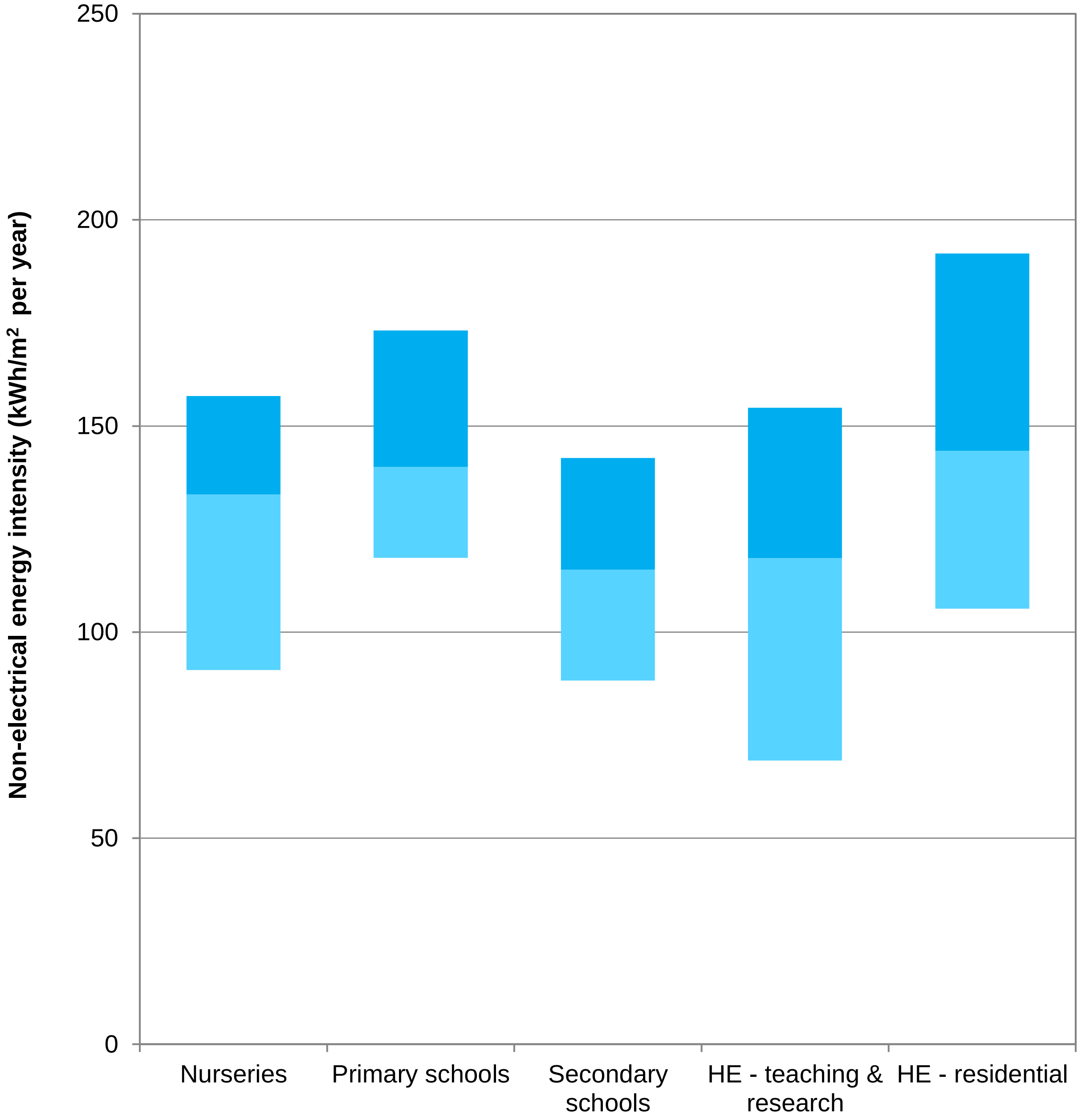
Figure 3.5: Distribution of electrical energy intensity by education sub-sector, 2014–15



Note: In box plots, the blue columns, when combined, indicate the range of floor areas covered by the interquartile range of results (the middle 50 per cent of data points). For series with fewer than 50 data points no percentiles outside the interquartile range can be shown.

Source: Energy use model results by sub-sector, England and Wales

Figure 3.6: Distribution of non-electrical energy intensity by education sub-sector, 2014–15



Note: In box plots, the blue columns, when combined, indicate the range of floor areas covered by the interquartile range of results (the middle 50 per cent of data points). For series with fewer than 50 data points no percentiles outside the interquartile range can be shown.

Source: Energy use model results by sub-sector, England and Wales

Education sub-sector energy end use breakdowns

Figure 3.7 shows the mean modelled energy intensity by end use for each of the sub-sectors in the education sector. Further data is provided in Appendix C where energy consumption and energy intensity is provided separately for electrical and non-electrical energy end use breakdowns by sub-sector.

Heating energy intensity was similar across all sub-sectors. Higher education – teaching & research had the highest intensity. This is believed to be due to the fact that schools tended to operate weekday hours in term times only, whilst higher education premises were often open year-round and at weekends (either for research staff or summer residential courses).

Initial expectations had been that higher education – residential heating intensity would be higher than the other sub-sectors. Upon closer inspection of the data it was found that a reasonable proportion of these premises were relatively new. This reduced the modelled estimate for heating intensity despite their longer hours of use. Hot water energy use was fairly low across the sector with the exception of higher education – residential premises where showers and baths resulted in significant consumption.

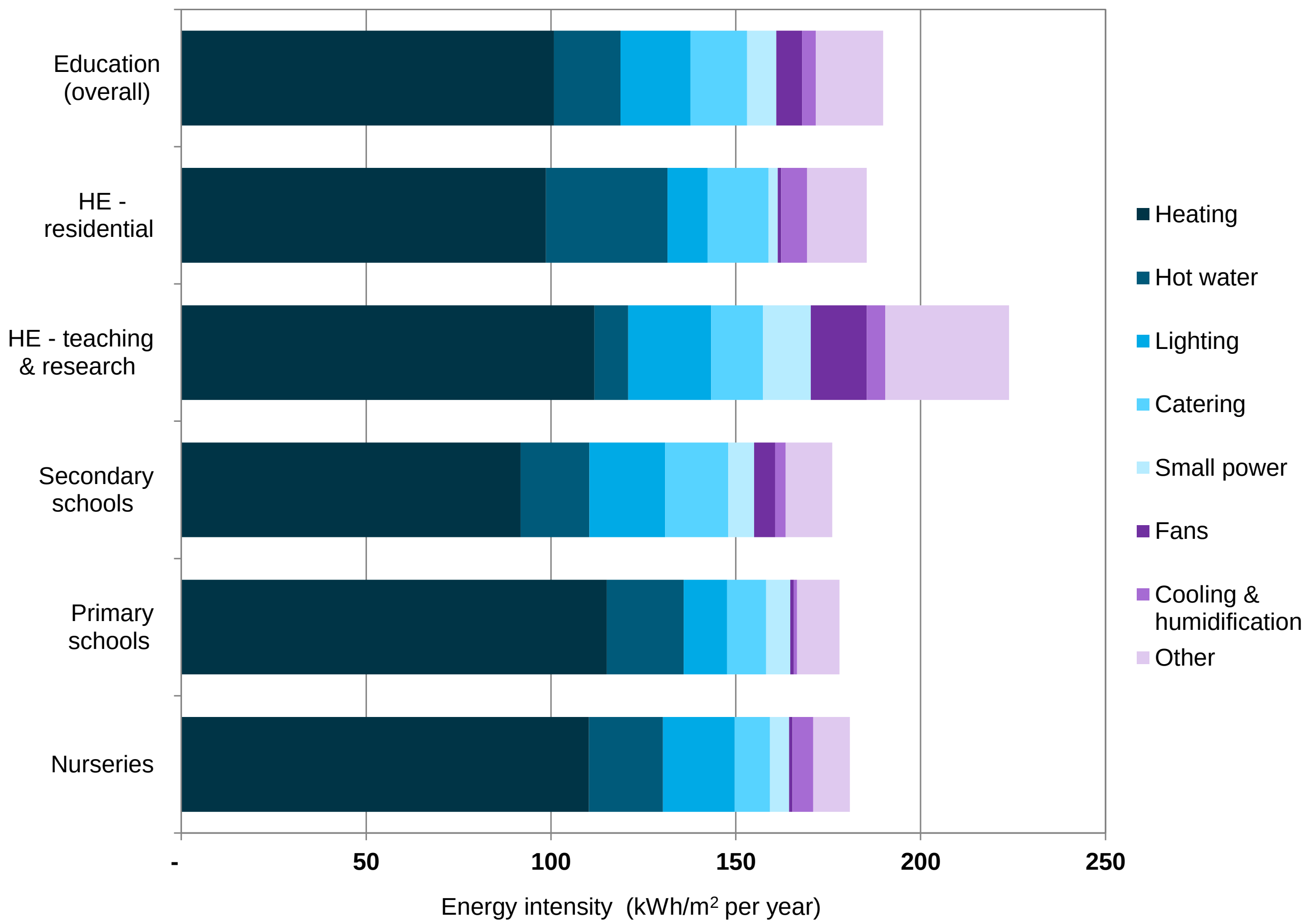
Lighting was a significant end use in all sub-sectors. It was highest in higher education – teaching & research and secondary schools. These premises tended to have a high incidence of activity areas with high light levels (offices, teaching space, and laboratories) and relatively long operational days. Conversely primary schools had the shortest operational hours, and higher education – residential premises tended to have much lower light levels than educational spaces.

Fans and cooling & humidification were most common in secondary schools and higher education – teaching & research premises. The presence of spaces like laboratories, computer rooms and lecture theatres with high internal gains or close temperature control requirements meant that such service needs are more common.

There was also a clear trend in small power use. It was highest in secondary schools and higher education – teaching & research premises. This was because computer based learning and office space was more common in these sub-sectors.

The “Other” end use category commonly included uses such as ICT equipment and entertainment equipment. End uses categorised as “Other” were most common in higher education – teaching & research, where laboratory equipment was a significant end use.

Figure 3.7: Mean energy intensity simplified end use breakdowns by education sub-sector, 2014–15



Source: Energy use model results by sub-sector, England and Wales

4. Abatement potential

In this section, abatement potential[27] for the education sector is considered. Abatement potential is calculated at a sub-sector and sector level.

Abatement method

In order to determine the abatement potential for each premises record, the abatement model identified appropriate abatement measures based on the responses from the telephone survey, and then calculated the energy saved by the measure compared with existing equipment based on the energy end use energy consumption calculated in the energy use model. Annex D provides more detail on the main groupings of abatement measures, and the technical annex sets out a detailed explanation of the abatement model. The abatement model calculates 95 individual measures, but these have been grouped into larger categories. Within each group of measures there will be some measures that are more cost-effective than others for the sector and sub-sectors. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole.

The abatement potential was calculated on the basis of replacing current equipment with a more efficient alternative, regardless of the age or efficiency of this current equipment. This captured the entire technical potential available. It did not take into account the likelihood of equipment being replaced as part of a planned replacement cycle or whether take-up would be limited due to barriers or site-specific factors.

The costs were based on standardised absolute installation costs[28], while the benefits were only based on the incremental reduction in energy consumption[29]. Replacement of systems which were not at the end of their life were therefore included, but will be more expensive, as the impact on energy consumption is likely to be smaller for new equipment, while the full capital costs are taken into account. This means that a measure may be cost-effective if the system is replaced at the end of its life - especially as at the end of life the cost of the more energy efficient alternative would be compared to replacement with a less efficient alternative - but, the same measure may not be cost-effective if the system is replaced earlier in its life. Replacing measures at the end of life will be less costly for organisations, but it would take longer for the full potential to be realised. While the costs include an allowance for installation costs and hassle costs, this may not not include all the wider disruption costs that may be faced by organisations upgrading equipment; for example it does not factor in the costs of relocating staff if it is not possible for staff to work on site while work is underway. The extent to which organisations face these costs will depend on whether upgrades are scheduled as part of a wider refurbishment.

To account for the impact of interactions between measures - for example if more efficient lights are installed the impact of using better lighting controls is smaller - the abatement measures in each premises were ordered by their return on investment. This way the impact of installing

[27] Abatement potential refers to the potential to improve the energy efficiency of the premises in a given sub-sector.

[28] The total cost consists of the capital cost, installation cost and annual operational costs. These costs were based on the costs of existing installations in non-domestic buildings.

[29] Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483278/Valuation_of_energy_use_and_greenhouse_gas_emissions_for_appraisal.pdf

cheaper measures was taken into account first before calculating the impact of more expensive measures.

The calculated costs and energy savings were weighted to represent the whole sub-sector and education sector throughout England and Wales.

Total technical abatement potential for education sector

The abatement potential for each sub-sector where it is available is shown in Table 4.1 and Figure 4.1. Each sub-sector can achieve between 29 to 39 per cent savings in electrical energy consumption and 45 to 54 per cent savings in non-electrical energy consumption[30]. This could be achieved at an overall capital expenditure of £2.1 billion.

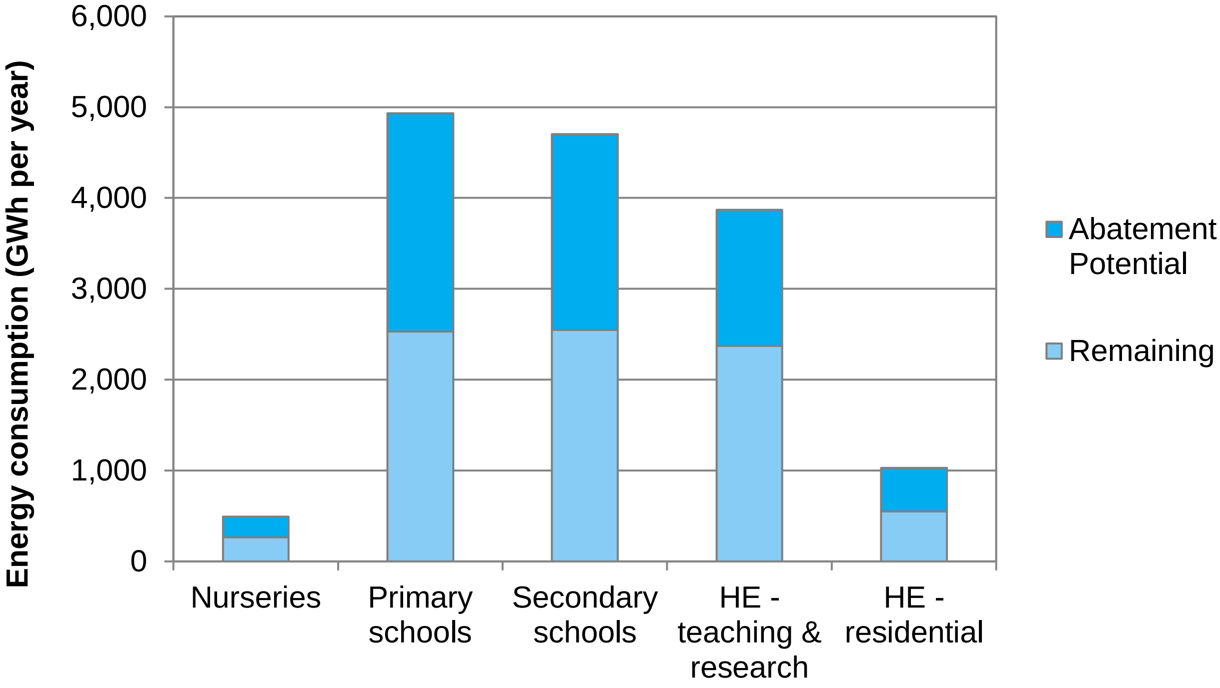
Table 4.1: Total abatement potential by education sub-sector, 2014–15

Sub-sector	Capital Expenditure required to deliver abatement potential (£ thousands)	Baseline energy consumption (Energy Use model)		Total abatement potential		
		Annual electrical energy consumption (GWh)	Annual non-electrical energy consumption (GWh)	Annual electrical energy savings (GWh)	Annual non-electrical energy savings (GWh)	Overall reduction (per cent)
Nurseries	137,300	160	330	60	170	46
Primary schools	678,800	1,140	3,790	380	2,030	49
Secondary schools	665,400	1,660	3,040	640	1,520	46
Higher education – teaching & research	460,500	1,660	2,210	510	990	39
Higher education – residential	123,000	300	730	90	390	46
Total	**2,064,900**	**4,930**	**10,100**	**1,670**	**5,090**	**45**

Source: Abatement model results for the sector by sub-sector, England and Wales

[30] All costs, energy and carbon savings are based on 2015 values and sourced from Interdepartmental Analysts' Group reference tables available at https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal. The costs presented are nominal.

Figure 4.1: Total abatement potential by education sub-sector, 2014–15

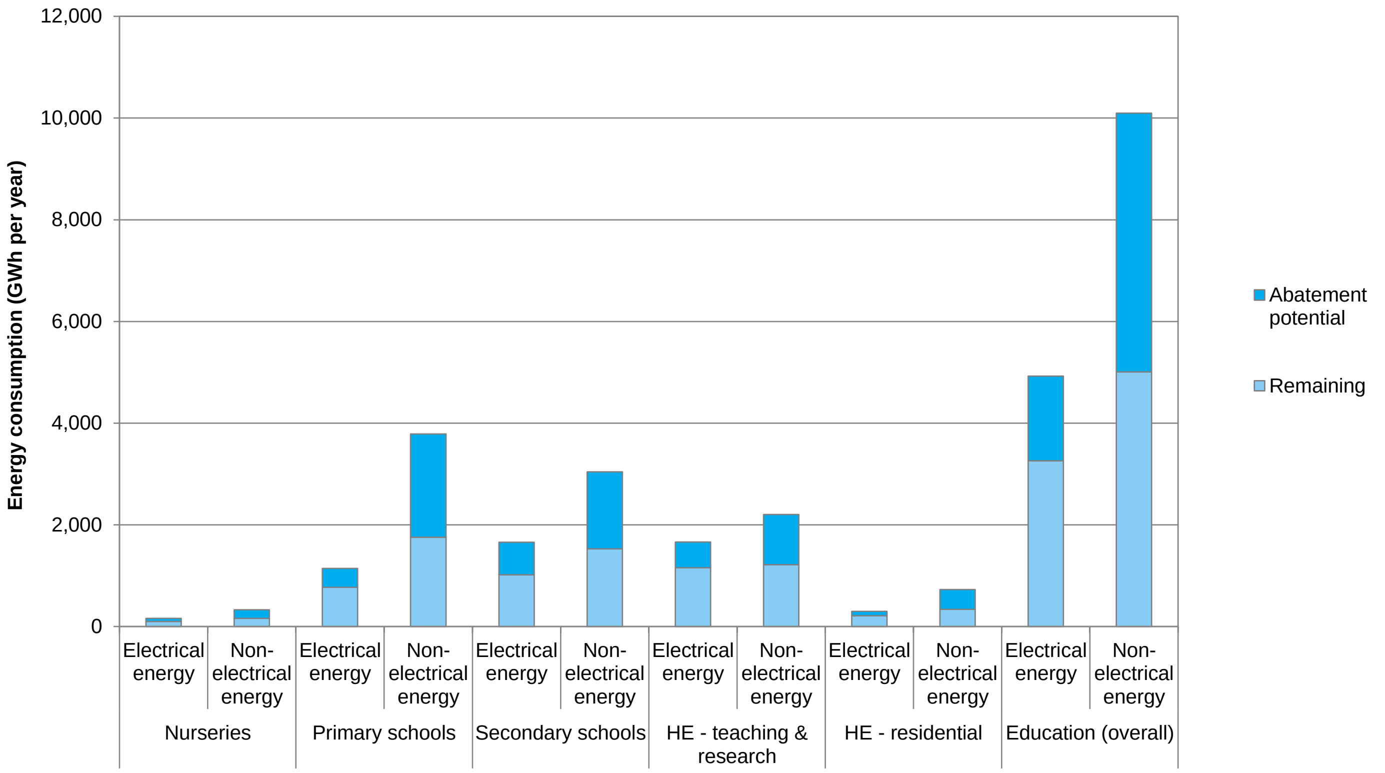


Source: Abatement model results by sub-sector, England and Wales

Figure 4.2 shows that the total technical abatement potential in 2014–15 varied by sub-sector: primary schools had the largest absolute and proportional scope for reduction (49 per cent of total energy consumption overall). This compared with 39 per cent in higher education – teaching and research. In primary schools there was a greater proportion of space heating (boiler replacement) and building fabric measures (insulation) than in others sub-sectors and this appears to explain the majority of the difference. Further detail of the abatement potential for each sub-sector is provided in Appendix D.

The results were separated into electrical and non-electrical energy. On a percentage basis there was marginally more abatement potential associated with savings in non-electrical energy use. This was likely due to the high prevalence of non-electrical energy being used as a fuel for space heating and building instrumentation and controls, and the associated savings from related abatement measures.

Figure 4.2: Abatement potential by energy type and education sub-sector, 2014–15



Source: Abatement model results by sub-sector, England and Wales

Marginal Abatement Cost Curve

As well as the total abatement potential and the costs of delivery, it is important to understand the overall cost-effectiveness of measures. Using the abatement model it was possible to assess the costs and benefits of measures from the point of view of society as a whole, by following Government guidance on the valuation of energy use and emissions.[31] This takes into account the capital expenditure, operational expenditure, social cost of energy, air quality impacts, and value of emissions, all discounted at the social discount rate. While this includes the main categories of costs, it was not possible to include the costs and benefits of all impacts on occupants: for example some measures may provide a potentially better occupant experience through improved illumination, or a potentially worse occupant experience through lack of control over light switches.

A measure is socially cost effective if the total social benefits outweigh the total social costs of the measure across the lifetime of the measure. This is a static measure of cost effectiveness based on current expected costs and benefits - for example this does not take into account potential reductions in capital costs that could result from more of that technology being installed. To enable groups of measures to be compared, a metric of social-cost effectiveness was calculated: Net Present Value of costs and benefits (NPV) divided by total energy savings over the lifetime of the measures in the group and plotted on a Marginal Abatement Cost Curve (MACC), which shows the level of abatement opportunity available and the costs associated with this opportunity if they were all implemented in 2014–15. The MACC in Figure 4.3 graphically represents each group of abatement opportunities as a block. The width of the block represents the total amount of abatement the measure can deliver in GWh and the height represents the cost-effectiveness. Because the measure groups are ranked by cost-effectiveness, the most cost-effective (delivering abatement at the least-cost per GWh) will be found on the left of the diagram. Moving to the right, measure groups become subsequently more costly.

As the MACC assesses cost from a societal perspective, we have supplemented this by providing the simple private payback periods for each measure group to help show how attractive these measures might be for individual organisations on the basis of how long it takes to recoup the costs of measures undertaken from the energy savings generated. Note that the payback period reflects the gross bill savings of the measure alone, rather than the bill savings that would be achieved by the measure if all other measures were installed.

The total abatement potential of the socially cost effective measure groups was 4,000 GWh, of which 1,250 GWh was electrical energy consumption and 2,750 GWh was non-electrical energy consumption. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. The total abatement potential relating to measure groups with a private payback of 3 years or less was 1,700 GWh, of which 410 GWh was electrical energy consumption and 1,290 GWh non-electrical energy consumption. Within each group of measures there will be some measures that are more cost-effective than others for each sub-sector. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole. Similarly the aggregation of measure groups from the sub-sector level to the sector level may hide measure groups that are cost effective in a particular sub-sector, but not for the sector as a whole.

There were a number of measure groups that were socially cost-effective. If implemented, these measure groups provide more financial benefits to society than costs. The largest cost-effective

[31] Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/483278/Valuation_of_energy_use_and_greenhouse_gas_emissions_for_appraisal.pdf

opportunities were lighting upgrades, carbon and energy management and building instrumentation & controls. These measure groups also had relatively low payback periods, suggesting they may be more likely to get taken up, but recognising that take-up will also depend on the extent to which there are barriers.

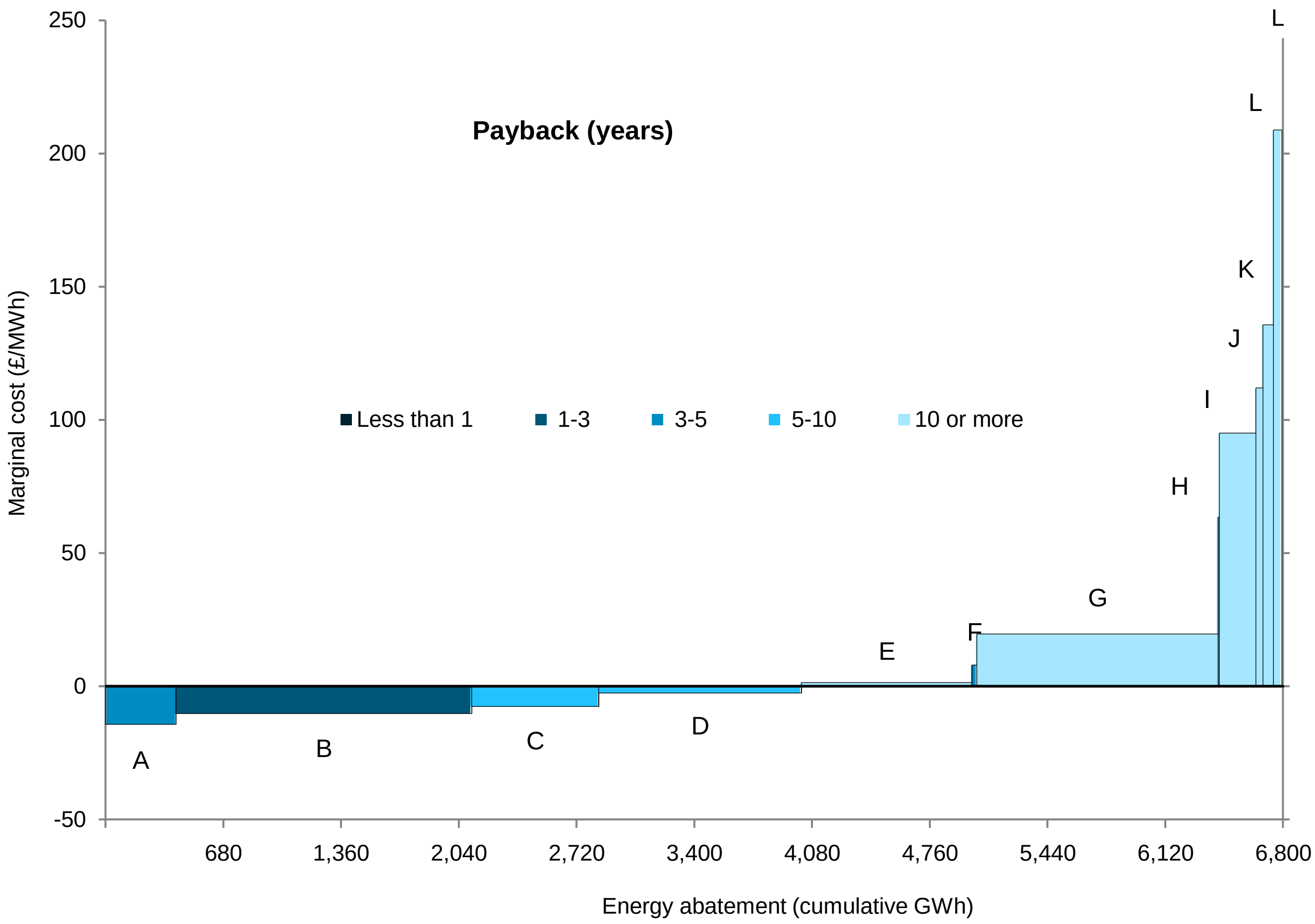
These modelled findings corresponded broadly with opportunities identified in the site surveys. Typically site surveys identified potential savings associated with carbon and energy management, space heating and lighting upgrades and building instrumentation & controls.

In terms of carbon and energy management measures it was found that on some premises the lights were often left on, computers were not powered down and windows were kept open and thermostatic radiator valves had all been set to the maximum temperature.

In several premises lighting upgrades to LEDs were identified. Many of the surveyed premises were fitted with T8 fluorescent lamps – more inefficient lamp types when compared with LEDs. The heating systems were also often reasonably old and there was scope for additional optimum start/stop controls on the boilers.

In some cases site surveys identified additional potential to that calculated in the modelled output for a record. Typically this would be the case where an exceptional characteristic about the premises had been identified at the site visit, which related to information not collected as part of the telephone survey. These additional abatement opportunities were often in relation to building instrumentation & controls and external lighting opportunities. For instance, there was a general tendency to have thermostats located in draughty corridors or large spaces. The temperatures monitored therefore were not necessarily reflective of temperatures across the site and was likely to result in overheating. In relation to external lighting, there were a number of premises where the lights were left on overnight, which was justified by the organisation on the grounds that it improved the ambience of the premises after dark, and perhaps energy bill savings were less of a concern to the organisation.

Figure 4.3: Marginal abatement cost curve by measure type, 2014–15



Note: the marginal abatement cost is calculated based on the social cost effectiveness, while the payback period is calculated from a private perspective.

A Hot water [MAC: £-14 per MWh. GWh: 400]

B Carbon and Energy Management [MAC: £-10 per MWh. GWh: 1,700]

C Lighting [MAC: £-8 per MWh. GWh: 730]

D Building instrumentation and control [MAC: £-3 per MWh. GWh: 1,170]

E Building fabric [MAC: £1 per MWh. GWh: 980]

F Cooled storage [MAC: £8 per MWh. GWh: 30]

G Space heating [MAC: £20 per MWh. GWh: 1,390]

H Swimming pools [MAC: £63 per MWh. GWh: 8]

I Ventilation [MAC: £95 per MWh. GWh: 210]

J Air conditioning and cooling [MAC: £112 per MWh. GWh: 40]

K Building services distribution systems [MAC: £136 per MWh. GWh: 60]

L Small appliances [MAC: £209 per MWh. GWh: 50]

Source: Abatement model results for the sector, England and Wales

Table 4.2[32] shows the abatement potential by measure type. The most significant available energy savings were associated with building instrumentation and control, carbon and energy management and space heating measures.

Table 4.2: Abatement potential by measure type, 2014–15

Measure type	Savings					**Total capital cost of measure (£ thousands)**
	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	
Air conditioning and cooling	4,200	10	40	-	40	52,300
Building fabric	26,500	180	20	960	980	486,800
Building instrumentation and control	34,500	220	70	1,100	1,170	172,900
Building services distribution systems	5,800	20	60	-	60	57,900
Carbon and energy management	73,400	370	410	1,290	1,700	81,700
Hot water	13,400	80	40	360	400	63,000
Humidification	-	-	-	-	-	-
Lighting	72,700	210	730	-	730	410,800
Cooled storage	2,700	8	30	-	30	12,400
Small appliances	3,400	10	30	20	50	64,000
Space heating	37,700	280	30	1,360	1,390	436,500
Swimming pools	300	2	1	7	8	2,600
Ventilation	20,700	60	210	-	210	223,900
Total	**295,400**	**1,430**	**1,670**	**5,090**	**6,760**	**2,064,900**

Source: Abatement model results for the sector, England and Wales

[32] Annual greenhouse gas emissions were estimated using the energy savings from the abatement model and the long run marginal electricity and fuel emission factors from IAG guidance on valuing greenhouse gas emissions published by DECC, updated on 10 December 2015 (see https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal for further information). Measures were assumed to be installed in 2015 and the annual emissions savings averaged over the lifetime of the measure.

Appendix A: Sampling quality statistics

This appendix provides summary quality statistics for the sample. The confidence intervals by sector for electrical energy intensity and non-electrical energy intensity by sub-sector are provided, and the the telephone survey response rates by sub-sector.

Confidence intervals

Table A.1: Confidence intervals for electrical energy intensity

	Mean (kWh/m^2)	Confidence interval (kWh/m^2)
Nurseries	59	± 12
Primary schools	41	± 5
Secondary schools	62	± 15
HE - teaching and research	96	± 41
HE - residential	54	± 13
Education	**62**	**± 10**

Table A.2: Confidence intervals for non- electrical energy intensity

	Mean (kWh/m^2)	Confidence interval (kWh/m^2)
Nurseries	122	± 20
Primary schools	137	± 13
Secondary schools	114	± 20
HE - teaching and research	128	± 42
HE - residential	132	± 23
Education	**126**	**± 11**

Response rates

Table A.3: Telephone survey response rates for the education sector

	Nurseries (%)	Primary schools (%)	Secondary schools (%)	HE - teaching & research (%)	HE - residential (%)	**Education sector (%)**
Completed interview	16	11	7	10	2	9
Still live[33]	63	63	72	2	0	50
Screening failure/other non-response[34]	0	0	0	0	1	0
Refusal	8	6	5	2	1	5
Other non-response	3	3	2	5	2	3
Invalid contact details	10	18	14	81	93	33

[33] This refers to sites which were prepared as part of the sample, but were not required. As such they may have been contacted to take part in a telephone survey but neither refused nor accepted (e.g. non answer, answer-phone, tried to make appointment).

[34] This refers to sites which were deemed out of quota during the sampling process, and also includes sites which did not pass the initial screening – this may have been due to a mismatch of sub-sector type between the sampling register and the response given during a telephone interview.

Appendix B: Education method challenges and data collection

This appendix provides detail of any non-standard methodology used for the education sector.

Education sector methodology challenges

In the case of the education sector it was not possible to adopt the standard approach to data collection described in the methodology section for all sub-sectors. The reasons are outlined in Table B.1.

Table B.1: Education sector approach challenges

Stage	Challenge	Response	Impact
Design	Schools and higher education premises sampled from datasets with a known floor area bias towards larger premises. Schools and higher education premises were predominantly sampled from the Display Energy Certificate database and these certificates were only obtained if premises exceeded floor area thresholds. The minimum floor area threshold for premises requiring a DEC when this data was sampled was 1,000 m^2.	During reporting the impact of this bias was noted.	The bias has been noted and the effect it has on truncating the distribution of public sector offices and should be considered when reviewing the results of the study.
Data collection	There was a poor response rate for higher education records	A non-standard data collection method was used - liaising directly with higher education organisations to fulfil the sample.	A risk of selection bias due to allowing respondents to select their own premises for survey. It was noted that there tended to be a degree of repetition of answers within the selection of premises selected by each respondent.

Stage	Challenge	Response	Impact
			Possibly due to the increased time burden resulting in less care being taken, but this could be due to similarities in the stock. Some of the energy data provided directly by respondents gave implausible energy intensities for their premises and had to be discounted.
Sample design	Higher education (HE) - residential records were initially sampled based on the “school boarding house” DEC category. This was because a ‘Higher education (HE) – residential’ benchmark category was not adopted by the rating system and this was deemed to be analogous. As a consequence, some unsuitable premises were initially sampled.	Interviewers needed to clearly define what activities were included in the sub-sector.	A significant proportion of the sample was not usable.
Data processing	Some matched energy data (from DECs) was out of date; and in some cases the presence of multiple DECs at a given address resulted in incorrect address matching.	DECs were manually looked up on the landmark register to collect the latest certificate and ensure correct matching to the premises.	Minimal after mitigation
Data processing	The “campus issue” was significant in, primarily, the higher education sub-sector – premises were often located on larger sites where they may not have effective sub metering, or the DEC selected in sampling may represent more than one building.	Further review was carried out with UCL to identify those DEC certificates where the consumption was not based on directly metered data. However this only identified the issue in some of the premises – for instance, another unmetered premises was identified in a site survey following	At an individual record level (and overall) a greater variance between modelled and matched data would be anticipated

Stage	Challenge	Response	Impact
		the screening using the UCL dataset	
Data processing	Mixed use premises were found in both higher education subsectors (teaching and research and residential). As each record only answered the telesurvey for the primary use, minimal information was available about the secondary use.	Exclusion of the secondary use was considered, but this was deemed impractical, as it would prevent any comparisons between modelled results and matched data. The secondary use was therefore modelled as a simplified activity area based on typical parameters, with fewer adjustments made in response to the telesurvey.	At an individual record level, significant variation between modelled and matched data would be expected in mixed use premises. If the secondary use had separate heating, ventilation or cooling systems this would not be accounted for in the modelling.
Data processing	The university teaching and research sub-sector encompasses a very broad range of premises uses and activities – from lecture theatres to laboratories to student bars. It was not possible to determine the intensity or type of specialist research equipment in laboratories within the telesurvey process; scientific and engineering premises in particular may have high energy equipment present which our method cannot account for.	Within the limitations of the BEES study, certain activity areas could only be modelled on a very simple basis. Laboratories were the most affected item in the education sector; these were modelled on an area basis, with minor adjustments for laboratory type only; base data was taken from reliable academic sources, but we would expect substantial variations in energy use on a case by case basis which the energy model cannot replicate.	At an individual record level (and overall) a greater variance between modelled and matched data would be anticipated. The BEES model will not account for large highly energy intensive specialist (e.g. particle accelerators, MRI scanners, etc.) equipment but include a default allowance for high levels of heating, ventilation and cooling, and also common laboratory equipment such as autoclaves and ovens which are found in chemical/biological laboratories.

Telephone survey and site survey data collection

Table B.2 shows that 220 telephone survey or equivalent records and 18 site surveys were completed in total.

Table B.2: Summary of data collection statistics, 2014–15

	Telephone survey						Site surveys	
Sub-sector	Target sample quota	Number of telephone surveys completed	Number of telephone survey equivalent records completed	Total telephone survey or equivalent records completed	Number of telephone survey records retained post-screening[35]	Average interview length (mins.)	Target sample size	Site surveys completed
Nurseries	50	50	0	50	35	20	6	2
Primary schools	50	54	0	54	41	26	6	5
Secondary schools	50	54	0	54	42	27	6	4
Higher Education – teaching & research	50	36	1	37	23	31	6	5
Higher Education - residential	50	4	21	25	2	29	6	2
Education sector	**250**	**198**	**22**	**220**	**165**	**27**	**30**	**18**

Source: Telephone survey or equivalent records, England and Wales

[35] See section 2 on Methods for details of the procedure for record screening on the grounds of data quality.

Appendix C: End use definitions and energy intensity end use breakdowns

This appendix provides definitions on the energy end uses and the energy intensity by end use category across each sub sector within the education sector. This is split out between electrical energy and non-electrical energy use.

Energy end use definitions

The definitions for the adapted CIBSE energy end uses are set out in Table C.1.

Table C.1: Definitions for energy end uses

End use category		Description
1	**Space heating**	Energy consumption for space heating (including via ventilation), excluding hot water heating, process heating and unusual end-uses such as swimming pool heating and frost protection of ramps. Includes electricity input to heat pumps directly associated with space heating should be included.
2	**Hot water**	Energy used for hot water (e.g. hand washing and drying, showers, manual dish washing in kitchenettes) including electrical consumption of any heat recovery systems, but not pumps and controls. Excludes water heating associated with central catering.
3	**Space cooling**	Energy consumption for chillers, cooling towers, and air-cooled condensers for comfort cooling purposes, including the condenser and cooling tower fans, sump heaters and ancillaries except pumps. Excludes dedicated computer and telecommunication cooling systems. Includes local coolers and apportioned cooling load of reversible heat pumps.
4	**Fans**	Ventilation fans, including recirculation fans and mechanical plant room fans, excluding condenser and cooling tower fans
5	**Pumps**	All pumps excluding those specific to unusual end uses such as swimming pools. Includes pumps used for central heating, hot water, and boiler ancillaries such as burner fans, flue boost or dilution fans and gas pressure boosters, chilled water and condenser water, cold water booster pumps and sump pumps.
6	**Controls**	Controls for mechanical and electrical services, building energy management systems, security and alarm systems.
7	**Humidification**	All humidification plant used to provide humidification for general building services including ventilation and air conditioning but excluding special energy uses such as swimming pool de-humidification.
8	**Lighting – internal**	All general internal lighting including task lights and emergency lights.

End use category		Description
9	**Lighting – external**	All external lighting associated with the premises, including for dedicated car parks and street lighting for dedicated access routes
10	**Lighting – display**	All display lighting including retail/artwork display or demonstration lighting, decorative lighting in lobbies etc.
11	**Small power equipment**	Office equipment uses within the general premises space comprising computer workstations, printers, and desk based telecommunications equipment. Also includes electronic point of sale equipment.
12	**ICT equipment**	All servers, central computers, telecommunications equipment, transmitters, etc. Typically but not always found in a dedicated room. Includes dedicated computer and telecommunication cooling systems. Excludes control equipment.
13	**Vertical transport**	All vertical transport devices including lifts, escalators, travellators and any other powered means of vertical passenger transport associated with the premises. Includes dedicated vertical transport controls.
14	**Catering - central**	Kitchen (or café) catering preparation and servery equipment including dishwashers, and water heating associated with catering. Excludes restaurant lighting, ventilation and air conditioning.
15	**Catering - distributed**	Energy use for food and drink preparation in kitchenettes, rest rooms, etc. including kettles, coffee making machines, microwaves, fridges and hot water boilers for drink making; also all food and drink vending machines for premises occupants, including those located in café and restaurant areas.
16	**Cooled storage**	All energy uses for devices or facilities providing commercial cold food storage e.g. chilled cabinets, freezers, cold rooms. It includes lighting in display cabinets and trace heating in display cabinet doors.
17	**Entertainment lighting**	Stage or performance lighting.
18	**Entertainment equipment**	Audio-visual equipment, gaming machines, etc. Includes projectors, TV screens, sound systems in all premises types
19	**Laundry**	Fabric washing and drying machines
20	**Medical equipment**	Energy used for medical equipment or health services in hospitals, doctor’s surgeries, dentists, vet centres, etc. Excludes equipment in laboratories.
21	**Laboratory equipment**	Energy used for equipment in laboratories.
22	**Pool/leisure**	All energy use associated with pool and sport leisure facilities within the premises. This should include heating, lighting, pumps, ventilation, humidification, and dedicated controls, alarms etc.
23	**Other**	Any other energy uses which fall outside categories 1 to 21, which are "normal" - i.e. are typical for the specific building type.

Source: Adapted from Upgrade of CIBSE TM22 from 2006 to 2012 version by Verco, March 2012

The energy end uses have been grouped for the purpose of presentation in the report. The groupings are set out in Table C.2.

Table C.2: Energy end use categories (detailed to reduced number) by energy type

Energy type	Detailed end use category	Reduced end use category
Electrical	Space heating	Heating
	Hot water	Hot water
	Space cooling	Cooling & humidification
	Fans	Fans
	Lighting - internal	Lighting
	Central catering	Catering
	Distributed catering	Catering
	Small power	Small power
	Pumps	Other
	Controls	Other
	Lighting - display	Other
	Lighting - external	Other
	Vertical transport	Other
	Cooled storage	Other
	Entertainment equipment	Other
	Pool/leisure	Other
	Laundry	Other
	ICT equipment	Other
	Lab equipment	Other
	Other - normal	Other
Non-electrical	Space heating	Heating
	Hot water	Hot water
	Catering	Catering
	Pool/leisure	Other

Note: The following sources were used to inform end use categories and how to simplify them: Definition of energy end uses in "Draft International Standard ISO/DIS 12655: Energy performance of buildings — Presentation of real energy use of buildings, 2011" (available at https://www.iso.org/obp/ui/#iso:std:iso:12655:ed-1:v1:en:term:3.6.5); and "Carbon Buzz reduced energy end uses, 2016" (available at http://www.carbonbuzz.org/index.jsp).

Table C.3 and Table C.4 show energy consumption by end use for each education sub-sector and for the sector combined. Table C.5 and Table C.6 show energy intensity by end use for each education sub-sector and for the sector combined.

Table C.3: Electrical energy consumption by energy end use category and education sub-sector, 2014–15

Simplified end use category	BEES end use category	Electrical energy consumption (GWh per year)					
		Nurseries	Primary schools	Secondary schools	Higher education - teaching & research	Higher education - residential	Educa-tion sector
Heating	Space heating	20	-	60	50	40	180
Hot water	Hot water	10	130	70	30	2	240
Cooling & humidification	Space cooling	5	30	80	80	2	190
Fans	Fans	3	30	150	260	10	450
Lighting	Lighting - internal	50	330	550	390	60	1,370
Catering	Central catering	10	110	190	90	40	440
Catering	Distributed catering	2	70	80	20	10	180
Small power	Small power	10	180	190	220	10	620
Other	Pumps	5	50	40	30	10	130
	Controls	3	30	30	20	5	90
	Lighting - display	-	-	-	20	10	30
	Lighting - external	10	30	20	20	-	70
	Vertical transport	1	-	-	20	1	20
	Cooled storage	10	-	-	5	40	50
	Entertainment equipment	1	20	20	60	20	120
	Pool/leisure	-	10	10	10	-	30
	Laundry	10	3	-	-	30	50
	ICT equipment	1	60	60	130	10	260
	Lab equipment	-	-	-	210	-	210
	Other	-	80	120	2	-	210
Total		**160**	**1,140**	**1,660**	**1,660**	**300**	**4,930**
Unweighted base		*35*	*41*	*42*	*23*	*24*	*165*

Source: Energy use model results by sub-sector, England and Wales

Table C.4: Non-electrical energy consumption by energy end use category and education sub-sector, 2014–15

Simplified end use category	**BEES energy end use category**	**Non-electrical energy consumption (GWh per year)**					
		Nurseries	Primary schools	Secondary schools	Higher education – teaching & research	Higher education - residential	**Educ -ation sector**
Space heating	Heating	280	3,190	2,390	1,880	510	8,240
Hot water	Hot water	40	450	430	130	180	1,230
Catering	Central catering	10	110	190	150	40	510
Other	Pool/leisure	-	40	40	50	-	120
Total		**330**	**3,790**	**3,040**	**2,210**	**730**	**10,100**
Unweighted base		*33*	*41*	*42*	*22*	*24*	*162*

Source: Energy use model results by sub-sector, England and Wales

Table C.5: Electrical energy intensity by energy end use category and education sub-sector, 2014–15

Simplified end use category	BEES end use category	Electrical energy intensity (kWh/m^2 per year) Nurseries	Primary schools	Second-ary schools	Higher education – teaching & research	Higher education - residential	**Educ-ation sector**
Heating	Space heating	8	-	2	3	7	2
Hot water	Hot water	5	5	3	2	0	3
Cooling & humidification	Space cooling	2	1	3	5	0	2
Fans	Fans	1	1	6	15	1	6
Lighting	Lighting - internal	19	12	21	22	11	17
Catering	Central catering	4	4	7	5	7	5
Catering	Distributed catering	1	2	3	1	2	2
Small power	Small power	5	6	7	13	2	8
Other	Pumps	2	2	1	2	1	2
	Controls	1	1	1	1	1	1
	Lighting - display	-	-	-	1	2	0
	Lighting - external	2	1	1	1	-	1
	Vertical transport	0	-	-	1	0	0
	Cooled storage	4	-	-	0	7	1
	Entertainment equipment	0	1	1	3	4	2
	Pool/leisure	-	0	0	0	-	0
	Laundry	4	0	-	-	6	1
	ICT equipment	0	2	2	7	2	3
	Lab equipment	-	-	-	12	-	3
	Other	-	3	5	0	0	3
Total		**59**	**41**	**62**	**96**	**54**	**62**
Unweighted base		*35*	*41*	*42*	*23*	*24*	*165*

Source: Energy use model results by sub-sector, England and Wales

Table C.6: Non-electrical energy intensity by energy end use category and education sub-sector, 2014–15

Simplified end use category	BEES energy end use category	Non-electrical energy intensity (kWh/m² per year) Nurseries	Primary schools	Secondary schools	Higher education – teaching & research	Higher education - residential	Education sector
Space heating	Heating	102	115	89	109	91	103
Hot water	Hot water	15	16	16	7	33	15
Catering	Central catering	5	4	7	9	8	6
Other	Pool/leisure	-	1	1	3	-	2
Total		**122**	**137**	**114**	**128**	**132**	**126**
Unweighted base		*35*	*41*	*42*	*23*	*24*	*165*

Source: Energy use model results by sub-sector, England and Wales

Appendix D: Abatement potential

The definitions for each measure type are included in this appendix as well as the abatement potential for each education sub-sector. For each sub-sector a table on abatement potential by measure type is provided as well as a marginal abatement cost curve.

Measure type definitions

The measure type definitions are included in Table D.1. The research team determined these definitions based on their experience as energy specialists. The full list of abatement model measures, and their mapping into relevant measure groups, is also shown. Please note that this list contains the full set of abatement measures used across the project, including some which were not employed in this sector.

Table D.1: Measure type definitions

Measure type	Definition	Measure name
Air conditioning and cooling	Measures associated with air conditioning and cooling plant	Cooling time controls Cooling re-commissioning Cooling temperature control Cooling plant upgrade (0-8 years old) Cooling plant upgrade (8-15 years old) Cooling plant upgrade (more than 15 years old) Free cooling Cooling zone controls
Building fabric	Measures associated with the external building fabric	Flexible plastic curtains on loading bays High speed shutter doors to loading bays Interlocks between heating systems and loading bay or vehicle access doors Replace glazing Cavity wall insulation Loft insulation Clean windows Ground insulation Insulation maintenance Internal/external wall insulation Reflective coatings for windows Blinds Flat roof insulation Draught proofing Double glazing

Building instrumentation and control	Measures associated with improving the controls and monitoring on standard building services	BMS installation BMS re-commissioning BMS maintenance Energy meters for kitchen facilities Energy meters for lifts and escalators Heating zone controls Time controls on the heating system Weather compensator controls on heating Time control on hot water system Lift maintenance
Building services distribution systems	Measures associated with improving the efficiency of the building's distribution systems	Voltage optimisation
Carbon and energy management	Measures associated with organisational policy, users of the building and the capacity of the core delivery teams	Awareness campaign targeted at HVAC (heating, ventilation and air conditioning) HVAC maintenance Improve sub-metering Procurement Energy management Awareness campaign targeted at catering usage Awareness campaign targeted at lift usage 'Low hanging fruit' energy awareness campaign Cooled storage procurement Catering equipment procurement Keeping external doors shut (retail) Reduced use of air curtains (retail) 'Intensive' energy awareness campaign Minimise simultaneous operation of heating and cooling systems
Cooled storage	Measures which improve the efficiency of the refrigeration plant	Optimise refrigeration controls Relocate catering equipment Replace central catering refrigeration equipment Replace cooled storage refrigeration equipment
Hot water	Measures associated with improving the efficiency of hot water used for domestic services; such as hot tap water	Replacement of central generation of hot water with point of use Domestic hot water maintenance Hot water efficiency measures (low flow taps, showers & baths)
Humidification	Measures associated with the systems regulating building humidity	Humidification control maintenance

Lighting	Measures associated with lighting improvements	Automatic controls on lighting Localised lighting controls CFL to LED lighting retrofit T12 to LED lighting retrofit T5 to LED lighting retrofit T8 to LED lighting retrofit T8 to T5 lighting retrofit Lighting maintenance T12 to T5 lighting retrofit External lighting – HID to LED External lighting control Dsiplay lighting controls
Small applicances	Measures associated with small power usage, such as computer upgrades	Replace catering equipment Automated shutdown for ICT usage Computer upgrade LCD flat screens Server virtualisation Thin clients Doors on fridges (retail)
Space heating	Measures that improve the efficiency of heating the building	Replace heating boiler plant with high efficiency type (0-8 years old) Replace heating boiler plant with high efficiency type (8-15 years old) Replace heating boiler plant with high efficiency type (15 years old or more) Boiler maintenance Holiday season plant shutdown Optimise heat zoning Thermostatic radiator valve (TRV) Pipe work insulation
Swimming pools	Measures that improve the efficiency of energy used for swimming pools	Energy meters for the pool complex Swimming pool covers Draught proofing of pool Pool maintenance
Ventilation	Measures that improve the efficiency of the ventilation systems	Optimising ventilation time controls Optimising ventilation zoning Variable speed drives Ventilation plant upgrade (0-8 years old) Ventilation plant upgrade (8-15 years old) Ventilation plant upgrade (15 years old or more) Motor replacement Motor controls Motor resizing

Note: The following sources were used to inform end use categories and how to simplify them: Definition of energy end uses in “Draft International Standard ISO/DIS 12655: Energy performance of buildings — Presentation of real energy use of buildings, 2011” (available at https://www.iso.org/obp/ui/#iso:std:iso:12655:ed-1:v1:en:term:3.6.5); and “Carbon Buzz reduced energy end uses, 2016” (available at http://www.carbonbuzz.org/index.jsp).

Nurseries

In nurseries there was an annual abatement potential of 60 GWh of electrical energy and 170 GWh of non-electrical energy (equivalent to 50 $ktCO_2e$ combined). This equates to a 38 per cent and 50 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this was £137m. The annual savings delivered would be £10m[36]. These figures are grouped according to measure type in Table D.2. The total abatement potential of the socially cost effective measure groups was 30 GWh, all of which was electrical energy consumption. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. There was no abatement potential relating to measure groups with a private payback of 3 years or less. Within each group of measures there will be some measures that are more cost-effective than others for each sub-sector. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole (Figure D.1).

Table D.2: Abatement opportunity data for nurseries, 2014–15

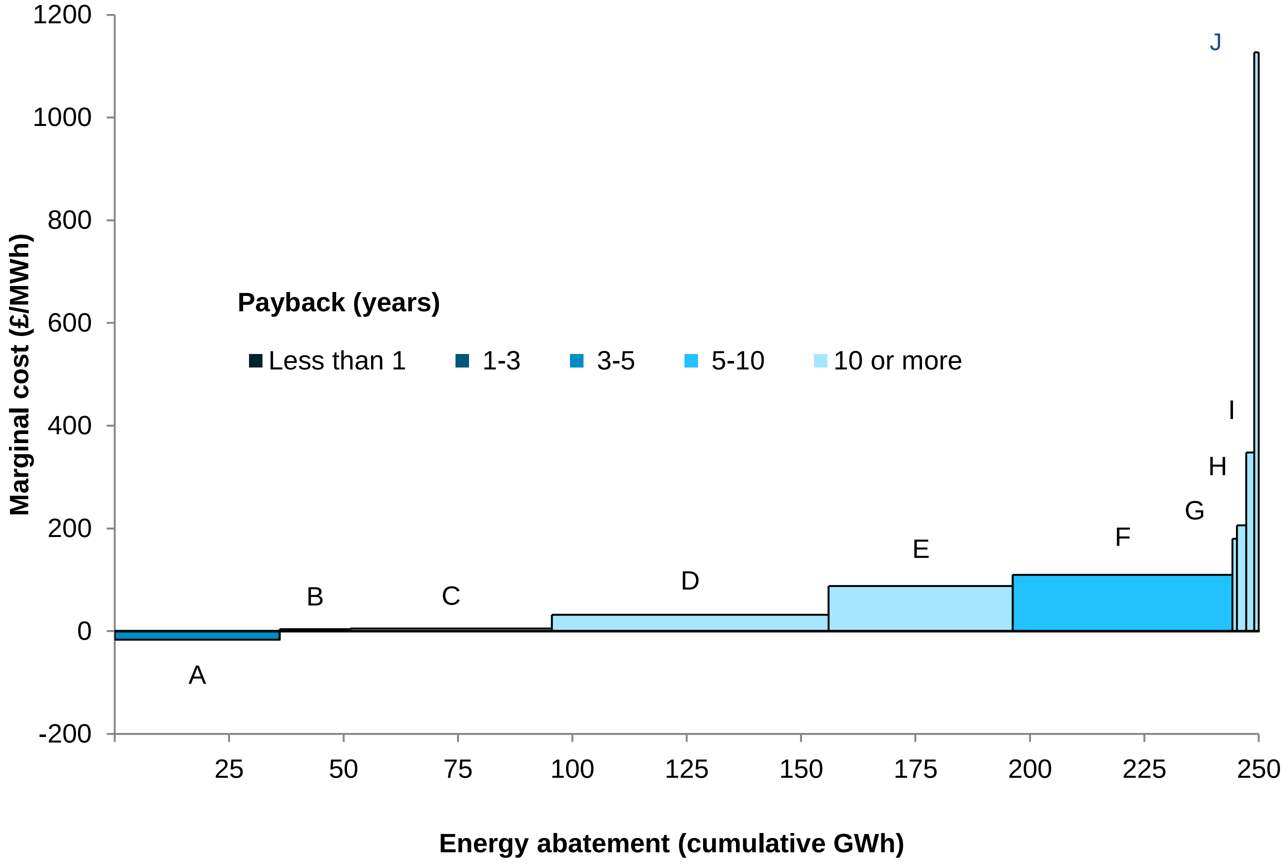
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Payback period (years)** [37]
Air conditioning and cooling	100	0	1	-	1	1,800	30
Building fabric	1,200	7	2	40	40	25,400	17
Building instrumentation and control	1,200	7	3	30	40	28,200	17
Building services distribution systems	200	1	2	-	2	2,800	8
Carbon and energy management	2,000	10	10	30	40	13,800	5
Hot water	400	3	1	10	10	4,500	9
Humidification	-	-	-	-	-	-	-
Lighting	3,200	9	30	-	30	16,000	4
Cooled storage	-	-	-	-	-	-	-
Small appliances	100	0	1	1	2	3,100	22
Space heating	1,700	10	4	50	60	34,600	17
Swimming pools	-	-	-	-	-	-	-
Ventilation	100	0	1	-	1	7,100	69
Total	**10,100**	**50**	**60**	**170**	**230**	**137,300**	‘’

Source: Abatement model results for sub-sector, England and Wales

[36] Annual savings relates to the financial savings associated solely with the reduced energy consumption.

[37] Payback relates to the duration of time after which the capital costs of a measure are recouped through the accumulated bill savings the measure delivers. Note that the payback period reflects the gross bill savings of the measure alone, rather than the bill savings that would be achieved by the measure if all other measures were installed.

Figure D.1: Marginal abatement cost curve for nurseries, 2014–15



Note: the marginal abatement cost is calculated based on the social cost effectiveness, while the payback period is calculated from a private perspective.

A Lighting [MAC: £-17 per MWh. GWh: 30]

B Hot water [MAC: £4 per MWh. GWh: 10]

C Building fabric [MAC: £5 per MWh. GWh: 40]

D Space heating [MAC: £32 per MWh. GWh: 60]

E Building instrumentation and control [MAC: £88 per MWh. GWh: 40]

F Carbon and Energy Management [MAC: £109 per MWh. GWh: 40]

G Air conditioning and cooling [MAC: £179 per MWh. GWh: 1]

H Building services distribution systems [MAC: £207 per MWh. GWh: 2]

I Small appliances [MAC: £349 per MWh. GWh: 2]

J Ventilation [MAC: £1,134 per MWh. GWh: 1]

Source: Abatement model results for sub-sector, England and Wales

Primary schools

In primary schools there was an annual abatement potential of 370 GWh of electrical energy and 2,030 GWh of non-electrical energy (equivalent to 490 $ktCO_2e$ combined). This equates to a 33 per cent and 54 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this is £679m. The annual savings delivered would be £89m[38]. These figures are grouped according to measure type in Table D.3. The total abatement potential of the socially cost effective measure groups was 1,590 GWh, of which 130 GWh was electrical energy consumption and 1,470 GWh was non-electrical energy consumption. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. The total abatement potential relating to measure groups with a private payback of 3 years or less was 610 GWh, of which 100 GWh was electrical energy consumption and 500 GWh non-electrical energy consumption. Within each group of measures there will be some measures that are more cost-effective than others for each sub-sector. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole (Figure D.2).

Table D.3: Abatement opportunity data for primary schools, 2014–15

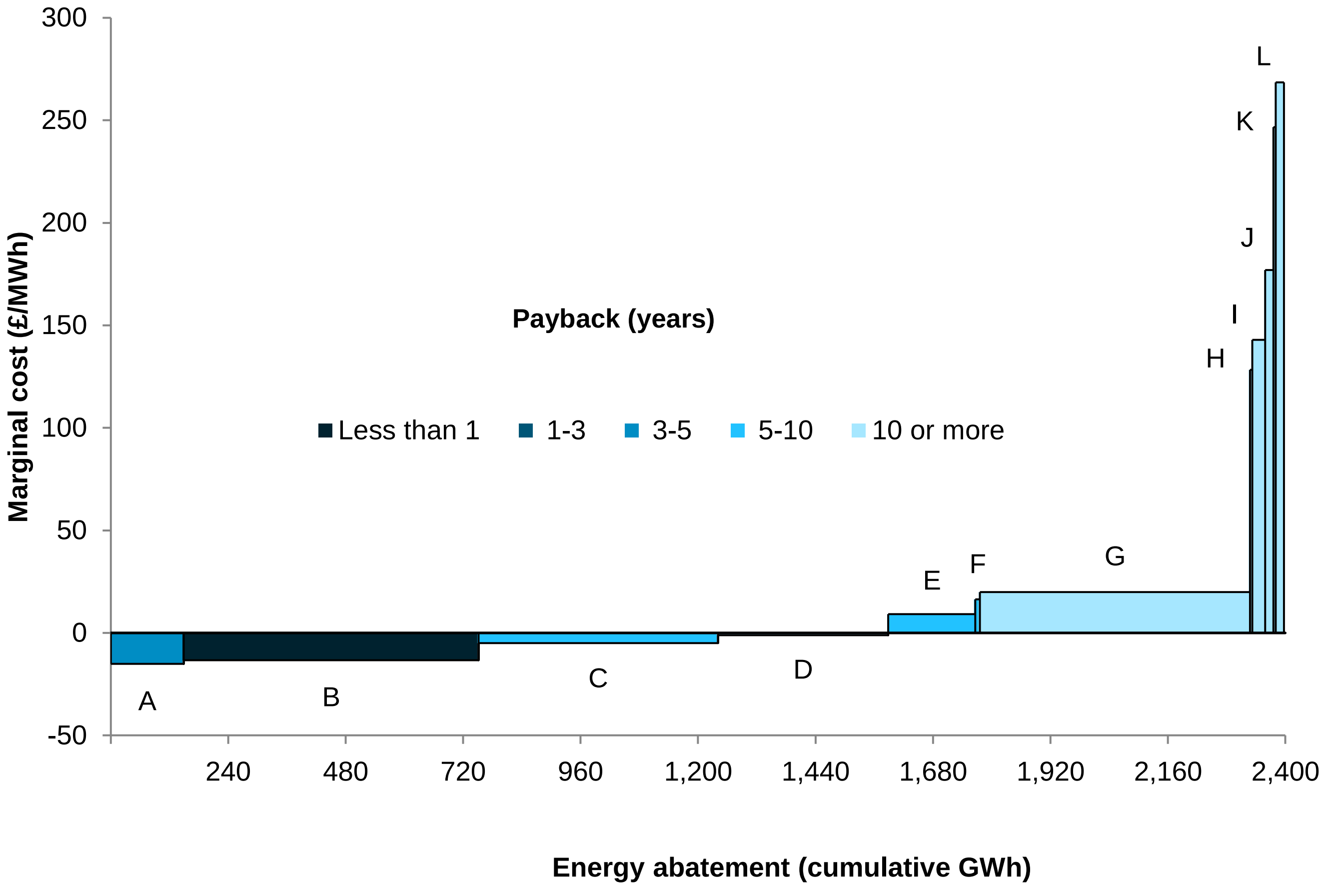
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Payback period (years)** [39]
Air conditioning and cooling	500	2	5	-	5	11,900	25
Building fabric	9,100	70	2	350	350	147,300	10
Building instrumentation and control	12,800	90	4	490	490	65,000	4
Building services distribution systems	1,600	5	20	-	20	19,500	8
Carbon and energy management	22,900	130	100	500	600	22,100	1
Hot water	5,300	30	20	130	150	23,400	4
Humidification	-	-	-	-	-	-	-
Lighting	17,800	50	180	-	180	128,900	6
Cooled storage	1,000	3	10	-	10	5,200	4
Small appliances	1,900	7	20	8	30	24,900	10
Space heating	14,200	100	2	550	550	190,700	13
Swimming pools	200	1	1	4	4	2,300	16
Ventilation	1,600	5	20	-	20	37,500	17
Total	**88,900**	**490**	**370**	**2,030**	**2,400**	**678,800**	‘’

Source: Abatement model results for sub-sector, England and Wales

[38] Annual savings relates to the financial savings associated solely with the reduced energy consumption.

[39] Payback relates to the duration of time after which the capital costs of a measure are recouped through the accumulated bill savings the measure delivers. Note that the payback period reflects the gross bill savings of the measure alone, rather than the bill savings that would be achieved by the measure if all other measures were installed.

Figure D.2: Marginal abatement cost curve for primary schools, 2014–15



Note: the marginal abatement cost is calculated based on the social cost effectiveness, while the payback period is calculated from a private perspective.

A Hot water [MAC: £-15 per MWh. GWh: 150]
B Carbon and Energy Management [MAC: £-13 per MWh. GWh: 600]
C Building instrumentation and control [MAC: £-5 per MWh. GWh: 491]
D Building fabric [MAC: £-1 per MWh. GWh: 350]
E Lighting [MAC: £9 per MWh. GWh: 180]
F Refrigeration [MAC: £16 per MWh. GWh: 10]
G Space heating [MAC: £20 per MWh. GWh: 550]
H Swimming pools [MAC: £128 per MWh. GWh: 4]
I Small appliances [MAC: £143 per MWh. GWh: 30]
J Building services distribution systems [MAC: £177 per MWh. GWh: 20]
K Air conditioning and cooling [MAC: £247 per MWh. GWh: 5]
L Ventilation [MAC: £269 per MWh. GWh: 20]

Source: Abatement model results for sub-sector, England and Wales

Secondary schools

In secondary schools there was an annual abatement potential of 640 GWh of electrical energy and 1,520 GWh of non-electrical energy (equivalent to 470 $ktCO_2e$ combined). This equates to a 39 per cent and 50 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this is £665m. The annual savings delivered would be £102m[40]. These figures are grouped according to measure type in Table D.4. The total abatement potential of the socially cost effective measure groups was 1,320 GWh, of which 480 GWh was electrical energy consumption and 840 GWh was non-electrical energy consumption. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. The total abatement potential relating to measure groups with a private payback of 3 years or less was 540 GWh, of which 140 GWh was electrical energy consumption and 390 GWh non-electrical energy consumption. Within each group of measures there will be some measures that are more cost-effective than others for each sub-sector. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole (Figure D.3).

Table D.4: Abatement opportunity data for secondary schools, 2014–15

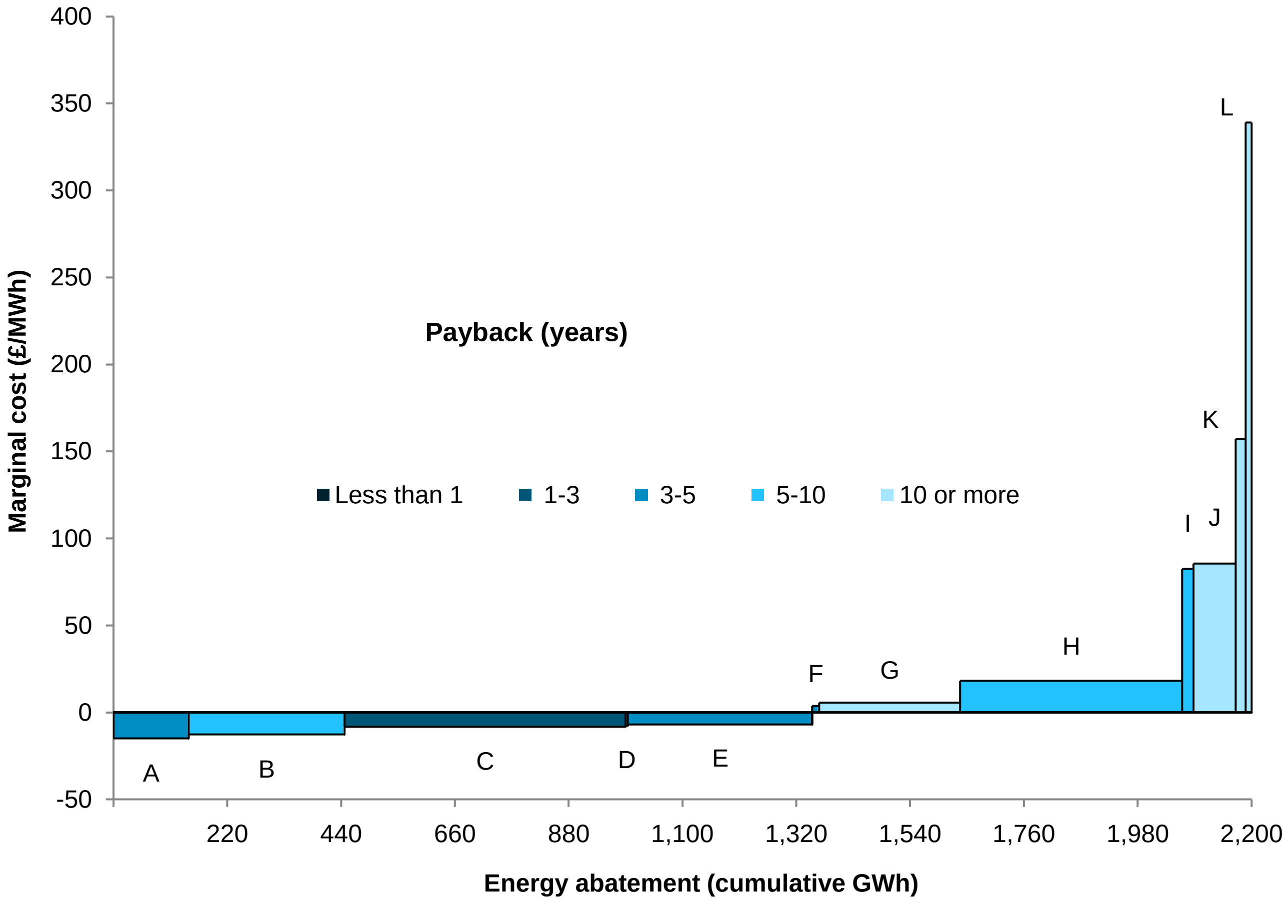
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Payback period (years)** [41]
Air conditioning and cooling	2,100	6	20	-	20	19,200	9
Building fabric	7,400	50	7	260	270	147,800	11
Building instrumentation and control	11,100	70	30	320	350	42,900	3
Building services distribution systems	1,900	6	20	-	20	20,500	7
Carbon and energy management	24,000	120	140	390	530	27,900	1
Hot water	4,700	30	20	130	140	21,400	4
Humidification	-	-	-	-	-	-	-
Lighting	29,400	80	300	-	300	150,900	5
Cooled storage	1,200	4	10	-	10	5,100	4
Small appliances	1,100	4	9	7	20	30,700	21
Space heating	11,600	80	10	410	420	112,800	10
Swimming pools	100	1	1	3	4	300	2
Ventilation	7,800	20	80	-	80	86,000	7
Total	**102,300**	**470**	**640**	**1,520**	**2,160**	**665,400**	‘’

Source: Abatement model results for sub-sector, England and Wales

[40] Annual savings relates to the financial savings associated solely with the reduced energy consumption.

[41] Payback relates to the duration of time after which the capital costs of a measure are recouped through the accumulated bill savings the measure delivers. Note that the payback period reflects the gross bill savings of the measure alone, rather than the bill savings that would be achieved by the measure if all other measures were installed.

Figure D.3: Marginal abatement cost curve for secondary schools, 2014–15



Note: the marginal abatement cost is calculated based on the social cost effectiveness, while the payback period is calculated from a private perspective.

A Hot water [MAC: £-15 per MWh. GWh: 140]
B Lighting [MAC: £-13 per MWh. GWh: 300]
C Carbon and Energy Management [MAC: £-8 per MWh. GWh: 530]
D Swimming pools [MAC: £-8 per MWh. GWh: 4]
E Building instrumentation and control [MAC: £-7 per MWh. GWh: 350]
F Refrigeration [MAC: £4 per MWh. GWh: 10]
G Building fabric [MAC: £6 per MWh. GWh: 270]
H Space heating [MAC: £18 per MWh. GWh: 420]
I Air conditioning and cooling [MAC: £82 per MWh. GWh: 20]
J Ventilation [MAC: £86 per MWh. GWh: 80]
K Building services distribution systems [MAC: £157 per MWh. GWh: 20]
L Small appliances [MAC: £339 per MWh. GWh: 20]

Source: Abatement model results for sub-sector, England and Wales

Higher education – teaching & research

In higher education – teaching & research premises there was an annual abatement potential of 510 GWh of electrical energy and 990 GWh of non-electrical energy (equivalent to 330 $ktCO_2e$ combined). This equates to a 31 per cent and 45 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this is £461m. The annual savings delivered would be £76m[42]. These figures are grouped according to measure type in Table D.5. The total abatement potential of the socially cost effective measure groups was 1,080 GWh, of which 350 GWh was electrical energy consumption and 730 GWh was non-electrical energy consumption. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. The total abatement potential relating to measure groups with a private payback of 3 years or less was 590 GWh, of which 140 GWh was electrical energy consumption and 440 GWh non-electrical energy consumption. Within each group of measures there will be some measures that are more cost-effective than others for each sub-sector. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole (Figure D.4).

Table D.5: Abatement opportunity data for higher education – teaching and research, 2014–15

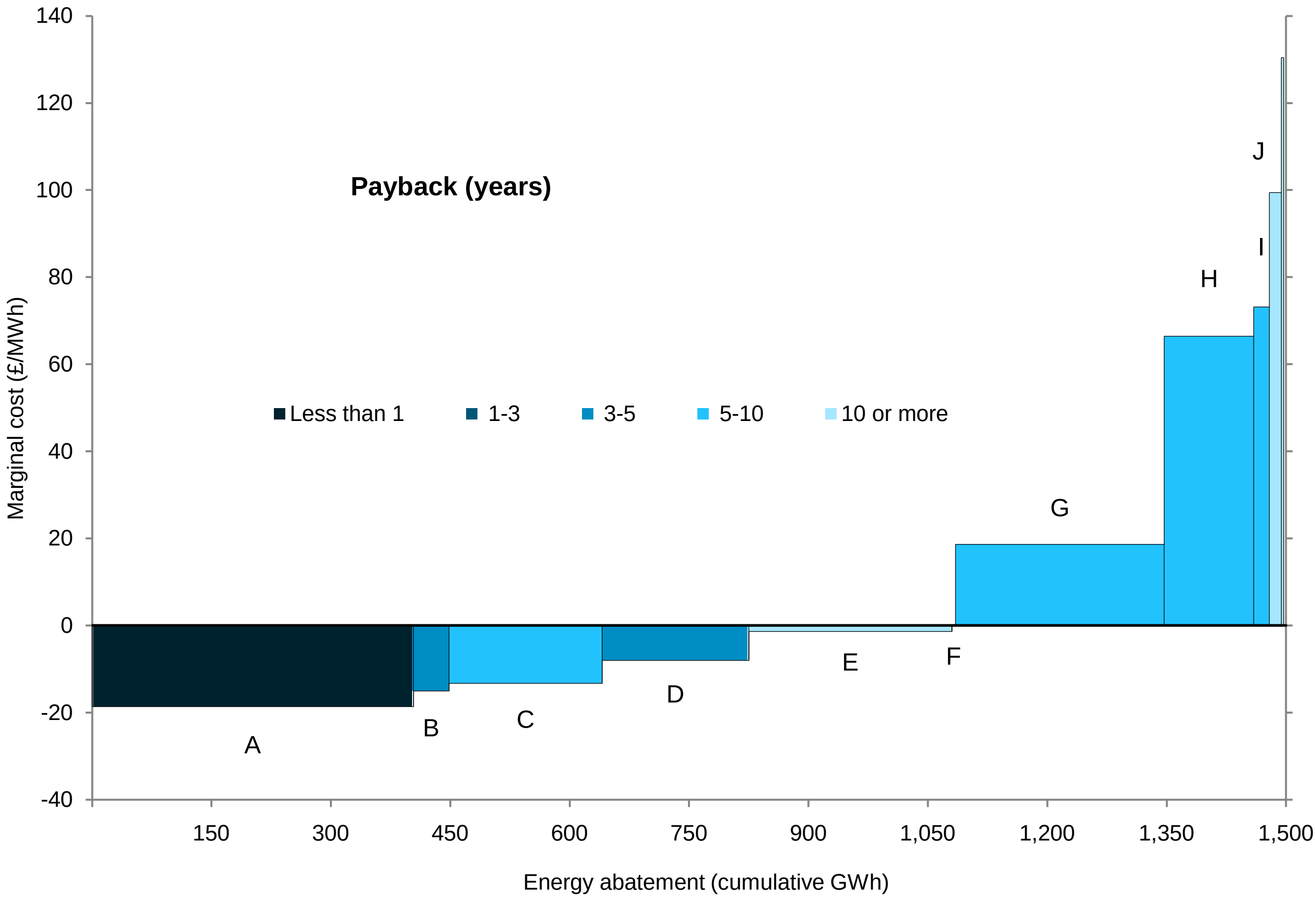
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Payback period (years)**[43]
Air conditioning and cooling	1,500	4	20	-	20	19,000	16
Building fabric	6,900	50	6	250	250	121,000	12
Building instrumentation and control	6,200	40	20	170	190	20,500	3
Building services distribution systems	2,000	6	20	-	20	12,800	5
Carbon and energy management	19,400	90	120	280	400	14,200	1
Hot water	1,600	9	6	40	50	7,500	4
Humidification	-	-	-	-	-	-	-
Lighting	19,100	50	190	-	190	97,600	4
Cooled storage	400	1	4	-	4	1,700	4
Small appliances	200	1	1	2	3	2,900	12
Space heating	7,200	50	7	260	260	71,200	11
Swimming pools	-	-	-	-	-	-	-
Ventilation	11,100	30	110	-	110	92,100	5
Total	**75,600**	**330**	**510**	**990**	**1,500**	**460,500**	‘’

Source: Abatement model results for sub-sector, England and Wales

[42] Annual savings relates to the financial savings associated solely with the reduced energy consumption.

[43] Payback relates to the duration of time after which the capital costs of a measure are recouped through the accumulated bill savings the measure delivers. Note that the payback period reflects the gross bill savings of the measure alone, rather than the bill savings that would be achieved by the measure if all other measures were installed.

Figure D.4: Marginal abatement cost curve for higher education – teaching and research, 2014–15



Note: the marginal abatement cost is calculated based on the social cost effectiveness, while the payback period is calculated from a private perspective.

A Carbon and energy management [MAC: £-19 per MWh. GWh: 400]

B Hot water [MAC: £-25 per MWh. GWh: 50]

C Lighting [MAC: £-13 per MWh. GWh: 190]

D Building instrumentation and control [MAC: £-8 per MWh. GWh: 190]

E Building fabric [MAC: £-1 per MWh. GWh: 250]

F Refrigeration . [MAC: £0 per MWh. GWh: 4]

G Space heating [MAC: £19 per MWh. GWh: 260]

H Ventilation [MAC: £66 per MWh. GWh: 110]

I Building services distribution systems [MAC: £73 per MWh. GWh: 20]

J Air conditioning and cooling [MAC: £100 per MWh. GWh: 20]

K Small appliances [MAC: £131 per MWh. GWh: 3]

Source: Abatement model results for sub-sector, England and Wales

Higher education – residential

In higher education – residential premises there was an annual abatement potential of 80 GWh of electrical energy and 390 GWh of non-electrical energy (equivalent to 100 $ktCO_2e$ combined). This equates to a 29 per cent and 54 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this is £123m. The annual savings delivered would be £19m[44]. These figures are grouped according to measure type in Table D.5. The total abatement potential of the socially cost effective measure groups was 300 GWh, of which 70 GWh was electrical energy consumption and 230 GWh was non-electrical energy consumption. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. The total abatement potential relating to measure groups with a private payback of 3 years or less was 120 GWh, of which 30 GWh was electrical energy consumption and 90 GWh non-electrical energy consumption. Within each group of measures there will be some measures that are more cost-effective than others for each sub-sector. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole (Figure D.4).

Table D.5: Abatement opportunity data for higher education – residential, 2014–15

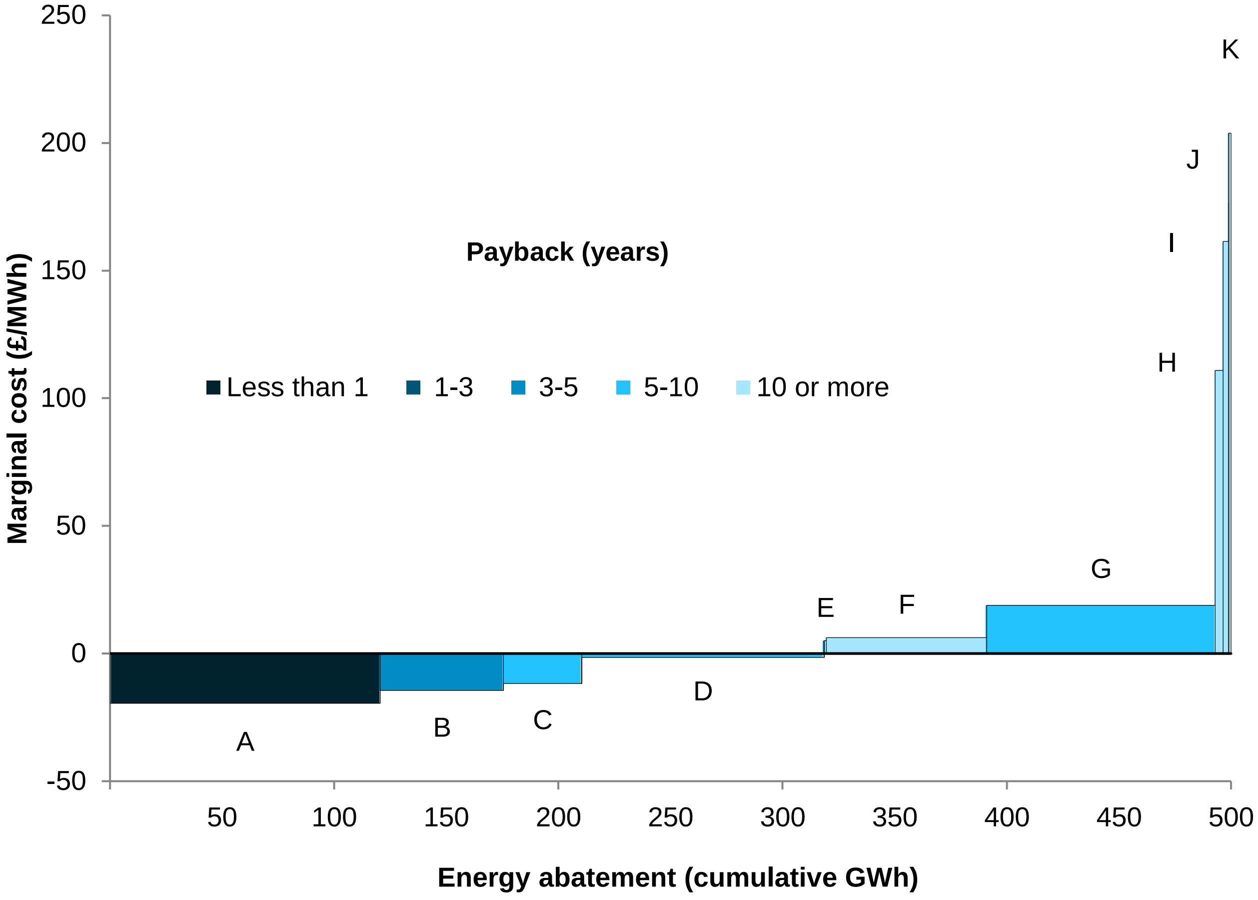
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Payback period (years)** [45]
Air conditioning and cooling	0	0	0	-	0	400	12
Building fabric	2,000	10	3	70	70	45,300	12
Building instrumentation and control	3,200	20	8	100	100	16,500	4
Building services distribution systems	200	1	2	-	2	2,400	6
Carbon and energy management	5,100	30	30	90	120	3,700	1
Hot water	1,400	10	0	50	50	6,200	4
Humidification	-	-	-	-	-	-	-
Lighting	3,300	9	30	-	30	17,400	5
Cooled storage	100	0	1	-	1	400	3
Small appliances	100	1	0	3	3	2,400	12
Space heating	2,900	20	6	90	100	27,300	10
Swimming pools	-	-	-	-	-	-	-
Ventilation	100	0	1	-	1	1,100	6
Total	**18,500**	**100**	**80**	**390**	**480**	**123,000**	‘’

Source: Abatement model results for sub-sector, England and Wales

[44] Annual savings relates to the financial savings associated solely with the reduced energy consumption.

[45] Payback relates to the duration of time after which the capital costs of a measure are recouped through the accumulated bill savings the measure delivers. Note that the payback period reflects the gross bill savings of the measure alone, rather than the bill savings that would be achieved by the measure if all other measures were installed.

Figure D.4: Marginal abatement cost curve for higher education – residential, 2014–15



Note: the marginal abatement cost is calculated based on the social cost effectiveness, while the payback period is calculated from a private perspective.

A Carbon and energy management [MAC: £-20 per MWh. GWh: 120]
B Hot water [MAC: £-14 per MWh. GWh: 50]
C Lighting [MAC: £-12 per MWh. GWh: 30]
D Building instrumentation and control [MAC: £-2 per MWh. GWh: 100]
E Refrigeration [MAC: £5 per MWh. GWh: 1]
F Building fabric [MAC: £6 per MWh. GWh: 70]
G Space heating [MAC: £19 per MWh. GWh: 100]
H Small appliances [MAC: £111 per MWh. GWh: 3]
I Building services distribution systems [MAC: £162 per MWh. GWh: 2]
J Air conditioning and cooling [MAC: £179 per MWh. GWh: 0]
K Ventilation [MAC: £204 per MWh. GWh: 1]

Source: Abatement model results for sub-sector, England and Wales

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