Department for
Business, Energy
& Industrial Strategy

Building Energy Efficiency Survey: Community, arts & leisure sector, 2014–15

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Any enquiries regarding this publication should be sent to us at nondomesticbuildings@decc.gsi.gov.uk

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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 community, arts & leisure 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.

Community, arts & leisure sector overview

The community, arts & leisure sector consisted of leisure centres, clubs & community centres, museums, theatres and places of worship; for the purpose of this study, it did not include community, arts & leisure premises that were present in other building types. The community, arts & leisure sector had a total floor area of 52 million m^2 (7 per cent of the total non-domestic stock) across 78,500 premises (5 per cent of the total non-domestic stock). The community, arts & leisure sector's total energy consumption was 11,790 GWh, comprising 3,680 GWh of electrical energy (4 per cent of the total non-domestic stock) and 8,110 GWh of non-electrical consumption (11 per cent of total non-domestic stock).

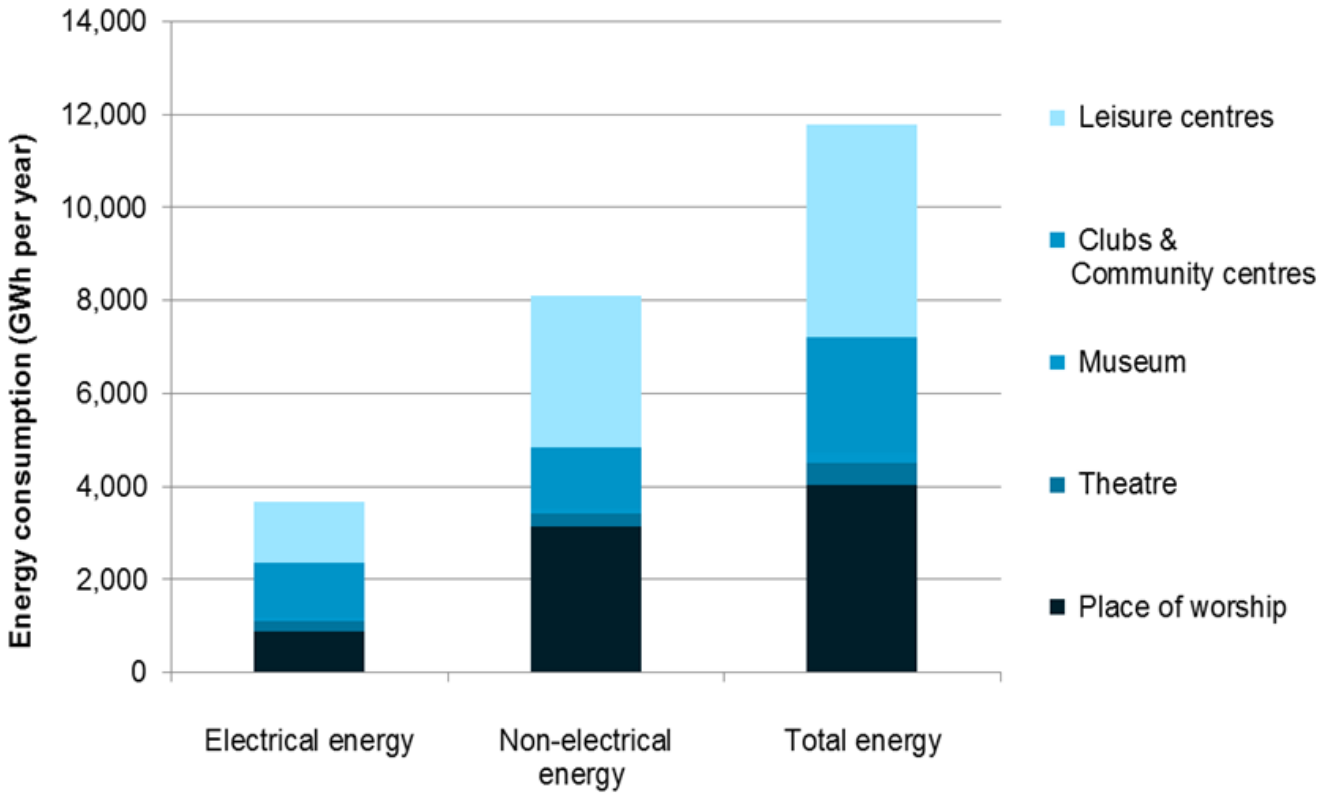
The findings in this report are based on data collected through 351 telephone surveys used in the energy use and abatement models and 32 site surveys in 2014–15.

Key findings

Energy consumption in the community, arts & leisure sector, 2014–15

- According to modelled data based on telephone survey responses, the sector consumed 11,790 GWh of energy. This included 3,680 GWh of electrical energy and 8,110 GWh of non-electrical energy per year (Figure 0.1).
- The largest energy consumer was leisure centres with 4,590 GWh of overall energy consumption (39 per cent of sector total). Places of worship were the second largest consumer with 4,020 GWh of overall energy consumption (34 per cent of sector total).
- The difference in absolute consumption between the sub-sectors did not always correlate to their overall size. Leisure centres was the largest sub-sector in terms of energy consumption, while only representing 14 per cent of the sector's overall floor area. In contrast, places of worship were by far the largest sub-sector in terms of floor area (63 per cent of sector total) but represented 34 per cent of the sector's total energy consumption.
- Leisure centres displayed the largest median energy intensity (499 kWh/m^2), followed by theatres (290 kWh/m^2) and clubs & community centres (245 kWh/m^2).
- Leisure centres typically displayed the highest median electrical energy intensity (153 kWh/m^2 for electrical energy). The second most energy intensive sub-sector in terms of electrical energy was theatres (102 kWh/m^2). Leisure centres displayed the highest median non-electrical energy intensity of 349 kWh/m^2, followed by theatres (193 kWh/m^2).
- The energy consumption of the community, arts & leisure sector was broken down into specific 'end uses'. The most significant end use was space heating (5,820 GWh, 49 per cent of total energy consumption), followed by pool/leisure (2,420 GWh, 21 per cent of total).

Figure 0.1: Energy consumption by energy type and community, arts & leisure sub-sector, 2014–15



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

Abatement potential in the community, arts & leisure sector, 2014–15

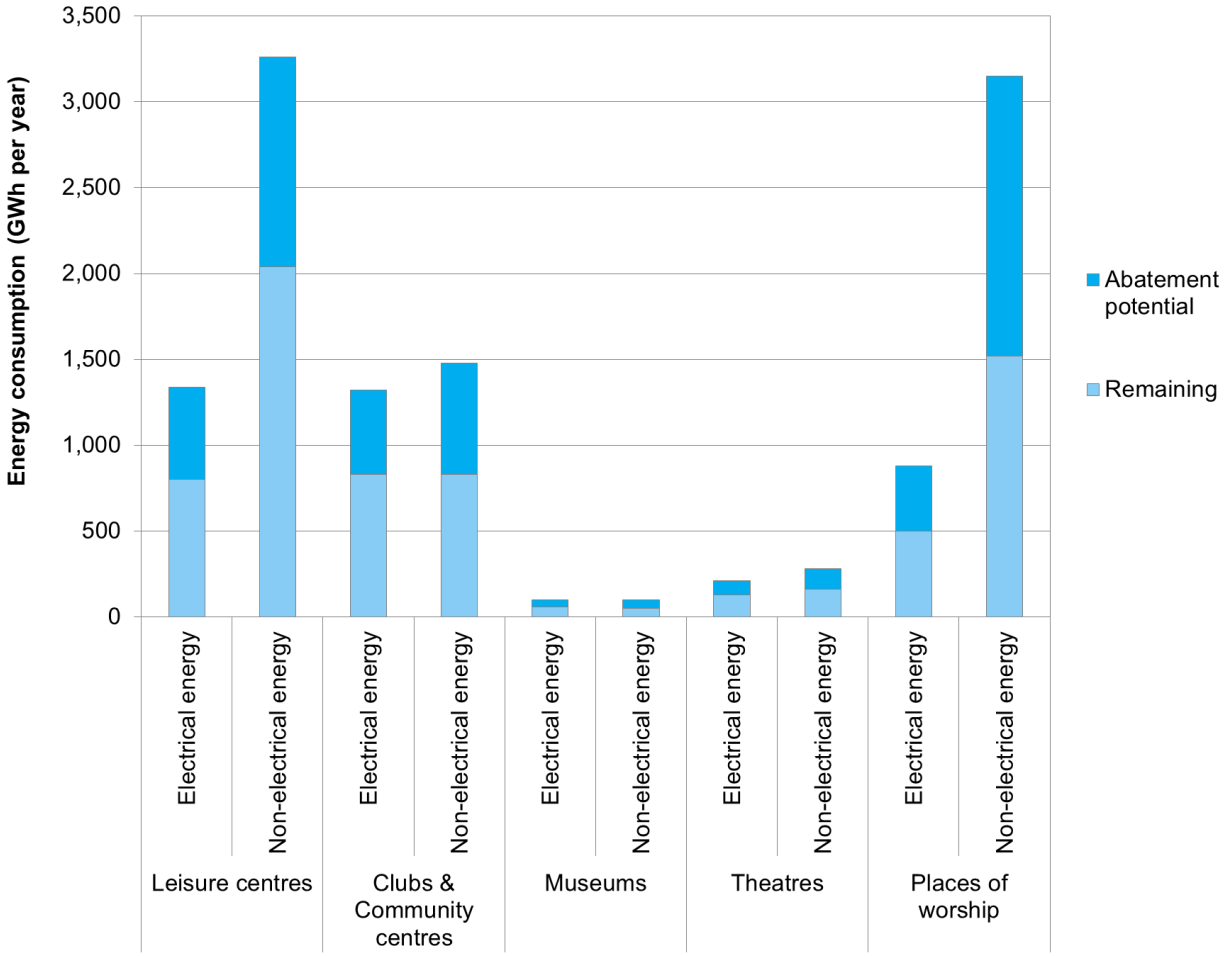
- According to modelled data based on telephone survey responses, Figure 0.2 shows abatement potential for the sector, broken down by sub-sector and fuel type. This represents the total abatement potential that is technically available, which relates to the possible reductions in energy consumption following 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 community, arts & leisure sector was 5,090 GWh of total energy. This consisted of 1,450 GWh of electrical energy (a 39 per cent reduction on consumption) and 3,640 GWh of non-electrical energy (a 45 per cent reduction on consumption).
- This could be achieved at a capital cost of £2.24 billion. The socially cost effective potential was 850 GWh of total energy consumption which consisted of 100 GWh of electrical energy consumption and 750 GWh of non-electrical energy consumption. Companies are more likely to be influenced by the payback period for improvement: overall there were 940 GWh of total energy savings with a private payback period[4] of 3

[4] Payback 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.

years or less (260 GWh of electrical energy abatement and 690 GWh of non-electrical energy abatement).

- The sub-sector with the largest relative and absolute abatement potential was places of worship who could reduce consumption by 2,010 GWh which spilts between 380 GWh of electrical energy (43 per cent reduction on consumption) and 1,630 GWh of non-electrical energy (52 per cent reduction on consumption).

Figure 0.2: Abatement potential by energy type and community, arts & leisure 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 community, arts & leisure sector – in terms of reductions in energy consumption – related 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 - related to the implementation of carbon and energy management programmes.

Table 0.1: Abatement potential in the community, arts & leisure sector 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 ($ktCO_2$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	
Air conditioning and cooling	6,800	20	70	-	70	77,300
Building fabric	22,500	130	60	660	720	436,600
Building instrumentation and control	29,100	170	100	750	850	158,100
Building services distribution systems	2,000	6	20	-	20	97,800
Carbon and Energy Management	43,100	210	260	690	940	120,200
Hot water	2,700	20	7	80	80	33,300
Humidification	0	0	0	0	0	0
Lighting	41,200	120	420	-	420	300,900
Cooled storage	14,300	40	140	-	140	71,100
Small appliances	700	3	5	8	10	15,200
Space heating	31,800	200	80	940	1,020	494,000
Swimming pools	24,100	130	110	500	620	264,200
Ventilation	18,500	60	180	10	200	174,800
Total	**236,800**	**1,100**	**1,450**	**3,640**	**5,090**	**2,243,400**

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

1. Community, arts & leisure sector

This report relates to the community, arts & leisure sector (one of ten sectors covered in the Building Energy Efficiency Survey (BEES)). This section provides definitions for the five community, arts & leisure sub-sectors (leisure centres, clubs & community centres, museums, theatres and places of worship). It then sets the community, arts & leisure 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 community, arts & leisure sector.

Table 1.1: Table of community, arts & leisure sub-sector definitions[5]

Sub-sector	Definition
Leisure centres	Refers to public and private sector premises used for sporting, exercise and/or leisure activities. Facilities may include swimming pools, large sports hall, squash courts, fitness suite, aerobics studios, outdoor grass and/or artificial pitches for football, hockey etc., a solarium, sauna and/or steam room.
Clubs & Community centres	'Clubs' refers to premises used for the meetings and activities of associations dedicated to a particular interest or activity, e.g. political clubs, social clubs etc. 'Community centres' refers to premises primarily used for public or private gatherings. This may include community group meetings, seminars, workshops, or performances. Gross Floor Area should include all space within the building(s), including meeting rooms, auditoriums, food service areas, lobbies, administrative/office space, mechanical rooms[6], storage areas, lift shafts, and stairwells.
Museums, Art galleries and Libraries (referred to as 'Museums')	'Museums' refers to premises that display collections to outside visitors for public viewing. Gross Floor Area should include all space within the building(s), including public collection display areas, meeting rooms, classrooms, gift shops, food service areas, administrative/office space, mechanical rooms, storage areas for collections, lift shafts, and stairwells. 'Art galleries' refers to premises in which works of art are exhibited such as paintings, sculpture and other installations. Gross Floor Area should include all space within the building(s), including public collection display areas, meeting rooms, classrooms, gift shops, food service areas, administrative/office space, mechanical rooms, storage areas for collections, lift shafts, and stairwells. 'Libraries' refers to premises used to store and manage collections of

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

[6] Refers to rooms dedicated to mechanical and electrical equipment.

Sub-sector	Definition
	literary and artistic materials such as books, periodicals, newspapers, films, etc. that can be used for reference or lending. Gross Floor Area should include all space within the building(s), including circulation rooms, storage areas, reading/study rooms, administrative space, kitchens used by staff, lobbies, conference rooms and auditoriums, fitness areas for staff, storage areas, stairways, and lift shafts.
Theatres, Cinemas and Concert halls (referred to as 'Theatres')	'Theatres' refers to premises in which plays and other dramatic performances are given. Gross Floor Area should include all space within the building(s), including seating areas, lobbies, concession stands, bathrooms, changing rooms, administrative/office space, mechanical rooms, storage areas, lift shafts, and stairwells. 'Cinemas' refers to premises used for public or private film screenings. Gross Floor Area should include all space within the building(s), including seating areas, lobbies, concession stands, bathrooms, administrative/office space, mechanical rooms, storage areas, lift shafts, and stairwells. 'Concert halls' refers to public premises designed for the performance of concerts. Gross Floor Area should include all space within the building(s), including seating areas, lobbies, concession stands, bathrooms, changing rooms, administrative/office space, mechanical rooms, storage areas, lift shafts, and stairwells.
Places of worship	Refers to premises that are used for religious worship. This includes churches, temples, mosques, synagogues, meeting houses, or any other buildings that primarily function as a place of religious worship. Gross Floor Area should include all areas inside the building that includes the primary worship area, including food preparation, community rooms, classrooms, and supporting areas such as toilets, storage areas, hallways, and lift shafts.

Source: Sub-sector definitions adapted from the US Energy Star scheme and adapted for the UK context.

Community, arts & leisure sector in the context of the wider non domestic stock

The community, arts & leisure sector accounts for 5 per cent of the non-domestic stock in terms of premises count (78,500) and 7 per cent in terms of floor area (52 million m^2 GIA[7])[8].

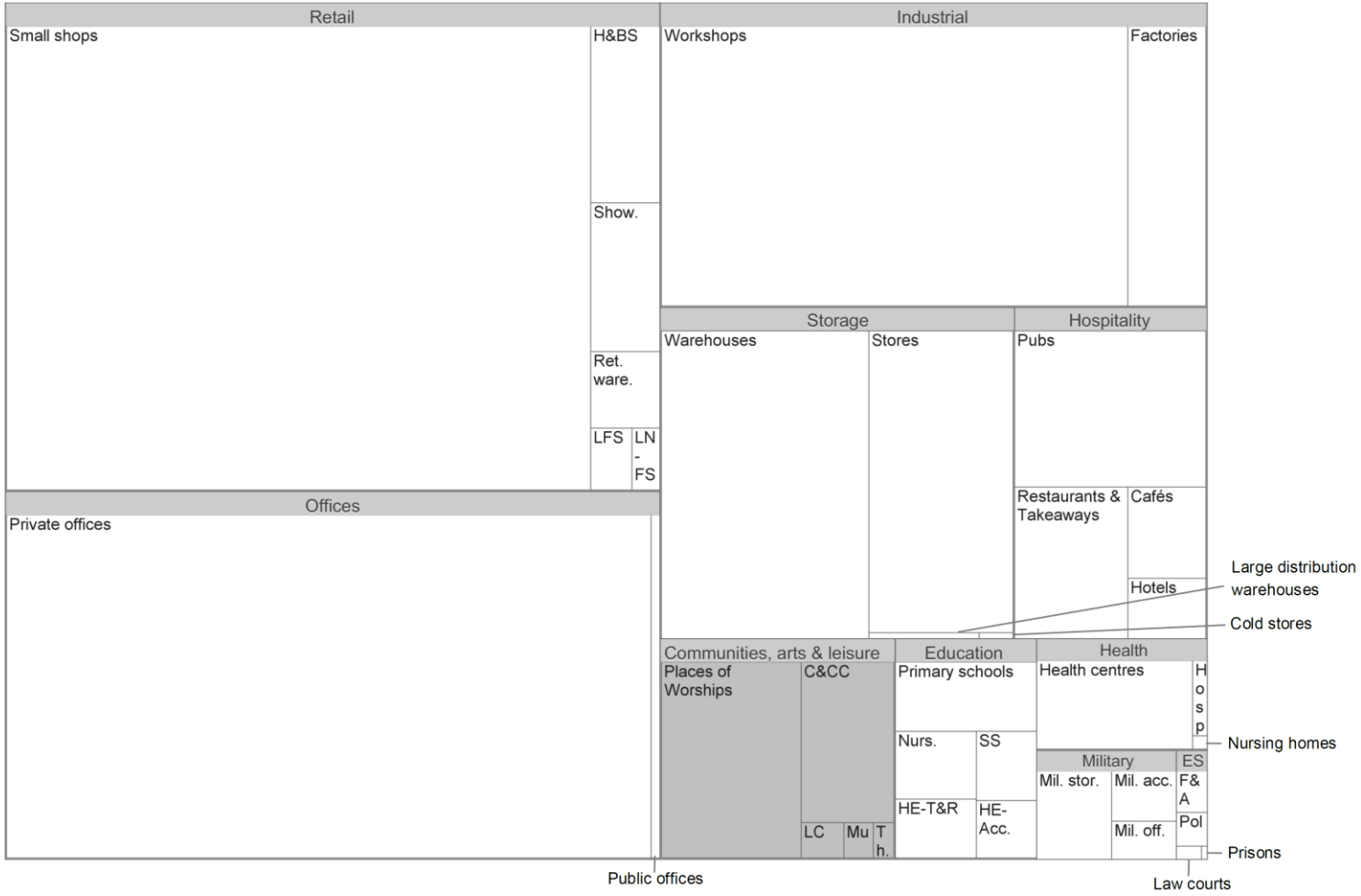
In terms of energy consumption the sector consumed 11,790 GWh of total energy per year. This comprised 3,680 GWh of electrical energy and 8,110 GWh of non-electrical energy per year, which is equivalent to 4 per cent and 11 per cent of non-domestic stock totals respectively. This information is set out in Figure 1.1 to Figure 1.3.

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

[8] 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

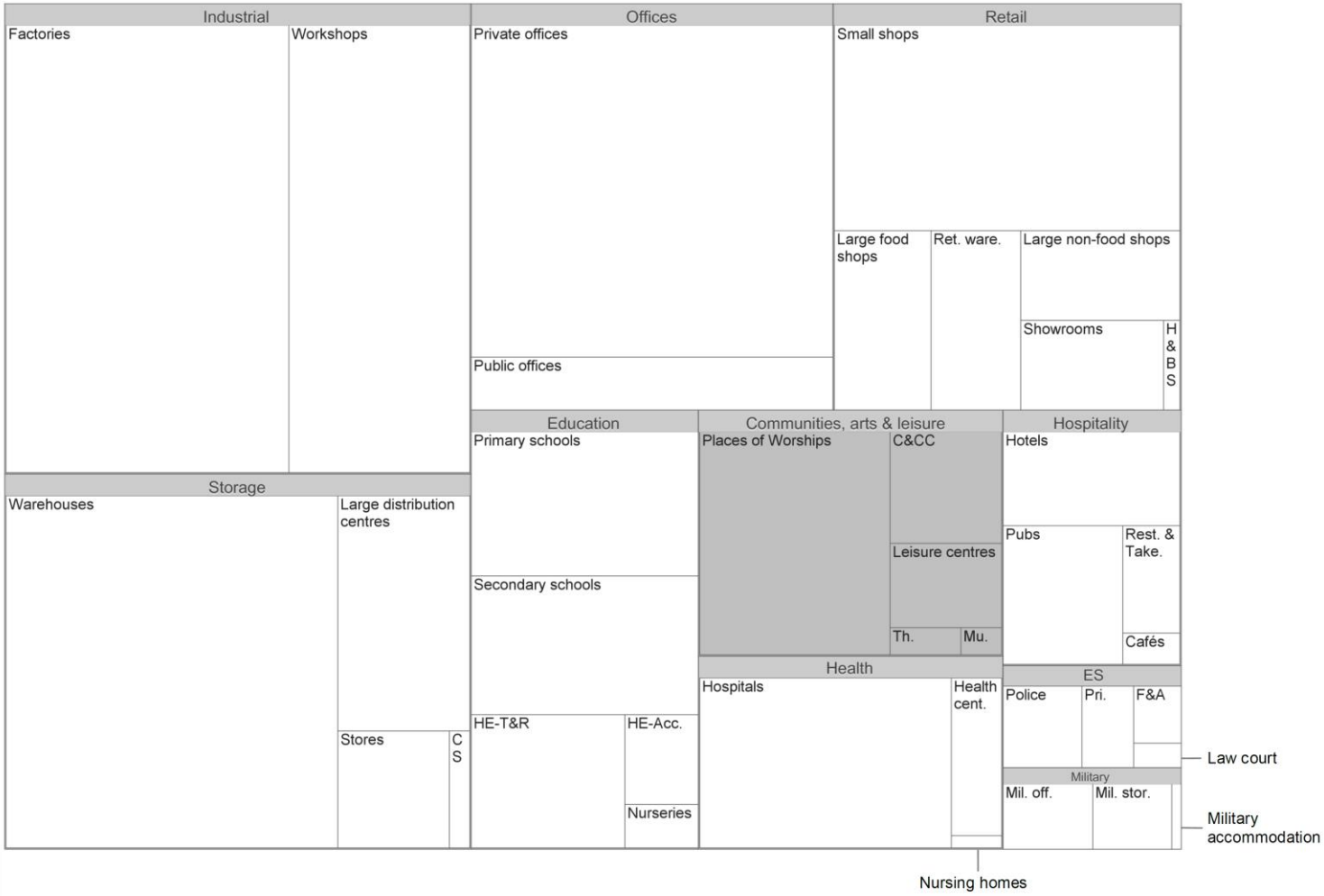
ID	Sub-sector
H&BS	Hairdressing & beauty salons
Show.	Showrooms
Ret. ware.	Retail warehouses
LFS	Large food shops
LN-FS	Large non-food shops
C&CC	Clubs & community centres
LC	Leisure centres
Mu.	Museums, Art galleries and Libraries
Th.	Theatres, cinemas and concert halls
Nurs.	Nurseries
SS	Secondary 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

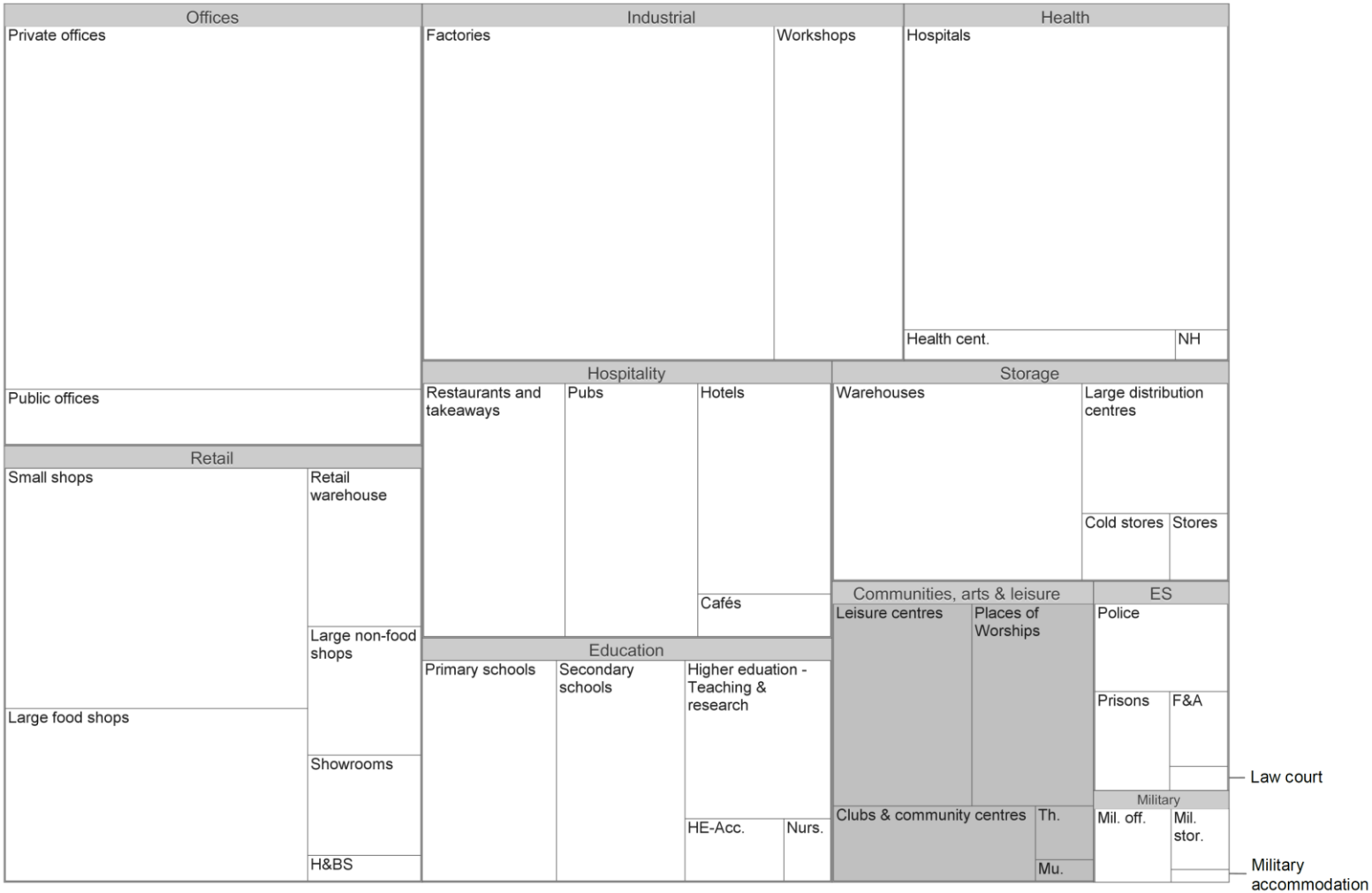
ID	Sub-sector
Ret. ware.	Retail warehouse
H&BS	Hairdressing & beauty salons
CS	Cold stores
HE-T&R	HE—Teaching and research
HE-Acc.	HE — Accommodation
C&CC	Clubs & community centres
LC	Leisure centres
Th.	Theatres, cinemas and concert halls
Mu.	Museums, Art galleries and Libraries
Health cent.	Health 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 gal-leries 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 community, arts & leisure sector

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

Community, arts & leisure premises varied greatly in size and complexity from small community centres and churches to large museums and cinemas. Some of the premises in the sector were simple, such as places of worship. These tended to have only minimal heating and lighting systems. Other sub-sectors were more complex, such as museums, art galleries and cinemas. These sub-sectors have extensive, customised heating and cooling systems designed to provide close control of conditions and cope with highly variable numbers of visitors.

Each sub-sector had a very different profile of core activities. Leisure premises provided spaces for sporting activities supported by changing areas, bars, catering facilities and office space. Arts premises were comprised of performance and/or exhibition space, although storage areas, customer rest facilities, catering and bar facilities were also common. Community centres were a varied sub-sector, with some premises being mainly providing cafe/bar facilities, some offering learning spaces such as classrooms, while others were halls for hire with kitchen facilities. Places of worship were predominantly made up of worship areas, although many included residential facilities and other facilities such as community halls and cafes. The clubs sub-sector was a mixture of social clubs and institutions; the majority were social clubs consisted primarily of bar and entertainment spaces supported by kitchens, storage, and staff & customer rest facilities.

In terms of energy end uses, swimming pools, saunas and tanning salons were common uses in leisure centres; whereas cooled storage for bar and cellar equipment was a common end use in theatres and clubs. Entertainment equipment including projectors, sound systems and stage lighting were all common uses in the theatres sub-sector (which includes cinemas, conference centres and concert halls).

Summary statistics for the community, arts & leisure sector

A number of standard characteristics for the community, arts & leisure 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. The key characteristics for the community, arts & leisure sector and how these vary across the 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 communities, arts & leisure sector all had very different characteristics reflecting the diverse nature of this sector.

The organisation size of community, arts & leisure sector premises was tailored by sub-sector to improve their relevance. Where organisation size was not defined based on total employee numbers the bandings are shown in Table 1.2.

Table 1.2: Organisation size tailoring by sub-sector

Sub-sector	Leisure centres	Clubs & Community centres	Places of worship
Organisation size	Leisure centres not asked about their organisation size	Community centres not asked about their organisation size	What is the maximum number of people the building can accommodate in normal use?
Micro	Not applicable	Not applicable	Not used
Small	Not applicable	Not applicable	Less than 50
Medium	Not applicable	Not applicable	50-249
Large	Not applicable	Not applicable	250 or more

Table 1.3 shows in terms of premises size, community, arts & leisure sub-sectors were mostly based in premises that had a floor area of greater than 1,000 m^2 e.g. leisure centres (96 per cent), theatres (95 per cent), museums (93 per cent). The sub-sectors with smaller premises were clubs & community centres and places of worship in which 86 per cent and 51 per cent of premises had floor areas of less than 1,000 m^2, respectively.

The majority of the premises in the community, arts & leisure sector were owner occupied. This was the case, at a sub-sector level, for places of worship (95 per cent), museums (85 per cent) and clubs & community centres (81 per cent). The only sub-sector where leased premises were common was leisure centres, where 55 per cent of floor area is leased.

In terms of energy management, the extent to which an organisation proactively managed energy there were two clearly different groups across the sub-sectors. Clubs & community centres and places of worship tended to have lower ambition, whilst leisure centres, museums and theatres had higher ambition levels. 79 per cent, 71 per cent and 67 per cent of theatres, museums and leisure centres respectively were 'actively seeking new ways to reduce energy use'. This compared to 50 per cent in clubs & community centres and 33 per cent in places of worship.

In terms of building age museums, clubs & community centres and places of worship and theatres were often based in buildings that were constructed prior to 1900 (42 per cent, 42 per cent and 29 per cent respectively). A large proportion of leisure centres were constructed after 1991 (45 per cent). Theatres had buildings across each of the age bandings.

Premises in all sub-sectors were most likely to occupy a whole building (92 per cent of the sector floor area overall). Leisure centres and museums also reported a small number of cases where they occupied buildings on multiple building sites.

Short operating hours were common in places of worship and museums (78 per cent and 44 per cent and respectively had peak operating hours[9] of less than 8 hours). Leisure centres typically had the longest peak operating hours, with 30 per cent having peak operating hours between 15 to 23 hours per day. Theatres and clubs & community centres tended to have peak operating hours between 9 to 15 hours per day (50 per cent and 48 per cent respectively). It is worth noting that within clubs & community centres, clubs tended to have longer hours whilst community centres operated less intensively.

[9] 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: Range of building and premises characteristics by community, arts & leisure sub-sector by percentage of floor area, 2014–15

Column percentages

	Community, arts & leisure sub-sector					
	Leisure centres (%)	Clubs & Community centres (%)	Museums (%)	Theatres (%)	Places of worship (%)	**Community, arts & leisure sector (%)**
Organisation size[10]						
Micro (0-9)	-	47	4	6	13	8
Small (10-49)	-	18	6	10	5	4
Medium (50-249)	-	-	35	54	31	47
Large (250+)	-	1	54	29	20	21
Don't know	-	1	1	1	-	0
Not asked	100	33	-	-	30	20
Total floor area (m^2)						
Less than 50	-	-	-	-	-	-
50-99	-	-	-	-	-	-
100-249	1	12	1	-	6	7
250-499	2	31	1	1	21	19
500-999	1	44	5	4	24	23
1,000-4,999	85	14	23	32	32	36
5,000-9,999	11	-	55	21	0	3
10,000+	0	-	14	41	17	12
Tenure						
Owned	38	81	85	67	95	84
Leased	55	19	15	33	5	15
Don't know	7	-	-	-	-	1

[10] Respondents were asked to indicate their organisation size based on the number of staff employed by the organisation as a whole, both in the UK and overseas.

Table 1.3 continued

	Community, arts & leisure sub-sector					
	Leisure centres (%)	Clubs & Community centres (%)	Museums (%)	Theatres (%)	Places of worship (%)	**Community, arts & leisure sector (%)**
Energy management ambition[11]						
Active	67	50	71	79	33	43
Passive	32	47	29	21	59	51
None	1	4	0	0	9	6
Don't know	0	0	0	0	0	0
Age of building						
Pre-1900	3	42	42	29	58	46
1900-1939	2	13	11	16	11	10
1940-1985	18	29	34	31	25	25
1986-1990	8	2	1	10	0	2
1991-2006	45	4	7	13	4	10
2007 or later	7	4	4	1	1	2
Don't know	17	6	0	0	2	5
Building structure						
Part of building	11	9	15	9	6	7
Whole building	86	91	75	82	94	92
Multiple buildings	3	0	10	8	0	1
Peak operating hours[12]						
8 or less	13	42	44	39	78	61
9-15	50	48	46	50	8	23
16-23	30	2	9	7	1	5
24	0	0	0	0	0	0
Don't know	0	4	1	2	9	7
Not asked	6	4	0	2	4	4

[11] '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".

[12] 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

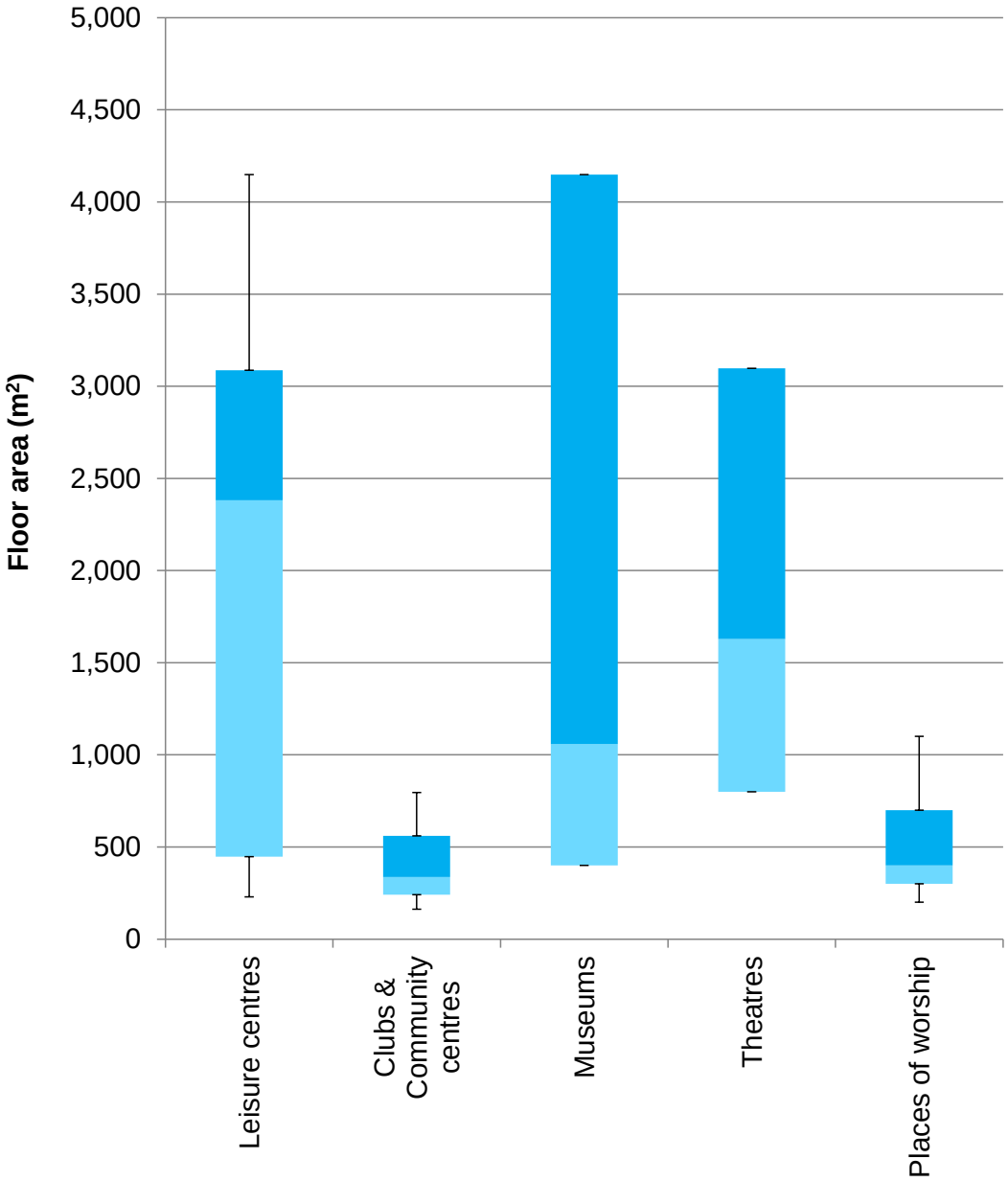
	Community, arts & leisure sub-sector					
	Leisure centres (%)	Clubs & Community centres (%)	Museums (%)	Theatres (%)	Places of worship (%)	**Community, arts & leisure sector (%)**
Opening hours[13]						
8 or less	2	19	20	53	9	38
9-15	29	52	58	28	52	34
16-23	59	16	12	5	34	16
24	3	5	9	1	1	2
Don't know	0	4	1	10	2	7
Not asked	6	4	-	3	2	*4*
Unweighted base	*77*	*96*	*41*	*46*	*91*	*351*

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

[13] 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 leisure centres (2,380 m^2) had the largest median floor area, followed by theatres (1,630 m^2) and museums (1,060 m^2). The distribution of floor area sizes for museums was much wider than for other sub-sectors, with the central 50 per cent of records having floor areas between 400 m^2 to 4,150 m^2 (this was 800-3,100 m^2 in theatres and 450-3,090 m^2 in leisure centres).

Figure 1.4: Premises size by community, arts & leisure sub-sector, 2014–15

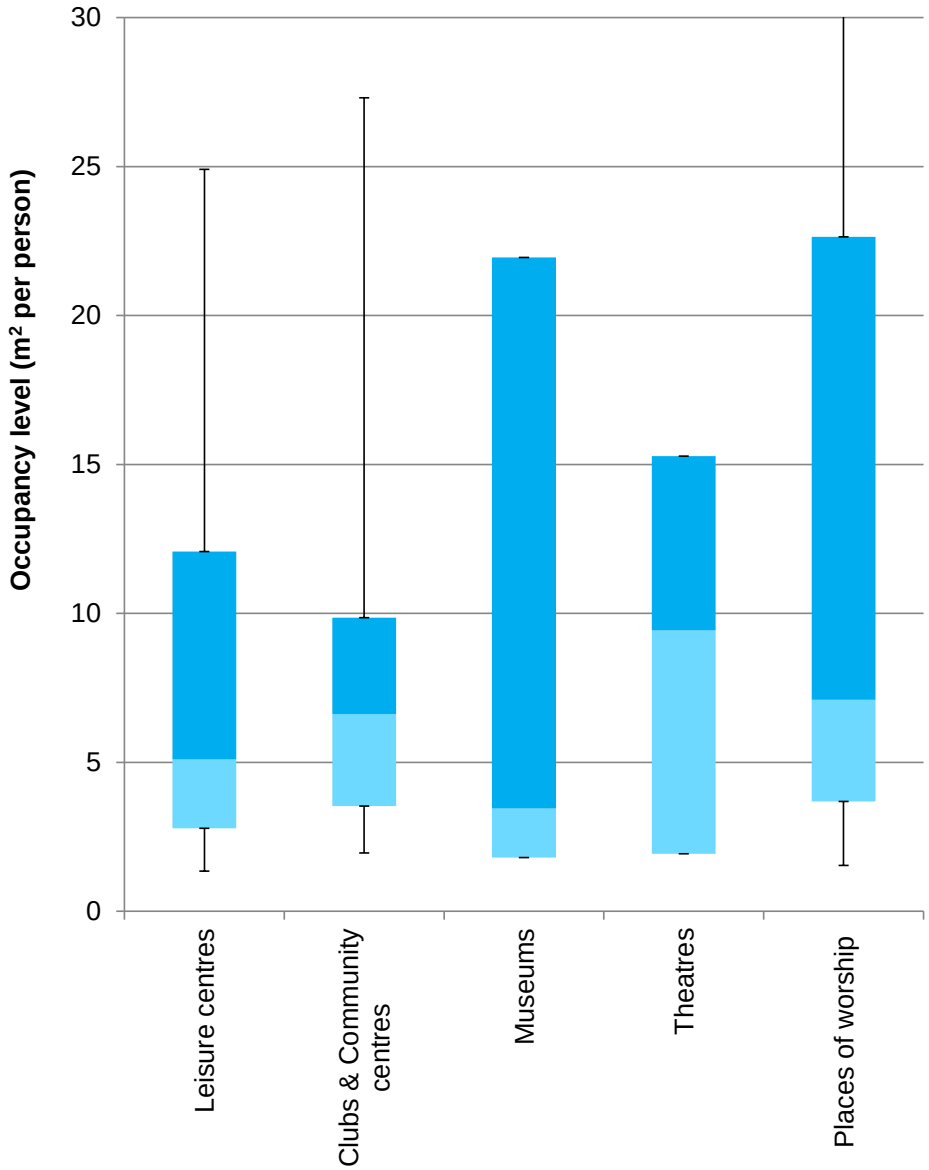


Note: In box and whisker plots, the blue columns, when combined, indicate the range of floor areas covered by the interquartile range of results (the middle 50 per cent of data points). The upper black bars extend to the 90th percentile, capturing a further 15 per cent of the total number of data points. The lower black bars span to the 10th percentile, also capturing 15 per cent of the total number of data points. Therefore within each sub-sector, 80 per cent of the total number of data points are displayed, with the outlying maxima and minima (10 per cent of data points each) excluded. For series with fewer than 50 data points, the black bars are excluded.

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[14]. Theatres showed the lowest occupancy level of 7 m^2 per person. This was followed by a median of 7 m^2 per person in both places of worship and clubs & community centres.

Figure 1.5: Occupancy level (floor area per staff and visitor number) by community, arts & leisure sub-sector, 2014—15



Note: In box and whisker 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). The upper black bars extend to the 90th percentile, capturing a further 15 per cent of the total number of data points. The lower black bars span to the 10th percentile, also capturing 15 per cent of the total number of data points. Therefore within each sub-sector, 80 per cent of the total number of data points are displayed, with the outlying maxima and minima (10 per cent of data points each) excluded. For series with fewer than 50 data points, the black bars are excluded.

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

[14] 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 community, arts & leisure sector.

Greater detail on the BEES methodology in relation to the community, arts & leisure 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 community, arts & leisure 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;[15]
- 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.[16]

The first two objectives are addressed in this and other sector 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 buildings 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 was performed at sub-sector level with bespoke questionnaires and modelling assumptions used at this level.

During the analysis process a number of sub-sectors were retrospectively merged, as it became apparent that some sub-sectors shared common characteristics in terms of building type and energy profile. Clubs and community centres were originally modelled as two separate sub-sectors which were amalgamated retrospectively. Leisure centres with swimming pool facilities and leisure centres without swimming pool facilities were also modelled separately and later merged. For each of these four affected sub-sectors, the underlying analysis was based on different questionnaires and a different set of modelling assumptions. Finally, nursing homes were originally included within the community, arts & leisure sector, before being retrospectively moved to the health sector[17].

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[15] 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.

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

[17] Analysis for the nursing homes sub-sector can be found in the associated BEES report for the health sector.

The study generated a database of 3,690 records. Each record may represent an entire building or premises within a larger building. The findings in this report are based on data collected for the community arts & leisure sector through 351 telephone surveys and 32 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 building.

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[18]. Using the Experian references in ND-NEED it was possible to add a contact telephone number. Analysis shows that the coverage of BEES included 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 building, 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, and 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 building). 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

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

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 community, arts & leisure sector, a total of 386 telephone survey or equivalent records were collected – following the record exclusion process a total of 351 records were retained for analysis. In this sector the share of records excluded was low (9 per cent of total), as the proportion of 'Don't know' responses, considered to indicate record reliability, was also low.

4. Secondly, record amendment was conducted on the remaining data. The remaining 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[19].
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.[20]
    - 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 community, arts & leisure sector is covered in "Methodology challenges in the community, arts & leisure 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.

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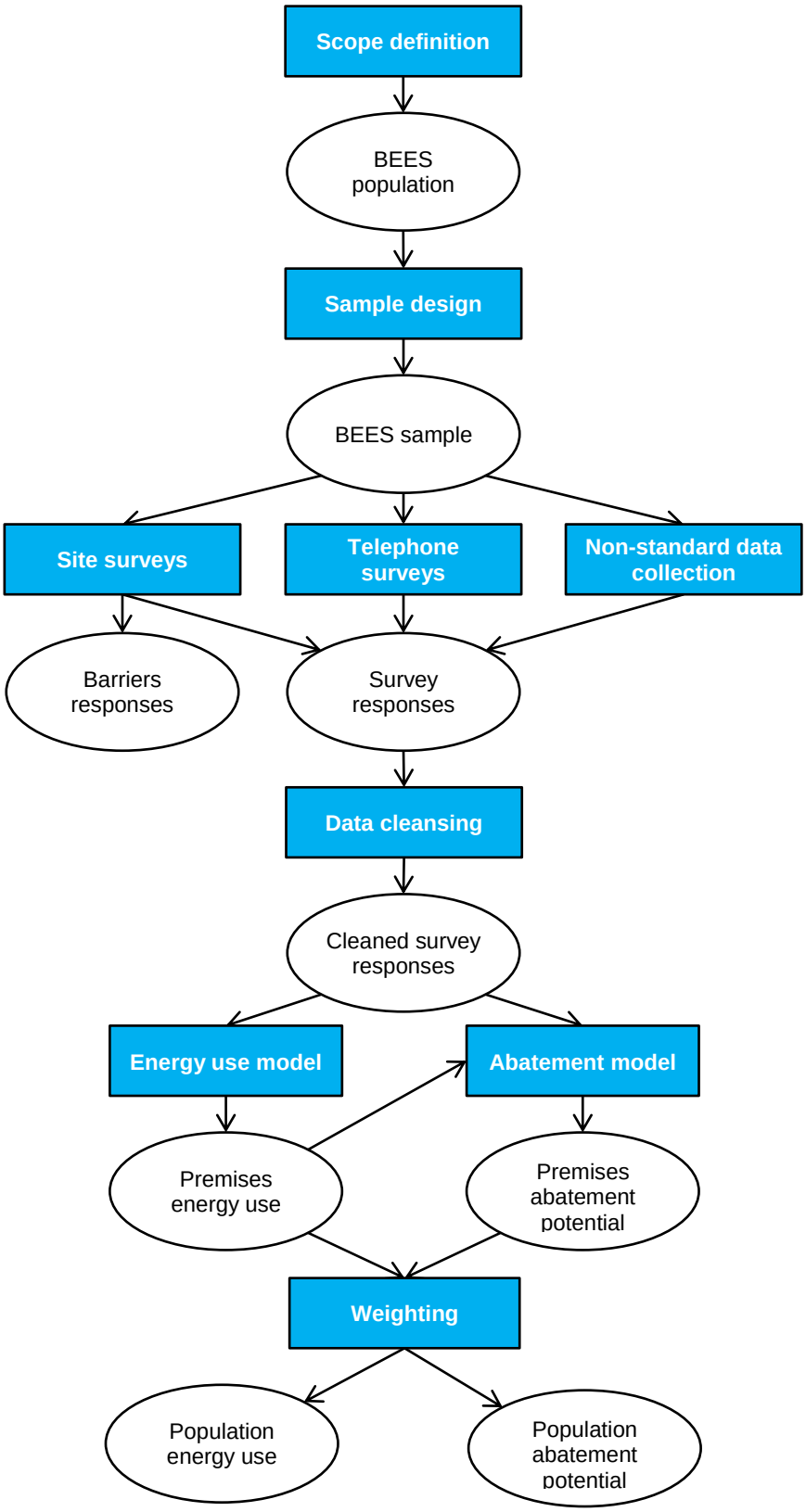
[19] For example, in one sub-sector a small number of respondents gave a 'Don't know' response to the question "Do you use electricity to heat tap water and/or showers and if so how much?". The vast majority of responses to within the sub-sector were 'None', so this was used as a proxy as it was deemed 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.

[20] 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 community, arts & leisure sector

For community, arts & leisure sub-sectors the BEES methodology was implemented as envisaged. There were however overarching complications, which needed to be accounted for during planning.

A summary of the key issues encountered in the sector, as selected by the project team, is set out below and a full description of these and other less significant issues is included in Appendix B:

- **Design** No comprehensive, reliable sampling frame incorporating floor area data was available for places of worship. In order to proceed in this sub-sector, the sampling frame had to be derived from multiple sources of data, including the Experian database. The respondent was also required to provide an estimate of the premises floor area during the telephone survey. The lack of a reliable floor area therefore also affected the energy use calculation for the premises and the ability for the team to calibrate the models. As a result the sub-sectors total floor area and premises level total consumption for this should be treated with caution.
- **Data collection** In a number of sub-sectors there was a high reliance on volunteers i.e. places of workshop and clubs & community centres. In these sub-sectors the telephone survey respondents may have been reasonably transient, could have had limited understanding of the energy usage attributes in the premises and were unlikely to have a strong level of knowledge regarding energy management. As a result the survey was simplified and also the quality of the responses may tend toward being less accurate.
- **Data collection** In the theatres sub-sector, none of the major cinema chains chose to participate in the study. Cinemas were under-represented as a result. This will have led to a bias in the sample for this sub-sector.
- **Data processing** Complex or specialist energy uses were present in a number of sub-sectors. These included swimming pools, stage lighting, audio visual equipment and specialist servicing and lighting arrangements for museum and gallery exhibits. These energy uses were reasonably uncommon across the non-domestic stock and presented a considerable challenge for energy and abatement modelling. A combination of site survey insight, benchmarking information and engineering judgement was required in order to account for these specialist energy uses. This means that there is less confidence in these end-uses than for the more standard end-uses.
- **Data processing** Uptake of site surveys was limited in clubs & community centres, and theatres. This reduced the extent to which modelling assumptions could be verified, reducing confidence in the energy use model outputs, particularly in relation to specialist end uses. Of the end uses affected, the most material are swimming pool consumption in leisure centres, and catering consumption across the sub-sectors.

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 community, arts & leisure sector.

Energy consumption and greenhouse gas emissions in the community, arts & leisure sector

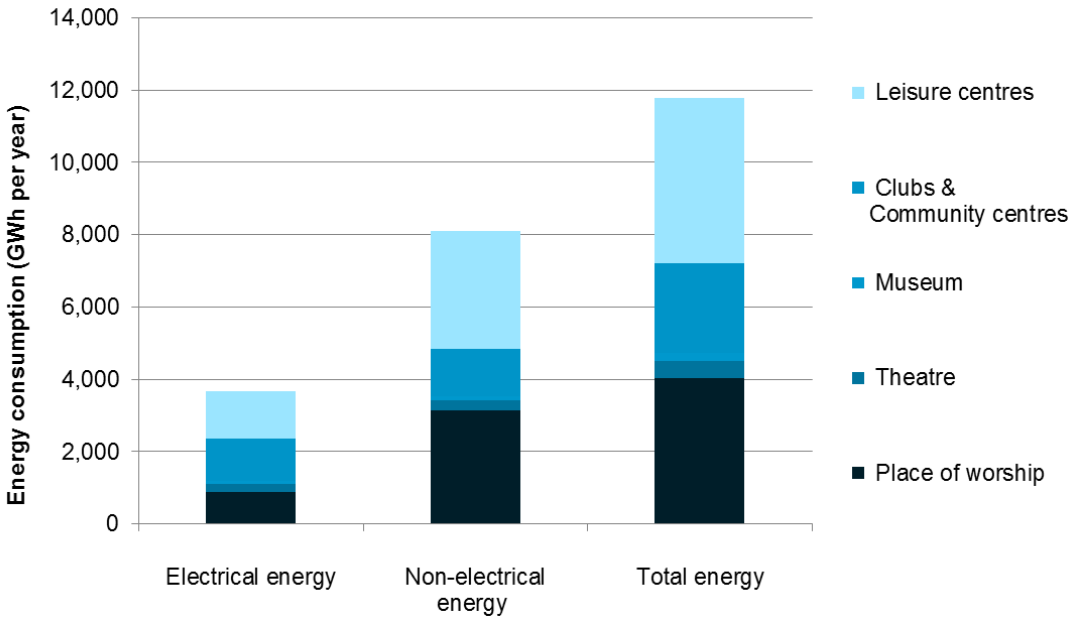
The electrical and non-electrical energy consumption of the community, arts & leisure sector is presented in Figure 3.1, broken down by the five community, arts & leisure sub-sectors (leisure centres, clubs & community centres, museums, theatres and places of worship).

The community, arts & leisure sector consumed 11,790 GWh of energy. This consisted of 3,680 GWh of electrical energy and 8,110 GWh of non-electrical energy per year (Figure 3.1).

The largest energy consumer in this sector was leisure centres with a consumption of 4,590 GWh of energy (39 per cent of sector total). This was split between 1,330 of electrical energy (36 per cent of sector total) and 3,260 GWh of non-electrical energy (40 per cent of sector total). This was despite the fact that this sub-sector was not the largest in the community, arts & leisure sector (8 million m^2 for leisure centres compared with 37 million m^2 for places of worship and 8 million m^2 for clubs).

Places of worship were the second largest consumer in the sector, with 4,020 GWh of energy (34 per cent of sector total). This was comprised of 880 GWh of electrical energy consumption (24 per cent of sector total) and 3,140 GWh of non-electrical energy consumption (39 per cent of sector total). Museums were the smallest consumer in the sector with 200 GWh of energy consumption, which was split into 110 GWh of electrical energy (3 per cent of sector total) and 100 GWh of non-electrical energy (1 per cent of sector total).

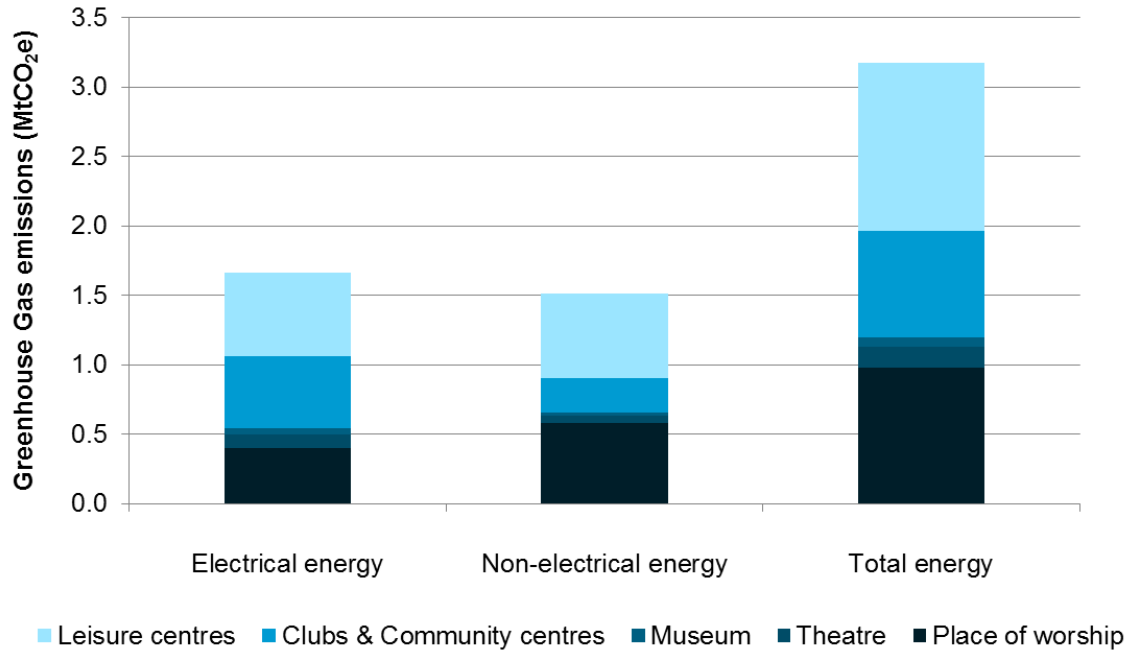
Figure 3.1: Electrical and non-electrical energy consumption by energy type and community, arts & leisure sub-sector, 2014–15



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

The greenhouse gas emissions for the community, arts & leisure sector are presented in Figure 3.2.[21] The total greenhouse gas emissions from the community, arts & leisure sector were estimated to be 3.2 $MtCO_2e$ per year. The annual emissions from electrical energy consumption were 1.7 $MtCO_2e$ and those from non-electrical energy consumption were 1.5 $MtCO_2e$.

Figure 3.2: Greenhouse gas emissions by energy type and by community, arts & leisure sub-sector, 2014–15



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

Energy consumption by end use

The total energy consumption by end use is presented in Figure 3.3 and Table 3.1. [22]

The energy use model defined 23 separate energy end uses in its analysis. These were derived by modelling the telephone survey inputs and were 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 ‘pool/leisure’). 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.

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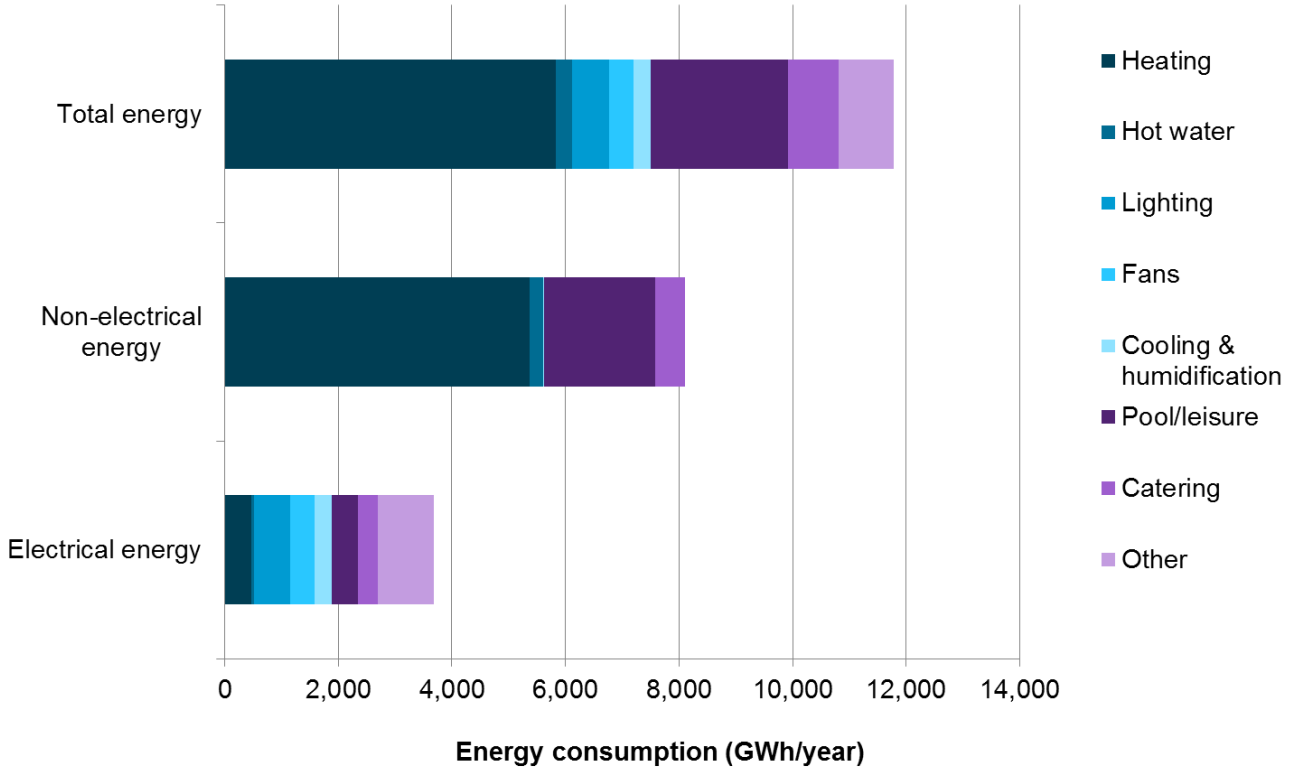
[21] Greenhouse gas emissions were estimated using energy consumption figures from the energy use model and grid average electricity and fuel emission factors from IAG guidance on valuing greenhouse gas emissions published by DECC, updated on 10 December 2015. See https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for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

[22] In the context of the BEES study, small power represents office equipment (comprising computers, printers and ancillary desktop equipment). Other plug-in loads are disaggregated into entertainment equipment, catering, pool/leisure equipment etc.

The total energy consumption for the community, arts & leisure sector was 11,790 GWh. The most significant end use was space heating (5,820 GWh, 49 per cent of total), followed by pool/leisure (2,420 GWh, 20 per cent). The most common end uses of electrical energy were internal lighting at 630 GWh (17 per cent of total), followed by cooled storage (490 GWh, 13 per cent), which accounts for around half of the 'other' category in Figure 3.3. The most significant non-electrical energy end uses were space heating at 5,360 GWh (66 per cent) followed by pool/leisure (1,970 GWh, 24 per cent).

Figure 3.3: Energy consumption by simplified end use breakdown for the community, arts & leisure 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 community, arts & leisure sector, 2014–15[23]

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	460	5,360	5,820
Hot water	Hot water	50	250	300
Lighting	Lighting - internal	630	-	630
Fans	Fans	430	-	430
Cooling & humidification	Space cooling	310	3	310
Pool/leisure	Pool/leisure	450	1,970	2,420
Catering	Catering	360	520	880
Other	Controls	70	-	70
	Cooled storage	490	-	490
	Entertainment equipment	20	-	20
	ICT equipment	10	-	10
	Laundry	6	-	10
	Lighting - display	10	-	10
	Lighting - external	130	-	130
	Medical equipment	-	-	-
	Pumps	90	-	90
	Small power	50	-	50
	Vertical transport	30	-	30
	Other	100	-	100
Total		**3,680**	**8,110**	**11,790**
Unweighted base		*351*	*325*	*351*

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

Community, arts & leisure 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 3.5, Figure 3.5 and Figure 3.6 present the distribution of energy intensity for all modelled records in each sub-sector within the community, arts & leisure sector, in terms of total energy intensity, electrical energy intensity and non-electrical energy intensity respectively.[26] In this report all

[23] In the context of the BEES study, small power represents office equipment (comprising computers, printers and ancillary desktop equipment). Other plug-in loads are disaggregated into entertainment equipment, catering, pool/leisure equipment etc.

[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.

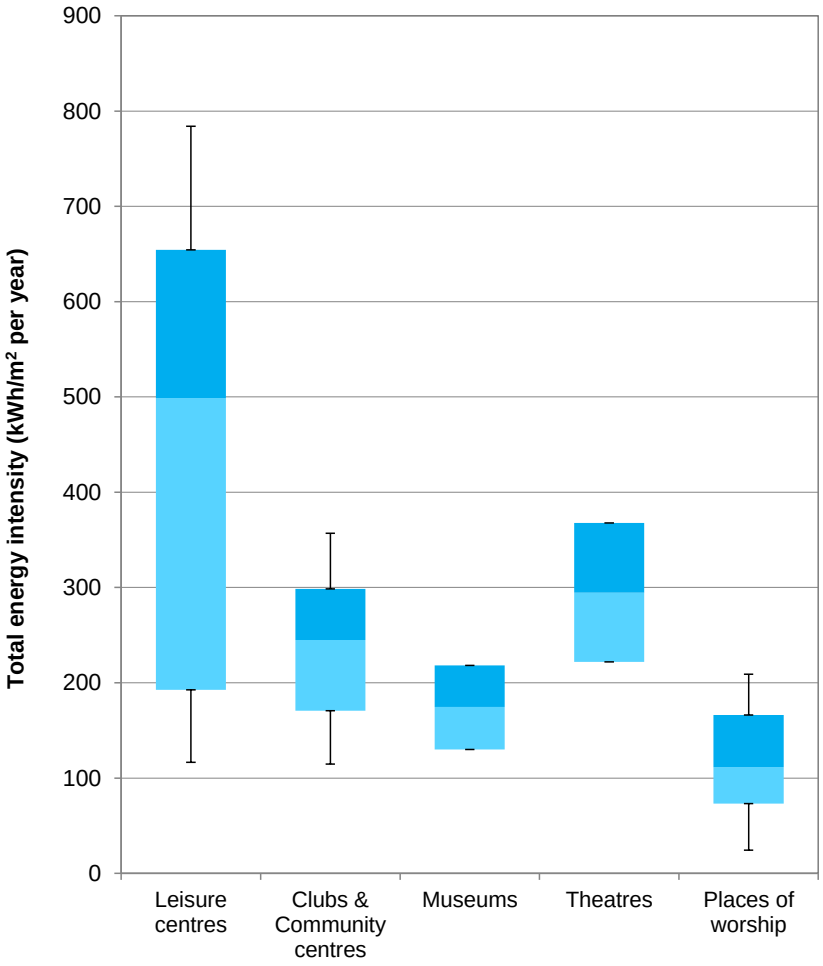
[26] Please note mean energy intensities are calculated by summing the total consumption associated with an end use and dividing it by the sub-sectors total floor area. The energy intensities for non-electrical uses are therefore based on the total population and do not make an allowance for where the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

intensity figures (excluding box plots) have been 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 leisure centres displayed the largest median energy intensity (499 kWh/m^2), followed by theatres (295 kWh/m^2) and clubs & community centres (245 kWh/m^2).

Figure 3.5 and Figure 3.6 shows that leisure centres typically displayed the highest median electrical energy intensity (153 kWh/m^2 for electrical energy). The second most energy intensive sub-sector in terms of electrical energy was theatres (102 kWh/m^2). Leisure centres displayed the highest median non-electrical energy intensity of 349 kWh/m^2, followed by theatres (193 kWh/m^2).

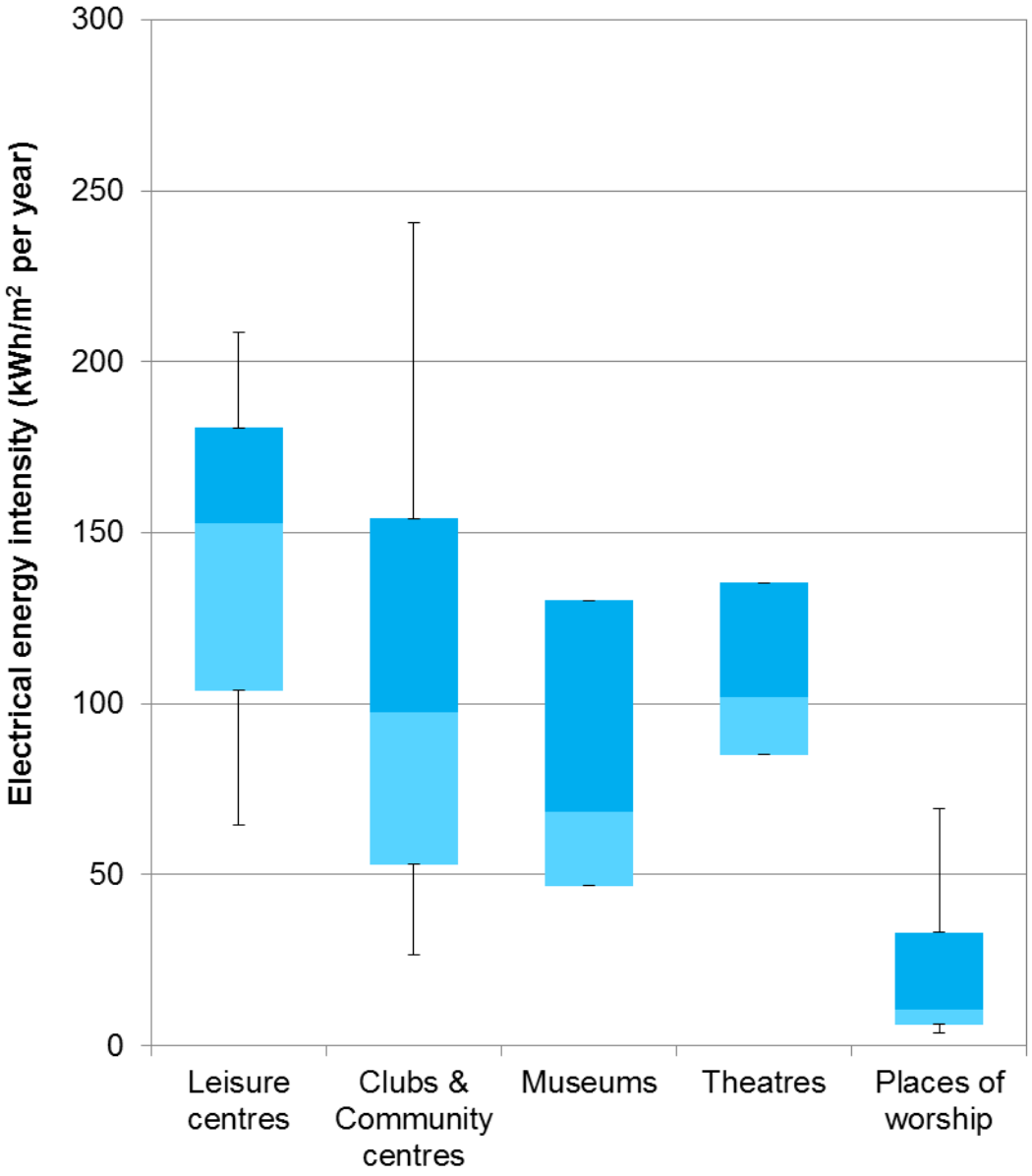
Figure 3.4: Distribution of total energy intensity by community, arts & leisure sub-sector, 2014—15



Note: In box and whisker 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). The upper black bars extend to the 90th percentile, capturing a further 15 per cent of the total number of data points. The lower black bars span to the 10th percentile, also capturing 15 per cent of the total number of data points. Therefore within each sub-sector, 80 per cent of the total number of data points are displayed, with the outlying maxima and minima (10 per cent of data points each) excluded. For series with fewer than 50 data points, the black bars are excluded.

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

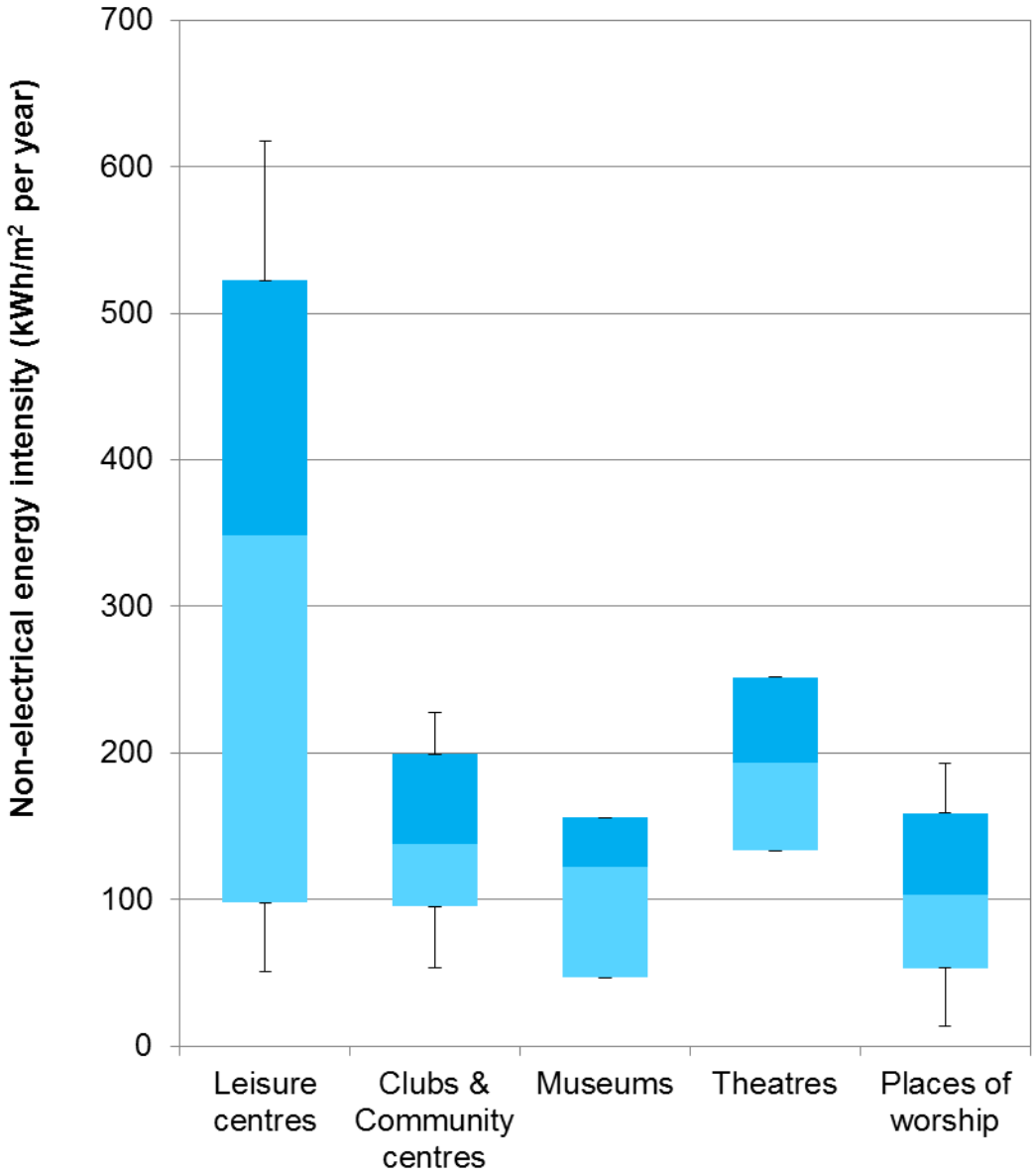
Figure 3.5: Distribution of electrical energy intensity by community, arts & leisure sub-sector, 2014—15



Note: In box and whisker 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). The upper black bars extend to the 90th percentile, capturing a further 15 per cent of the total number of data points. The lower black bars span to the 10th percentile, also capturing 15 per cent of the total number of data points. Therefore within each sub-sector, 80 per cent of the total number of data points are displayed, with the outlying maxima and minima (10 per cent of data points each) excluded. For series with fewer than 50 data points, the black bars are excluded.

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

Figure 3.6: Distribution of non-electrical energy intensity by community, arts & leisure sub-sector, 2014—15



Note: In box and whisker 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). The upper black bars extend to the 90th percentile, capturing a further 15 per cent of the total number of data points. The lower black bars span to the 10th percentile, also capturing 15 per cent of the total number of data points. Therefore within each sub-sector, 80 per cent of the total number of data points are displayed, with the outlying maxima and minima (10 per cent of data points each) excluded. For series with fewer than 50 data points, the black bars are excluded.

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

Community, arts & leisure sub-sector energy end use breakdowns

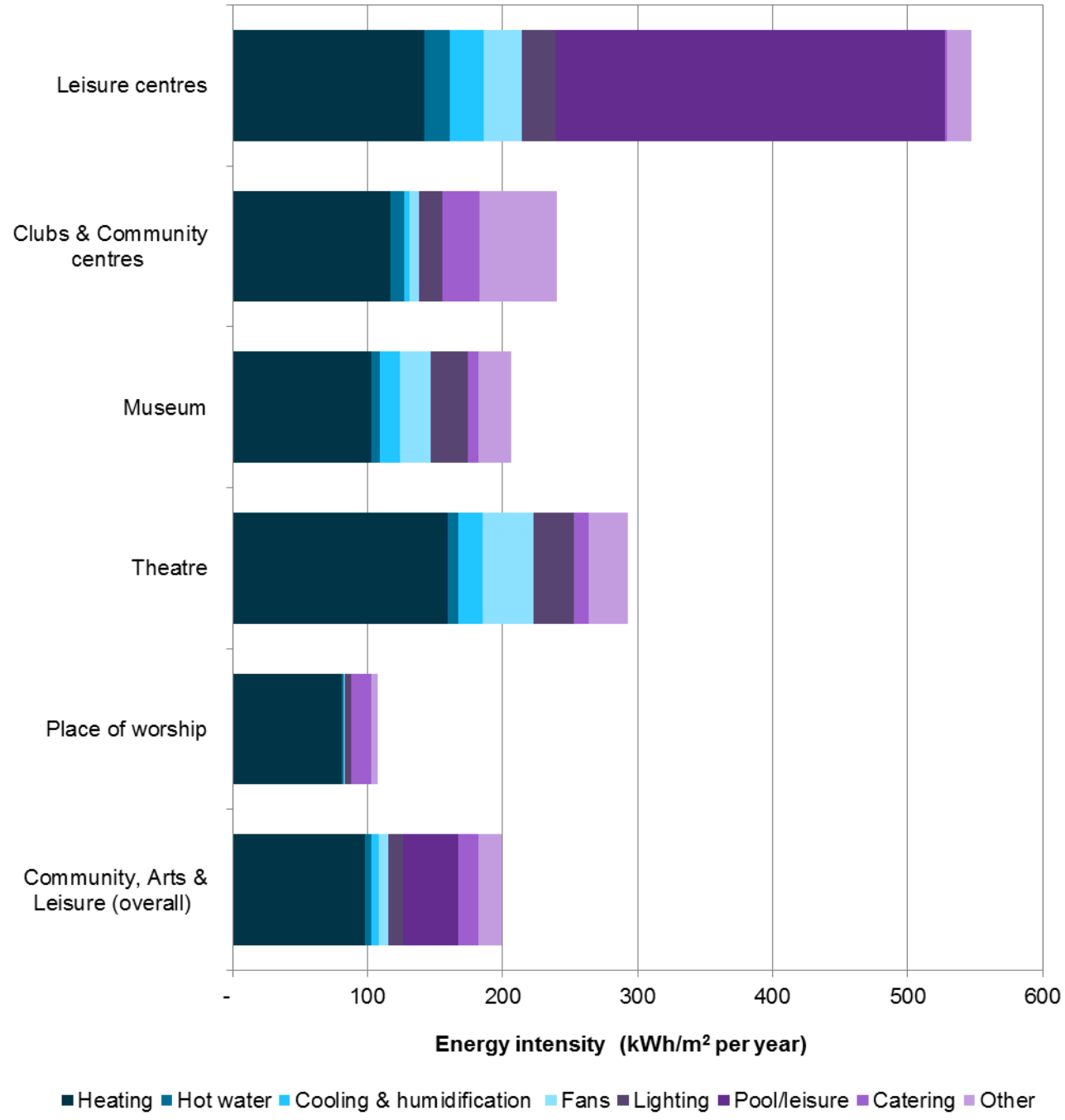
Figure 3.7 shows the mean modelled energy intensity by end use for each of the sub-sectors in the community, arts & leisure sector. Further data is provided in Appendix C where energy consumption and energy intensity is provided separately for electrical and non-electrical energy end use breakdowns by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

Heating energy consumption was the largest contributor to the sector's energy intensity. In theatres, heating intensity was high due to high ceiling spaces in auditoria. Leisure centres also feature high heating intensity; they tend to have long hours of use, and wet changing areas which are heated to a high temperature with extensive ventilation. Hot water energy intensity is considerable in leisure centres, driven by showers and washing.

Despite only occurring in one sub-sector, pool/leisure energy use was significant in the sector overall. This end use includes all the energy used in swimming pool halls (including all heating, ventilation and lighting) plus energy use for other leisure activities such as saunas and gym equipment. Swimming pools were by far the largest contributor to this energy use across the sector. Catering energy intensity was also significant within the sector, especially within clubs & community centres and places of worship.

Energy use for fans and cooling was considerable in museums, leisure centres and theatres. In leisure centres mechanical ventilation is necessary for changing areas, and air conditioning was common in gymnasiums and fitness studios. Some museums and galleries have sophisticated heating and cooling systems for close control of temperature and humidity to preserve the exhibits; these systems often run 24 hours a day. At the opposite end of the spectrum, mechanical ventilation and cooling were very rare in places of worship and clubs & community centres.

Figure 3.7: Mean energy intensity simplified end use breakdowns by community, arts & leisure 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 community, arts & leisure 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. Appendix 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. This will be more expensive than end of life replacement, as the impact on energy consumption is likely to be smaller for where equipment is newer, 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 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

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[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 community, arts & leisure sector throughout England and Wales.

Total technical abatement potential for community, arts & leisure sector

The abatement potential for each sub-sector where it is available is shown in Table 4.1 and Figure 4.1 and Figure 4.2. The total abatement potential was between 38 and 50 per cent of total energy consumption[30]. Each sub-sector can achieve between 36 to 43 per cent savings in electrical energy consumption and 37 to 52 per cent savings in non-electrical energy consumption. This could be achieved at an overall capital expenditure of £2.2 billion.

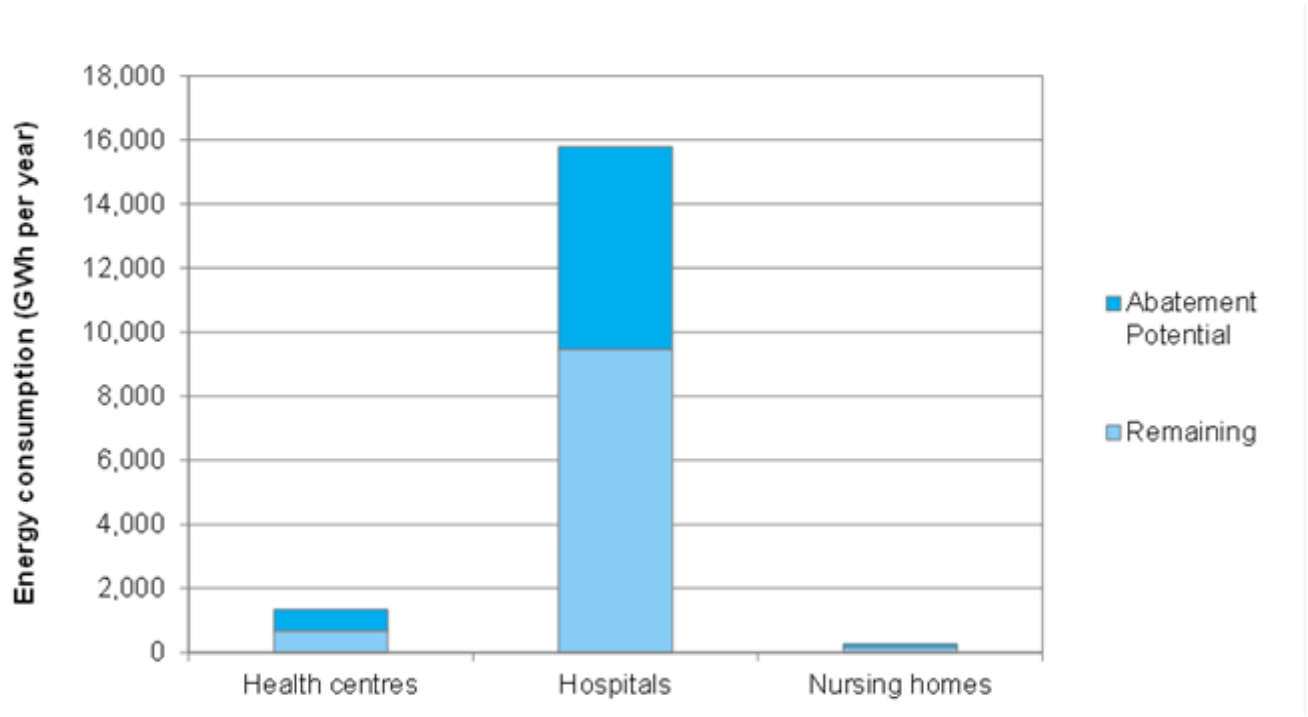
Table 4.1: Total abatement potential by community, arts & leisure sub-sector, 2014–15

		Baseline energy consumption (Energy Use model)		Total abatement potential		
Sub-sector	**Capital Expenditure required to deliver abatement potential (£ thousands)**	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)
Leisure centres	569,400	1,330	3,260	540	1,220	38
Clubs & Community centres	452,300	1,150	1,320	420	610	42
Museums	31,300	110	100	40	50	45
Theatres	59,500	210	280	80	120	40
Places of worship	1,131,000	880	3,140	380	1,630	50
Total	**2,243,400**	**3,680**	**8,110**	**1,450**	**3,640**	**43**

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 community, arts & leisure sub-sector, 2014—15

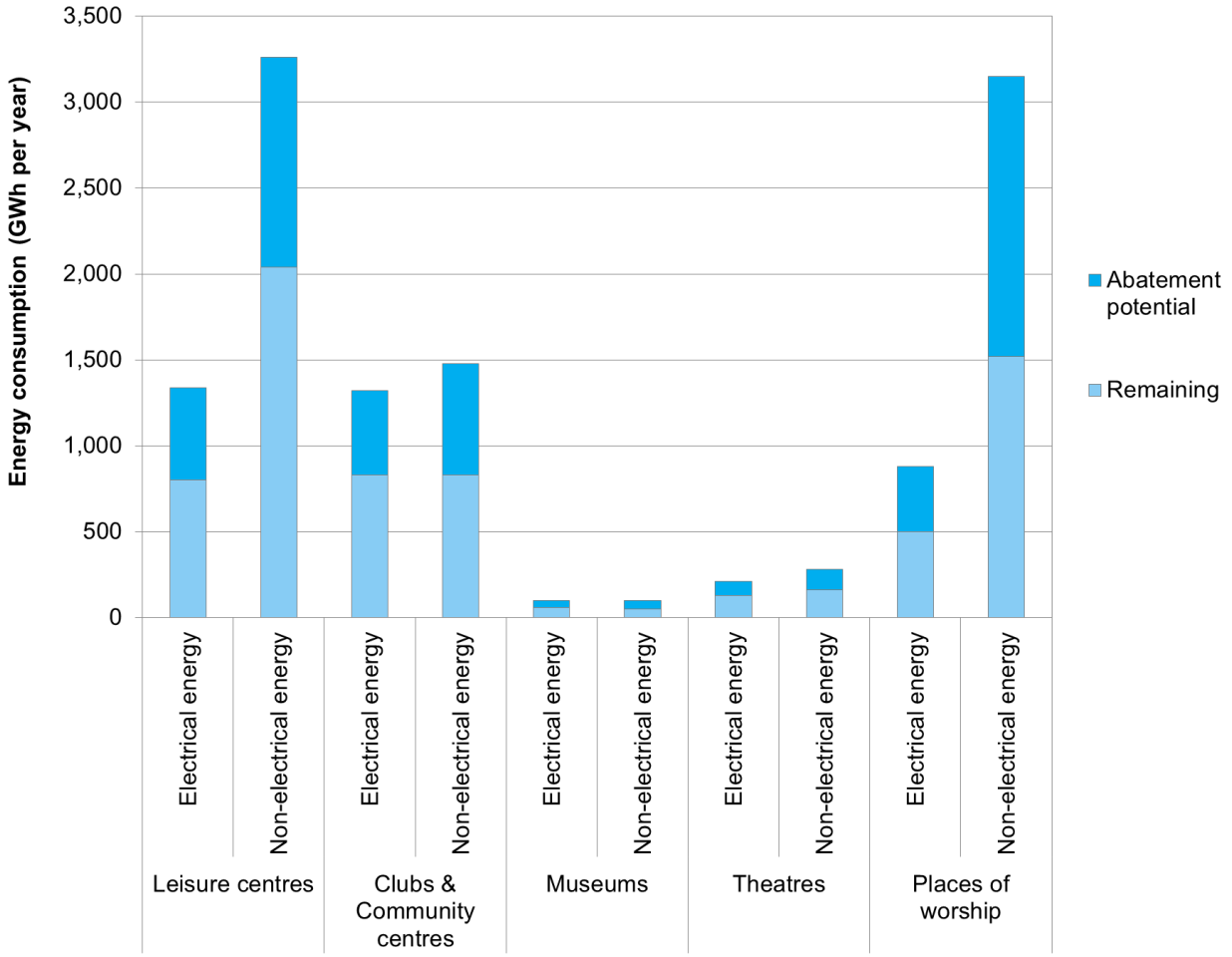


Source: Abatement model results by sub-sector, England and Wales

Figure 4.2 shows that the abatement potential varied by sub-sector: places of worship had the largest absolute and proportional scope for reduction (50 per cent of total energy consumption overall). This compared with 45 per cent in museums and 38 per cent in leisure centres. 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 is 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. Further detail of the abatement potential for each sub-sector is provided in Appendix D.

Figure 4.2: Total abatement potential by energy type and community, arts & leisure 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 850 GWh, of which 100 GWh was electrical energy consumption and 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 940 GWh, of which 260 GWh was electrical energy consumption and 690 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.

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[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

Only building instrumentation and controls were socially cost-effective when the measure group was examined at the sector level. If implemented, this measure group would provide more financial benefits to society than costs. This measure group also had a relatively low payback periods, suggesting it may be more likely to get taken up, but recognising that take-up will also depend on the extent to which there are barriers.

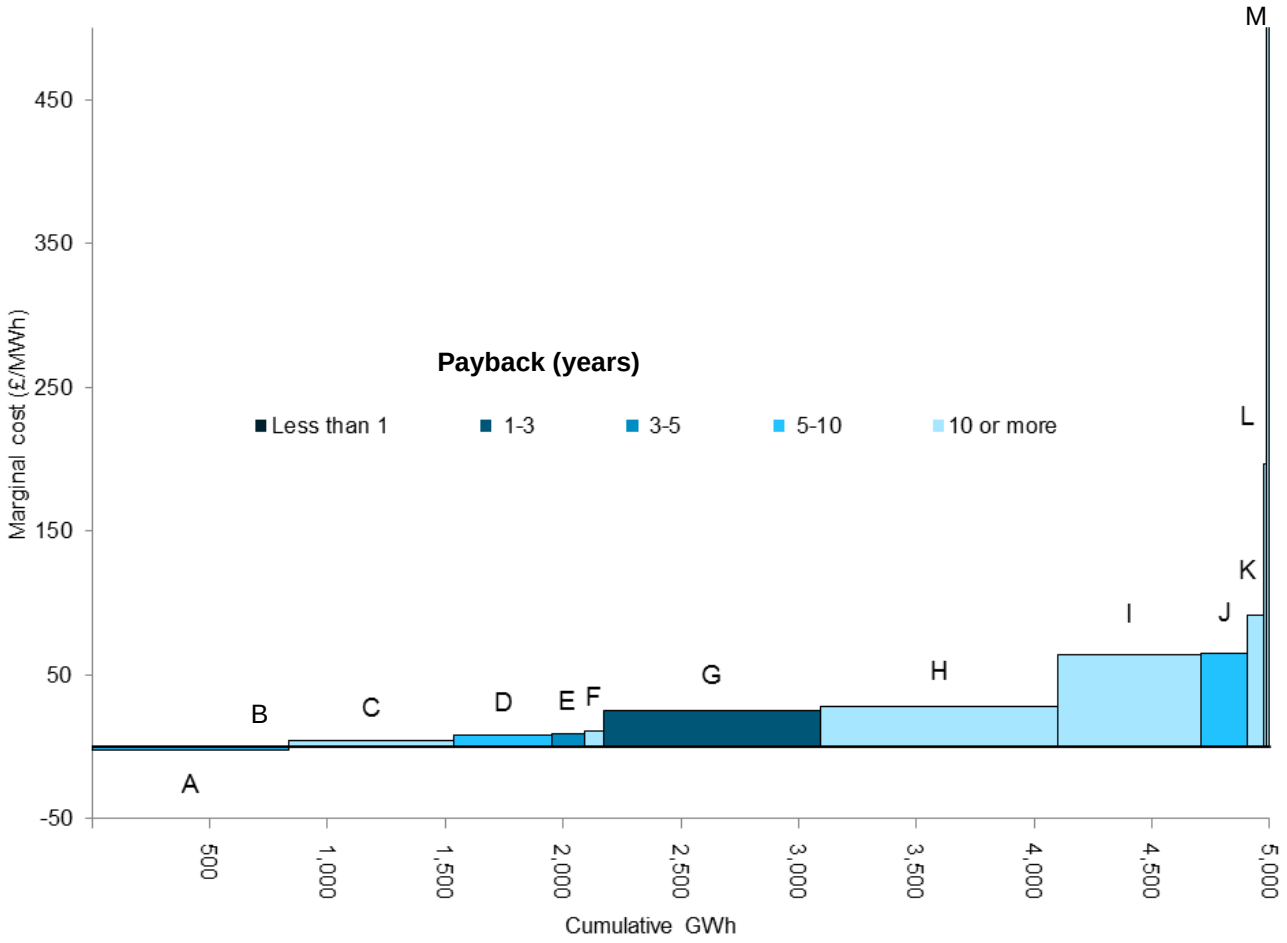
These modelled findings corresponded broadly with opportunities identified in the site surveys. Typically site surveys identified potential savings associated with space heating controls, ventilation controls, lighting upgrades and building fabric measures. It was found that in some premises the lights were often left on when rooms were not occupied, identifying savings in carbon and energy management measures.

In several premises lighting upgrades to LEDs were identified with standard fluorescent and halogen lighting still common in the sector. Controls issues were common especially with heating systems; opportunities identified included start/stop controls on boilers, systems being left in standby mode in summer, installation of weather compensation controls[32] and a review of zone controls to ensure that they are being used effectively to match how spaces are used. Opportunities for ventilation upgrades (installation of efficient motors and variable speed drives) and controls improvements were also commonly noted on site.

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. On sites with more complex heating, cooling and ventilation systems, regular review and testing of building management system sensors and controls settings was identified as an opportunity, with faulty sensors and poorly set controls identified in premises where the site contact was not aware of this.

[32] Devices which use external sensors to adjust system controls to compensate for changes in outdoor temperature automatically.

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 Building instrumentation and control [MAC: £-2 per MWh.. GWh: 850]

B Humidification [MAC: £4 per MWh.. GWh: 1]

C Building fabric [MAC: £4 per MWh.. GWh: 710]

D Lighting [MAC: £8 per MWh.. GWh: 420]

E Cooled storage [MAC: £9 per MWh.. GWh: 140]

F Hot water [MAC: £11 per MWh.. GWh: 80]

G Carbon and Energy Management [MAC: £25 per MWh.. GWh: 940]

H Space heating [MAC: £27 per MWh.. GWh: 1,020]

I Swimming pools [MAC: £64 per MWh.. GWh: 620]

J Ventilation [MAC: £65 per MWh.. GWh: 200]

K Air conditioning and cooling [MAC: £92 per MWh.. GWh: 70]

L Small appliances [MAC: £196 per MWh.. GWh: 10]

M Building services distribution systems [MAC: £730 per MWh.. GWh: 20]

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

Table 4.2 shows the abatement potential by measure type. The most significant available energy savings were associated with carbon and energy management, space heating measures and building instrumentation and control.[33]

Table 4.2: Abatement potential by measure type, 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-electri-cal energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**
Air conditioning and cooling	6,800	20	70	-	70	77,300
Building fabric	22,500	130	60	660	720	436,600
Building instrumentation and control	29,100	170	100	750	850	158,100
Building services distribution systems	2,000	6	20	-	20	97,800
Carbon and Energy Management	43,100	210	260	690	940	120,200
Hot water	2,700	20	7	80	80	33,300
Humidification	0	0	0	0	0	0
Lighting	41,200	120	420	-	420	300,900
Cooled storage	14,300	40	140	-	140	71,100
Small appliances	700	3	5	8	10	15,200
Space heating	31,800	200	80	940	1,020	494,000
Swimming pools	24,100	130	110	500	620	264,200
Ventilation	18,500	60	180	10	200	174,800
Total	**236,800**	**1,100**	**1,450**	**3,640**	**5,090**	**2,243,400**

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

[33] 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 statistics

This appendix provides summary quality statistics for the sample. The confidence intervals by sub-sector for electrical energy intensity and non-electrical energy intensity by 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)
Clubs & community centres	111	± 15
Museums	107	± 23
Leisure Centres	159	±15
Places of worship	23	± 6
Theatres	126	± 19
Community, Arts & Leisure	**62**	**± 11**

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

	Mean (kWh/m^2)	Confidence interval (kWh/m^2)
Clubs & community centres	128	± 18
Museums	100	± 23
Leisure Centres	389	± 55
Places of worship	83	± 17
Theatres	167	± 32
Community, Arts & Leisure	**137**	**± 24**

Response rates

Table A.3: Telephone survey response rates for the community, arts & leisure sector

	Leisure centres (%)	Clubs & Community centres (%)	Museums (%)	Theatres (%)	Places of worship (%)	**Community, arts & leisure sector (%)**
Completed interview	7	10	9	10	8	9
Still live[34]	64	70	55	43	55	61
Screening failure/other non-response[35]	4	0	2	3	1	2
Refusal	6	3	3	4	7	5
Other non-response	4	7	15	22	6	8
Invalid contact details	15	9	16	17	23	16

[34] 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).

[35] 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: Community, arts & leisure method challenges and data collection

This appendix provides detail of any non-standard methodology used for the community, arts & leisure sector.

Community, arts & leisure sector methodology challenges

In the case of the community, arts & leisure 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: Community, arts & leisure sector approach challenges

Stage	Challenge	Response	Impact
Design	No source dataset for floor area for places of worship.	Respondents were asked to provide an estimate of the total floor area of the building; if area not known, the equivalent number of 3-bedroom houses was asked.	Floor area data at record level much less reliable than VOA or DEC data used for other sub-sectors. As a result record level calculation of absolute energy consumption will be less accurate. The overarching floor area for the sub-sector as a whole is also based on a range of sources, of variety of ages. The findings therefore for places of worship have a lower confidence associated with them.
Data collection	In a number of sub-sectors there is a high reliance on volunteers i.e. places of workshop and clubs & community centres	The survey was simplified and tested during the pilots to ensure there was not a prohibitive number of 'Don't knows'. Findings were also validated during the site surveys to test whether there were any questions which were consistent poorly understood.	Following piloting and telephone survey simplification this had no major ongoing issue on the ability to produce energy use calculation using the records.

Stage	Challenge	Response	Impact
Data collection	Major cinema chains declined to participate in the study; only 3 cinemas responded to the telesurvey.	No further action could be taken.	Cinemas will be under-represented in the overall presentation of data for the theatres sub-sector.
Data processing	Squash courts are excluded from VOA floor area for sports centres. This was not known at the time of telephone survey drafting, and the number of squash courts was not asked.	No further action could be taken as the missing area could not be assigned correctly to the records.	Squash courts are estimated to make up in the region of 10% of floor area of sports facilities.
Data processing	Swimming pool hall servicing and energy consumption is very complex; it is beyond the capacity of the energy model to model systems discretely. It was also very challenging for site surveyors to accurately determine end use energy breakdowns between heating, hot water and pool halls, as no sub-metering was present at the sites which were surveyed.	Swimming pool energy use was based on well-established industry benchmarks with limited basic adjustments.	Performance of the energy model was good when compared to matched energy data, so the impact on data quality is believed to be low.
Data processing	A net to gross ratio for club floor area could not be derived from available data due to limited site survey sample and VOA area irregularities.	The net to gross ratio was estimated based on evidence from the hospitality sector, with which the clubs sub-sector has the most commonality.	Confidence in the sub-sector's gross floor area is low.
Data processing	No matched energy data source was available for places of worship.	Calibration process was undertaken by comparison with 6 site surveys only. Dominant end uses are heating and lighting, so this was deemed to be acceptable. It was noted, however, that the site survey sample did not include any sites with high heating energy	This sub-sector only made up a very small share of the non-domestic stock. Many places of worship were underheated compared with other sectors. The energy consumption estimate for heating may be an under-estimate overall.

Stage	Challenge	Response	Impact
		intensity.	
Data processing	Theatres sub-sector was merged from originally 3 distinct sub-sectors (theatre, cinema, concert hall). Questions in the telephone survey were therefore required to be more generic than in many other sub-sectors. Site survey data was insufficient to identify key features of each sub-type (only one theatre and one concert hall were site surveyed).	Model calibration was carried out by drawing comparison with matched energy data, by separating the sub-types and examining overall variation between modelled and matched data. This approach does not offer end-use level insight into how energy is used, so calibration adjustments to the model were based on best engineering judgement.	Confidence level in the energy end use breakdown for this sub-sector was low. This should be considered if the results are to be used in future work. Energy consumed by entertainment equipment and entertainment lighting was particularly affected by this, as this was the only sub-sector where it was found at high intensities.
Data processing	Museums sub-sector was merged from originally 3 distinct sub-sectors (museum, gallery, and library). Questions in the telephone survey were therefore required to be more generic than in many other sub-sectors. Site survey data was insufficient to identify key features of each sub-type (three museums and one library were site surveyed).	Model calibration was carried out by drawing comparison with matched energy data, by separating the sub-types and examining overall variation between modelled and matched data. This approach does not offer end-use level insight into how energy is used, so calibration adjustments to the model were based on best engineering judgement and any themes which could be drawn from the three museum site surveys.	Confidence level in the energy end use breakdown for this sub-sector was low. This should be considered if the results are to be used in future work. Lighting installations were found to be highly customised, and model estimates for lighting are also presented with low confidence.

Telephone survey and site survey data collection

Table B.2 shows that 351 telephone survey or equivalent records and 32 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[36]	Average interview length (mins.)	Target sample size	Site surveys completed
Leisure centres	100	87	0	87	77	27	12	11
Clubs & Community centres	100	100	0	100	96	25	6	6
Museums	50	47	0	47	41	30	9	7
Theatres	50	50	0	50	46	31	6	2
Places of worship	102	102	0	102	91	29	6	6
Community, arts & leisure sector	**402**	**386**	**0**	**386**	**351**	**27**	**39**	**32**

Source: Telephone survey or equivalent records, England and Wales

[36] 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 community, arts & leisure 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 below.

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.

End use category		Description
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.
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**	Energy used for equipment in laboratories.

End use category		Description
	equipment	
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 below.

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 (e.g. lifts)	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).

Tables C.3 and C.4 show energy consumption by end use for each community, arts & leisure sub-sector and for the sector combined. Tables C.5 and C.6 show energy intensity by end use for each community, arts & leisure sub-sector and for the sector combined.

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

		Electrical energy consumption (GWh per year)					
Simplified end use category	**BEES end use category**	Leisure centres	Clubs & Comm -unity centres	Museums	Thea -tres	Places of worship	**Comm -unity, arts & leisure sector**
Heating	Space heating	40	130	20	10	270	460
Hot water	Hot water	10	20	-	-	10	50
Cooling & humidification	Space cooling	210	40	10	30	20	300
Fans	Fans	240	70	20	60	40	430
Lighting	Lighting - internal	210	170	20	50	180	630
Pool/leisure	Pool/leisure	450	-	-	-	-	450
Catering	Distributed catering	10	20	-	-	10	40
	Central catering	-	110	-	10	200	320
Other	Medical equipment	-	-	-	-	-	-
	ICT equipment	-	-	-	-	-	10
	Cooled storage	30	450	-	10	-	490
	Small power	-	40	10	-	-	50
	Pumps	30	20	-	10	30	90
	Controls	10	10	-	-	40	70
	Humidification	-	-	-	-	-	-
	Laundry	-	-	-	-	-	10
	Lighting - display	-	-	10	10	-	10
	Lighting - external	60	20	-	-	50	130
	Entertainment lighting	-	-	-	20	-	20
	Vertical transport (e.g. lifts)	10	10	-	-	10	30
	Entertainment equipment	10	40	-	10	20	80
	Lab equipment	-	-	-	-	-	-
	Other	-	-	-	-	10	20
Total		**1,330**	**1,150**	**110**	**210**	**880**	**3,680**
Unweighted base		*77*	*96*	*41*	*46*	*91*	*351*

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

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

Simplified end use category	BEES end use category	Non-electrical energy consumption (GWh per year)					
		Leisure centres	Clubs & Community centres	Museums	Theatres	Places of worship	**Community, arts & leisure sector**
Heating	Heating	1,150	1,080	90	260	2,780	5,360
Hot water	Hot water	140	80	10	10	10	250
Catering	Catering	-	160	-	10	350	520
Pool/leisure	Pool/leisure	1,970	-	-	-	-	1,970
Other	Other	-	-	-	-	-	-
Total		**3,260**	**1,320**	**100**	**280**	**3,140**	**8,110**
Unweighted base		*77*	*96*	*41*	*46*	*91*	*351*

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

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

Simplified end use category	BEES end use category	Electrical energy intensity (kWh/m^2 per year)					
		Leisure centres	Clubs & Comm -unity centres	Museums	Theatres	Places of worship	**Comm -unity, arts & leisure sector**
Heating	Space heating	5	13	15	5	7	8
Hot water	Hot water	2	2	1	1	0	1
Cooling & humidification	Space cooling	25	4	10	18	0	5
Fans	Fans	28	7	23	38	1	7
Lighting	Lighting - internal	25	17	20	27	5	11
Pool/leisure	Pool/leisure	54	-	-	-	-	8
Catering	Distributed catering	1	2	2	2	0	1
	Central catering	-	10	2	3	5	5
Other	Medical equipment	-	-	-	-	-	-
	ICT equipment	0	0	5	0	0	0
	Cooled storage	3	43	0	5	-	8
	Small power	0	3	10	0	0	1
	Pumps	4	2	2	3	1	2
	Controls	1	1	1	2	1	1
	Humidification	-	-	3	-	-	0
	Laundry	0	0	0	0	0	0
	Lighting - display	0	-	7	3	-	0
	Lighting - external	7	2	2	2	1	2
	Entertainment lighting	-	-	-	12	-	0
	Vertical transport (e.g. lifts)	1	0	1	1	0	0
	Entertainment equipment	1	4	2	4	0	1
	Lab equipment	-	-	0	-	-	0
	Other	0	0	0	0	0	0
Total		**159**	**111**	**107**	**126**	**23**	**62**
Unweighted base		*77*	*96*	*41*	*46*	*91*	*351*

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

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

Simplified end use category	BEES end use category	Non-electrical energy intensity (kWh/m^2 per year)					
		Leisure centres	Clubs & Community centres	Museums	Theatres	Places of worship	**Community, arts & leisure sector**
Heating	Heating	137	105	87	155	74	90
Hot water	Hot water	17	8	5	7	0	4
Catering	Catering	-	16	4	5	9	9
Pool/leisure	Pool/leisure	235	-	-	-	-	33
Other	Other	-	-	3	-	-	0
Total		**389**	**128**	**100**	**167**	**83**	**137**
Unweighted base[37]		*77*	*96*	*41*	*46*	*91*	*351*

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

[37] Unweighted bases are higher than in table C.4 due to the inclusion of the floor area for all records in the sector.

Appendix D: Abatement potential

The definitions for each measure type are included in this appendix as well as the abatement potential for each community, arts & leisure 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).

Leisure centres

In leisure centres there was an annual abatement potential of 540 GWh of electrical energy and 1,220 GWh of non-electrical energy (equivalent to 390 $ktCO_2e$ combined). This equates to a 40 per cent and 38 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this is £569m. The annual savings delivered would be £85m[38]. These figures are grouped according to measure type in Table D.2. The total abatement potential of the socially cost effective measure groups was 710 GWh, of which 260 GWh was electrical energy consumption and 440 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 520 GWh, of which 110 GWh was electrical energy consumption and 400 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.2: Abatement opportunity data for leisure centres, 2014–15

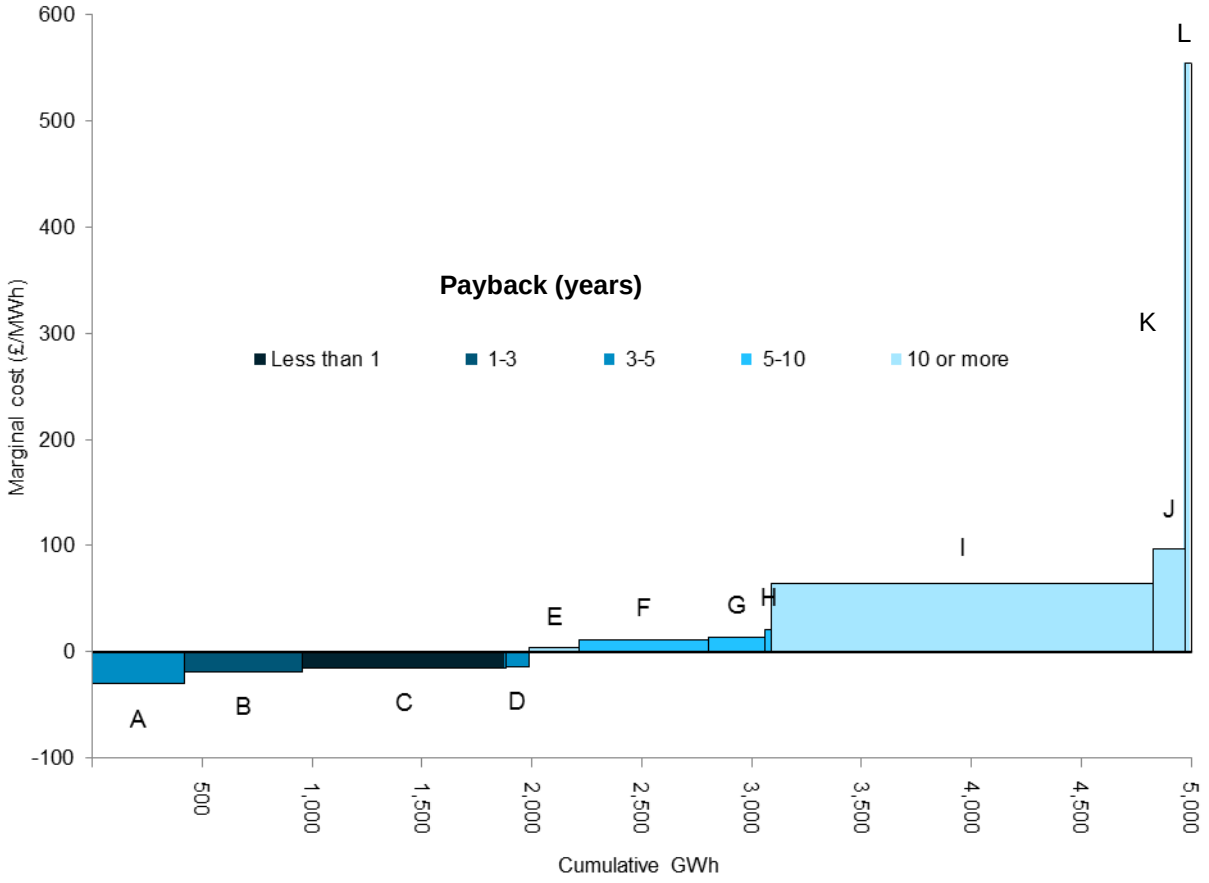
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Payback period (years)** [39]
Air conditioning and cooling	4,500	10	50	-	50	49,000	17
Building fabric	2,500	20	8	70	80	36,100	9
Building instrumentation and control	6,700	40	30	160	190	13,900	2
Building services distribution systems	1,000	3	10	-	10	35,400	23
Carbon and Energy Management	14,900	70	90	240	330	12,000	1
Hot water	1,100	8	1	40	40	5,200	4
Humidification	-	-	-	-	-	-	-
Lighting	14,500	40	150	-	150	50,900	3
Cooled storage	500	2	5	-	5	3,300	6
Small appliances	100	0	0	2	2	1,700	13
Space heating	5,800	40	7	200	210	48,400	10
Swimming pools	24,100	130	110	500	620	264,200	10
Ventilation	8,900	30	90	6	90	49,300	5
Total	84,600	390	540	1,220	1,760	569,400	‘’

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.1: Marginal abatement cost curve for leisure centres, 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: £-30 per MWh. GWh: 150]
B Building instrumentation and control [MAC: £-19 per MWh. GWh: 190]
C Carbon and Energy Management [MAC: £-15 per MWh. GWh: 330]
D Hot water [MAC: £-14 per MWh. GWh: 40]
E Building fabric [MAC: £4 per MWh. GWh: 80]
F Space heating [MAC: £11 per MWh. GWh: 210]
G Ventilation [MAC: £14 per MWh. GWh: 90]
H Cooled storage [MAC: £20 per MWh. GWh: 10]
I Swimming pools [MAC: £64 per MWh. GWh: 620]
J Air conditioning and cooling [MAC: £97 per MWh. GWh: 50]
K Small appliances [MAC: £137 per MWh. GWh: 1]
L Building services distribution systems [MAC: £555 per MWh. GWh: 10]

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

Clubs & community centres

In clubs & community centres there was an annual abatement potential of 420 GWh of electrical energy and 610 GWh of non-electrical energy (equivalent to 240 $ktCO_2e$ combined). This equates to a 36 per cent and 46 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this is £452m. The annual savings delivered would be £57m[40]. These figures are grouped according to measure type in Table D.3. The total abatement potential of the socially cost effective measure groups was 260 GWh, of which 130 GWh was electrical energy consumption and 140 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 200 GWh, of which 70 GWh was electrical energy consumption and 130 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 clubs & community centres, 2014–15

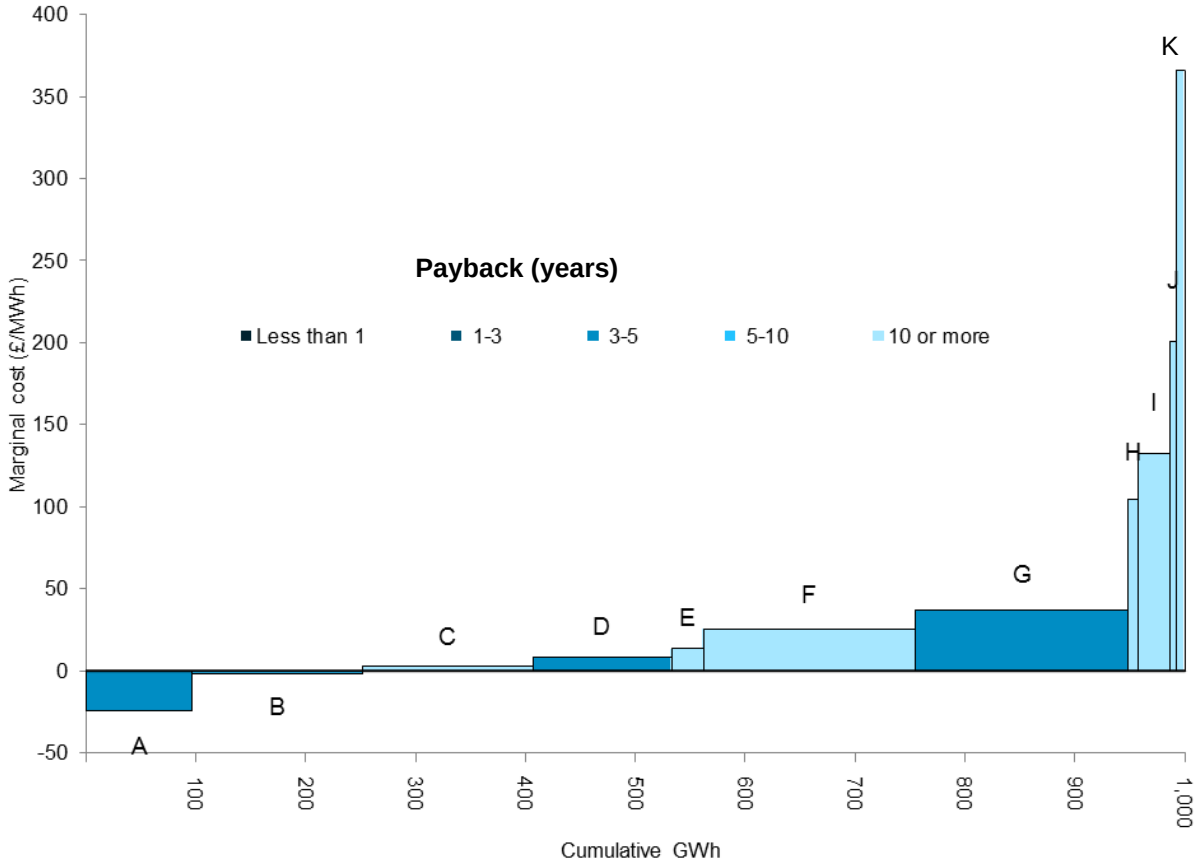
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Payback period (years)** [41]
Air conditioning and cooling	700	2	8	-	8	11,500	17
Building fabric	5,300	30	20	150	160	94,300	12
Building instrumentation and control	6,200	30	30	140	160	32,700	4
Building services distribution systems	700	2	7	-	7	16,300	15
Carbon and Energy Management	10,600	50	70	130	200	32,900	3
Hot water	900	5	3	30	30	11,800	11
Humidification	-	-	-	-	-	-	-
Lighting	10,000	30	100	-	100	41,900	3
Cooled storage	12,600	40	130	-	130	62,100	5
Small appliances	300	1	2	3	5	5,600	17
Space heating	6,600	40	20	170	200	99,600	12
Swimming pools	-	-	-	-	-	-	-
Ventilation	3,200	10	30	1	30	43,500	9
Total	**57,000**	**240**	**420**	**610**	**1,030**	**452,300**	‘’

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.2: Marginal abatement cost curve for clubs & community centres, 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: £-24 per MWh. GWh: 100]
B Building instrumentation and control [MAC: £-2 per MWh. GWh: 160]
C Building fabric [MAC: £3 per MWh. GWh: 160]
D Cooled storage [MAC: £8 per MWh. GWh: 130]
E Hot water [MAC: £13 per MWh. GWh: 30]
F Space heating [MAC: £26 per MWh. GWh: 200]
G Carbon and energy management [MAC: £37 per MWh. GWh: 200]
H Air conditioning and cooling [MAC: £105 per MWh. GWh: 10]
I Ventilation [MAC: £132 per MWh. GWh: 30]
J Small appliances [MAC: £200 per MWh. GWh: 5]
K Building services distribution systems [MAC: £366 per MWh. GWh: 10]

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

Museums

In museums there was an annual abatement potential of 40 GWh of electrical energy and 50 GWh of non-electrical energy (equivalent to 20 $ktCO_2e$ combined). This equates to a 39 per cent and 52 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this is £31m. The annual savings delivered would be £5m[42]. These figures are grouped according to measure type in Table D.4. The total abatement potential of the socially cost effective measure groups was 40 GWh, of which 20 GWh was electrical energy consumption and 20 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 30 GWh, of which 10 GWh was electrical energy consumption and 20 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 museums, 2014–15

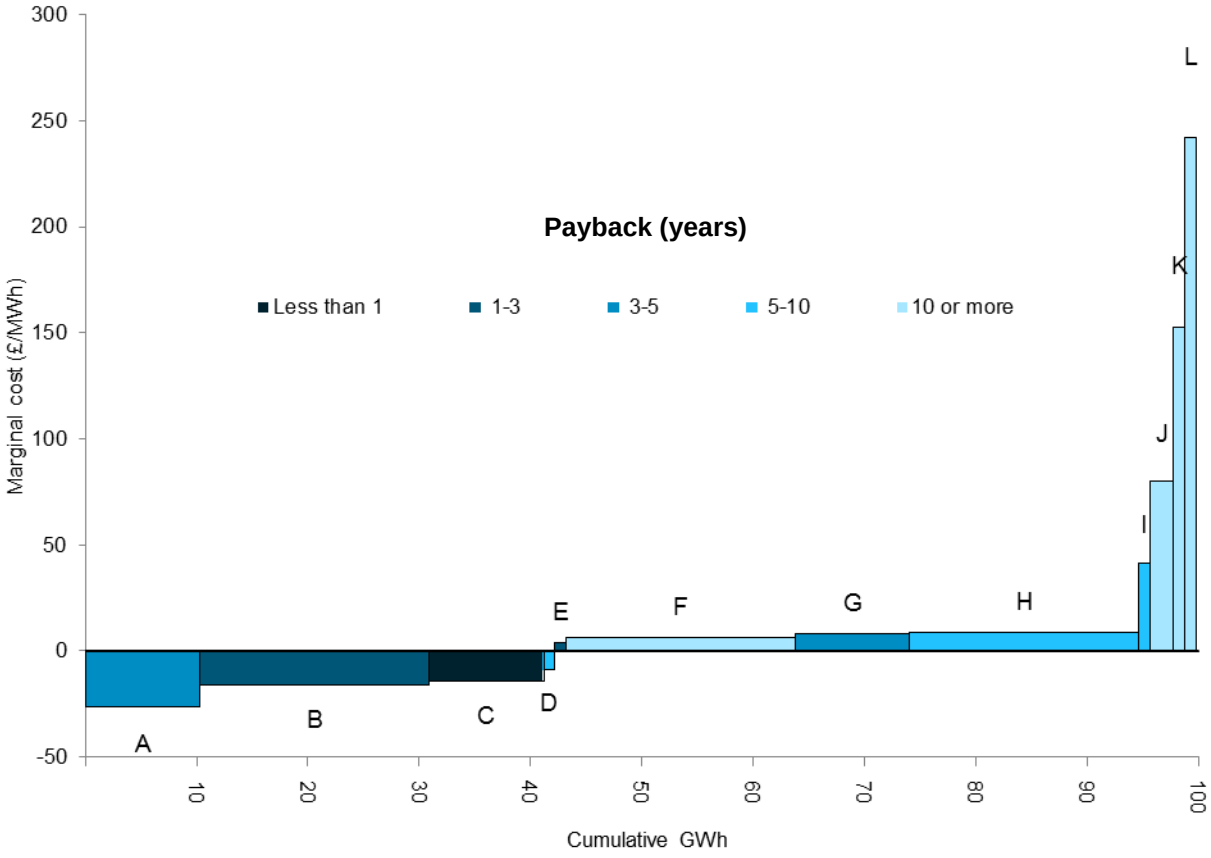
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	Payback period (years)[43]
Air conditioning and cooling	**200**	**1**	**2**	**-**	**2**	**2,100**	**14**
Building fabric	**700**	**3**	**3**	**20**	**20**	**10,700**	**10**
Building instrumentation and control	**800**	**4**	**5**	**10**	**20**	**2,200**	**2**
Building services distribution systems	**100**	**0**	**1**	**-**	**1**	**2,100**	**13**
Carbon and Energy Management	**900**	**4**	**7**	**7**	**10**	**700**	**1**
Hot water	**0**	**0**	**0**	**1**	**1**	**300**	**5**
Humidification	**0**	**0**	**0**	**0**	**0**	**0**	**2**
Lighting	**1,000**	**3**	**10**	**-**	**10**	**3,500**	**3**
Cooled storage	**0**	**0**	**0**	**-**	**0**	**100**	**6**
Small appliances	**0**	**0**	**0**	**0**	**0**	**100**	**13**
Space heating	**600**	**3**	**2**	**20**	**20**	**4,100**	**7**
Swimming pools	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Ventilation	**1,100**	**3**	**10**	**0**	**10**	**5,400**	**4**
Total	**5,400**	**20**	**40**	**50**	**90**	**31,300**	‘’

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.3: Marginal abatement cost curve for museums, 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: £-26 per MWh. GWh: 10]
B Building instrumentation and control [MAC: £-16 per MWh. GWh: 20]
C Carbon and energy management [MAC: £-14 per MWh. GWh: 10]
D Hot water [MAC: £-9 per MWh. GWh: 1]
E Humidification [MAC: £4 per MWh. GWh: 1]
F Building fabric [MAC: £6 per MWh. GWh: 20]
G Ventilation [MAC: £8 per MWh. GWh: 10]
H Space heating [MAC: £9 per MWh. GWh: 20]
I Cooled storage [MAC: £42 per MWh. GWh: 1]
J Air conditioning and cooling [MAC: £80 per MWh. GWh: 2]
K Small appliances [MAC: £152 per MWh. GWh: 1]
L Building services distribution systems [MAC: £242 per MWh. GWh: 1]

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

Theatres

In theatres there was an annual abatement potential of 80 GWh of electrical energy and 120 GWh of non-electrical energy (equivalent to 50 $ktCO_2e$ combined). This equates to a 36 per cent and 42 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this is £60m. The annual savings delivered would be £11m[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 110 GWh, of which 30 GWh was electrical energy consumption and 80 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 70 GWh, of which 30 GWh was electrical energy consumption and 40 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 theatres, 2014–15

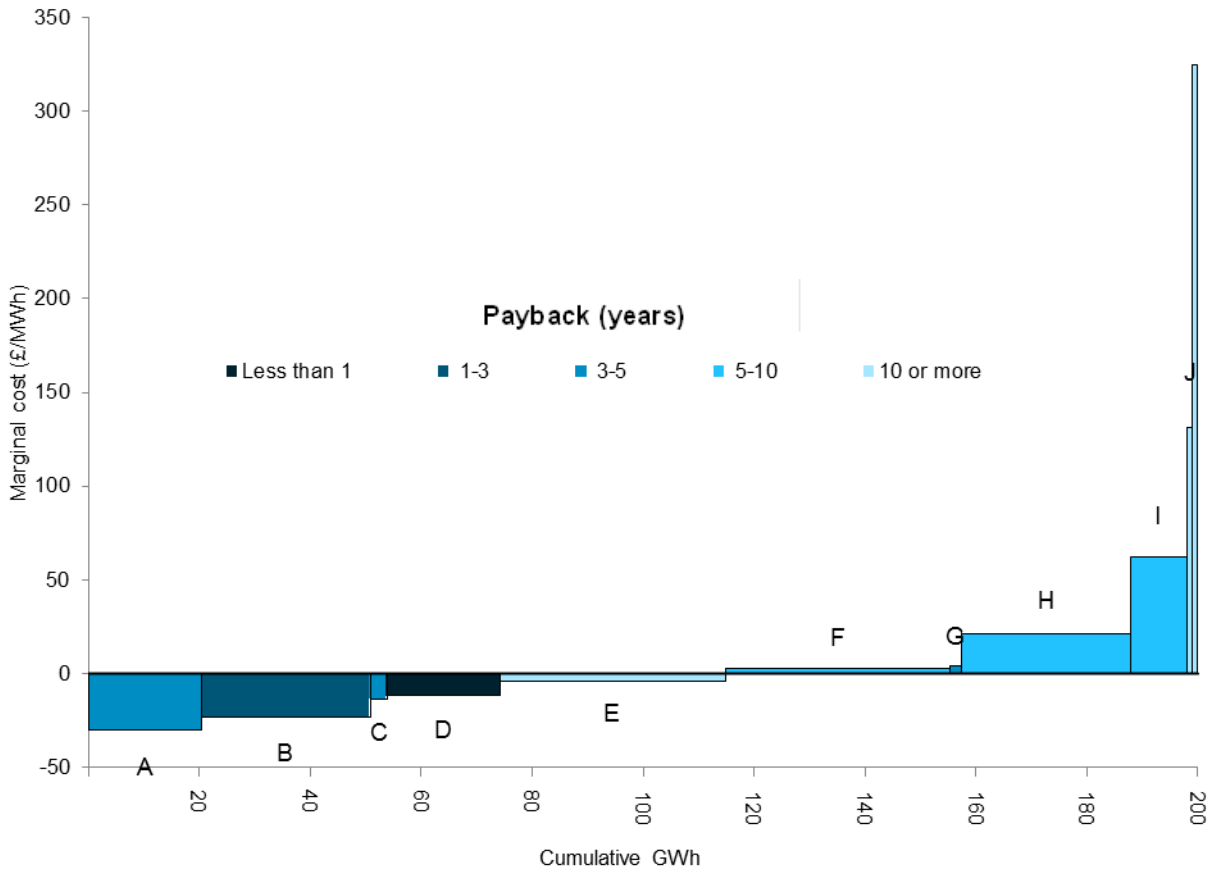
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	Payback period (years) [45]
Air conditioning and cooling	900	3	9	-	9	8,000	13
Building fabric	1,100	7	2	40	40	14,900	10
Building instrumentation and control	1,400	7	7	30	30	1,500	1
Building services distribution systems	100	0	1	-	1	2,300	14
Carbon and Energy Management	1,000	4	7	10	20	900	1
Hot water	100	1	0	3	4	600	4
Humidification	-	-	-	-	-	-	-
Lighting	1,800	5	20	-	20	6,000	3
Cooled storage	200	1	2	-	2	1,000	5
Small appliances	0	0	0	0	0	300	12
Space heating	1,200	8	1	40	40	7,100	8
Swimming pools	-	-	-	-	-	-	-
Ventilation	2,900	9	30	2	30	17,000	5
Total	**10,700**	**50**	**80**	**120**	**200**	**59,500**	‘’

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. K

[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 theatres, 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: £-30 per MWh. GWh: 20]
B Building instrumentation and control [MAC: £-23 per MWh. GWh: 30]
C Hot water [MAC: £-13 per MWh. GWh: 3]
D Carbon and energy management [MAC: £-12 per MWh. GWh: 20]
E Building fabric [MAC: £-4 per MWh. GWh: 40]
F Space heating [MAC: £3 per MWh. GWh: 40]
G Cooled storage [MAC: £4 per MWh. GWh: 2]
H Ventilation [MAC: £21 per MWh. GWh: 30]
I Air conditioning and cooling [MAC: £62 per MWh. GWh: 10]
J Small appliances [MAC: £131 per MWh. GWh: 1]
K Building services distribution systems [MAC: £325 per MWh. GWh: 1]

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

Places of worship

In places of worship there was an annual abatement potential of 380 GWh of electrical energy and 1,630 GWh of non-electrical energy (equivalent to 410 $ktCO_2e$ combined). This equates to a 43 per cent and 52 per cent reduction on electrical and non-electrical energy consumption respectively. The capital cost to achieve this is £1.1bn. The annual savings delivered would be £79m[46]. These figures are grouped according to measure type in Table D.6. There was no socially cost effective abatement potential. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. There was also 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.5).

Table D.6: Abatement opportunity data for places of worship, 2014–15

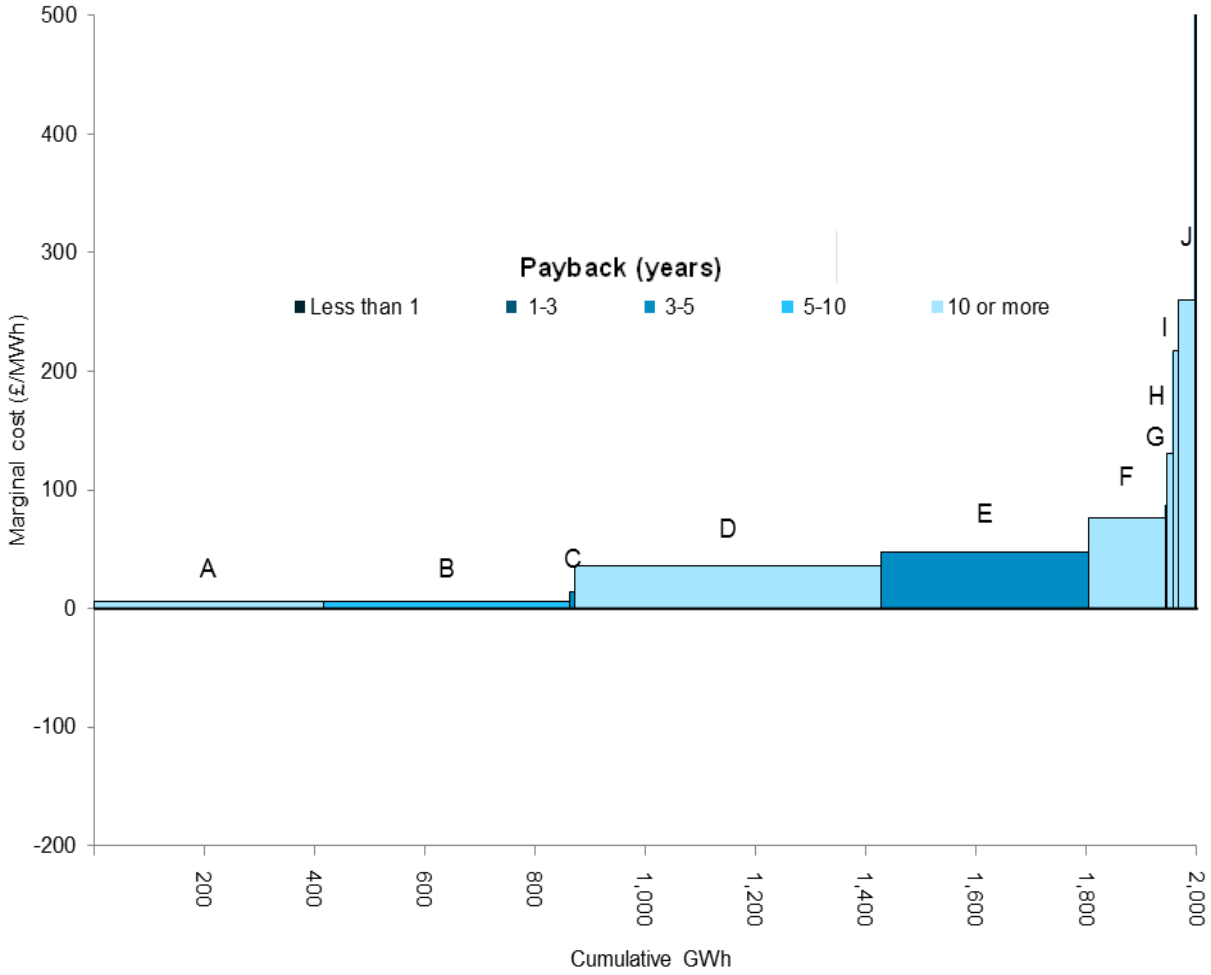
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	Payback period (years) [47]
Air conditioning and cooling	500	1	5	-	5	6,700	20
Building fabric	13,000	80	30	390	420	280,600	15
Building instrumentation and control	14,000	90	40	410	450	107,700	6
Building services distribution systems	200	1	2	-	2	41,800	53
Carbon and Energy Management	15,700	80	80	300	380	73,700	4
Hot water	400	2	3	7	9	15,400	31
Humidification	-	-	-	-	-	-	-
Lighting	14,100	40	140	-	140	198,600	11
Cooled storage	900	3	9	-	9	4,600	5
Small appliances	300	1	2	4	6	7,500	20
Space heating	17,600	110	50	510	560	334,700	16
Swimming pools	-	-	-	-	-	-	-
Ventilation	2,300	7	20	4	30	59,600	14
Total	**79,100**	**410**	**380**	**1,630**	**2,010**	**1,131,000**	‘’

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

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

[47] 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.5: Marginal abatement cost curve for places of worship, 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 Building fabric [MAC: £5 per MWh. GWh: 420]
B Building instrumentation and control [MAC: £6 per MWh. GWh: 450]
C Cooled storage [MAC: £13 per MWh. GWh: 10]
D Space heating [MAC: £36 per MWh. GWh: 560]
E Carbon and energy management [MAC: £48 per MWh. GWh: 380]
F Lighting [MAC: £76 per MWh. GWh: 140]
G Air conditioning and cooling [MAC: £87 per MWh. GWh: 5]
H Hot water [MAC: £131 per MWh. GWh: 10]
I Small appliances [MAC: £217 per MWh. GWh: 10]
J Ventilation [MAC: £260 per MWh. GWh: 30]
K Building services distribution systems [MAC: £3,282 per MWh. GWh: 2]

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

Department for Business, Energy & Industrial Strategy
3 Whitehall Place
London SW1A 2AW
www.gov.uk/beis