Department for
Business, Energy
& Industrial Strategy

Building Energy Efficiency Survey: Health 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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Contents

Notes on statistical conventions

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

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[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 health 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.

Health sector overview

The health sector consisted of health centres[4], hospitals and nursing homes. The health sector had a total floor area of 45 million m^2 (6 per cent of the total non-domestic stock) across 28,900 premises (2 per cent of the total non-domestic stock). The health sector's total energy consumption was 17,380 GWh. The sector's electrical energy consumption was 6,240 GWh (7 per cent of the total non-domestic stock) and non-electrical consumption was 11,140 GWh (15 per cent of total non-domestic stock).

The findings in this report are based on data collected through 166 telephone surveys used in the energy use and abatement models and 13 site surveys in 2014–15.

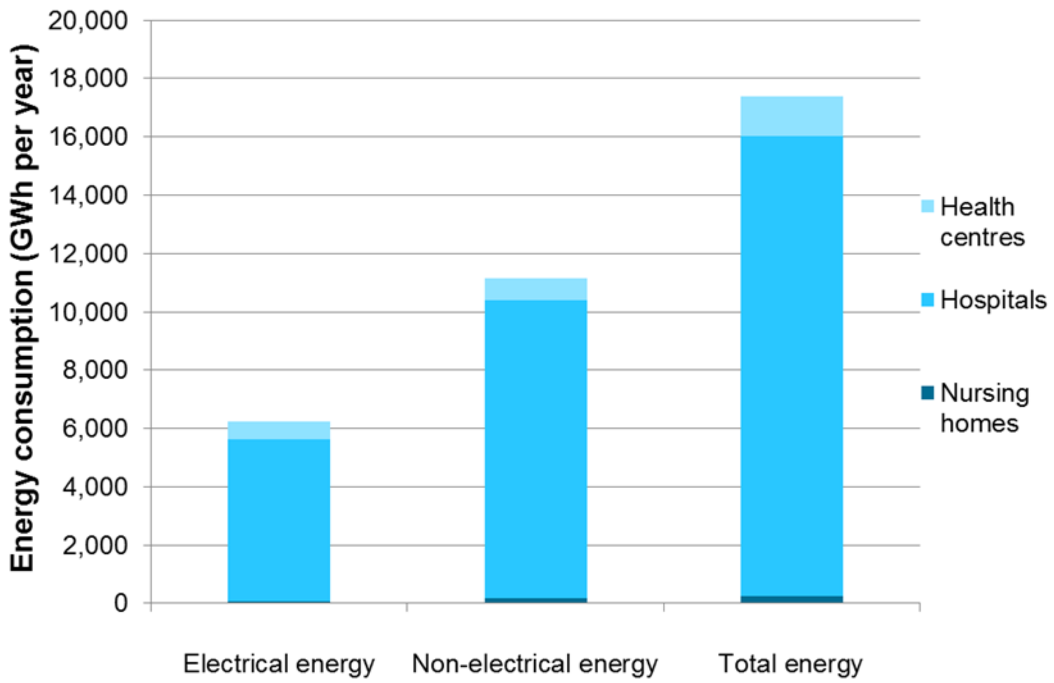
Key findings

Energy consumption in the health sector, 2014–15

- According to modelled data based on telephone survey responses, the sector consumed 17,380 GWh of energy in total. This comprised of 6,240 GWh of electrical energy and 11,140 GWh of non-electrical energy per year (Figure 0.1).
- The largest energy consumer in this sector was hospitals, with 15,780 GWh total energy consumption (91 per cent of sector total): Health centres were the second largest consumer, with 1,340 GWh of total energy consumption (8 per cent of sector total).
- The difference in absolute consumption between the sub-sectors matched with their overall size. Hospitals was the largest sub-sector in terms of energy consumption, while also representing 83 per cent of the sector's overall floor area. In contrast, nursing homes represented 1 per cent of the sector's floor area (the smallest of the three sub-sectors) as well as 1 per cent of the overall energy consumption - also the smallest.
- Hospitals displayed the highest median total energy intensity (386 kWh/m^2), closely followed by nursing homes (385 kWh/m^2).
- Hospitals typically displayed the highest median electrical energy intensity (124 kWh/m^2). The second most energy intensive sub-sector in terms of electrical energy was nursing homes (83 kWh/m^2). Nursing homes displayed the highest median non-electrical energy intensity of 292 kWh/m^2, followed by hospitals (255 kWh/m^2).
- The energy consumption of the health sector was broken down into specific 'end uses'. The most significant end use was space heating (6,710 GWh, 39 per cent of total energy consumption), followed by medical equipment (3,410 GWh, 20 per cent of total).

[4] Health centres include GP surgeries and dentist surgeries.

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



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

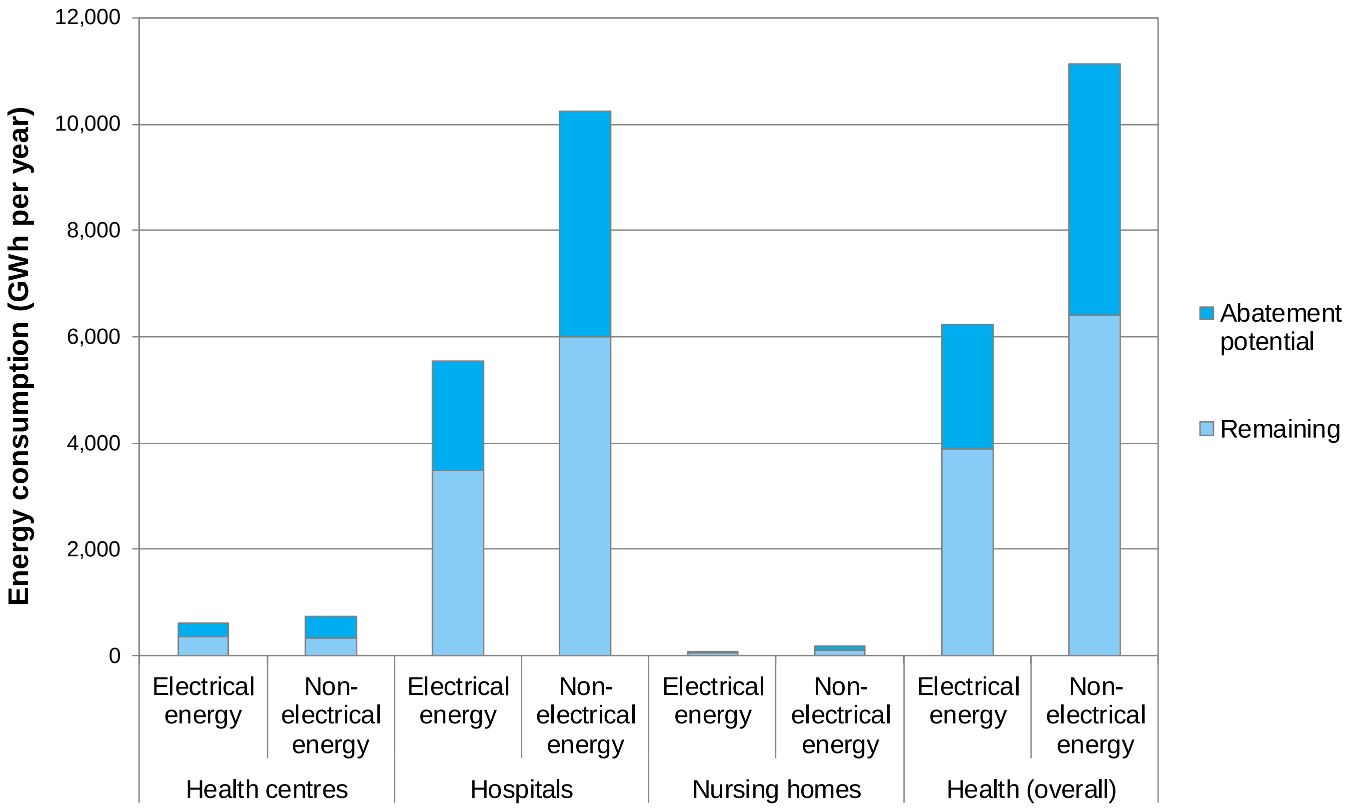
Abatement potential in the health sector, 2014–15

- 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 health sector was 7,080 GWh of total energy consumption (41 per cent reduction on consumption). This comprised 2,350 GWh of electrical energy (a 38 per cent reduction) and 4,730 GWh of non-electrical energy (a 42 per cent reduction).
- This could be achieved at a capital cost of £1.7 billion. The socially cost effective potential was 4,430 GWh of total energy which consisted of 1,500 GWh of electrical energy consumption and 2,930 GWh of non-electrical energy. Organisations are more likely to be influenced by the payback period for improvement: overall there were 4,020 GWh of total energy savings with a private payback period[5] of 3 years or less (1,480 GWh of electrical energy abatement and 2,540 GWh of non-electrical energy abatement).

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

- The sub-sector with the largest absolute abatement potential was hospitals with 6,310 GWh of overall energy consumption. This comprised 2,070 GWh of electrical energy (37 per cent reduction on consumption) and 4,240 GWh of non-electrical energy (41 per cent reduction on consumption).

Figure 0.2: Abatement potential by energy type and health 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 D. The largest group of savings for the health sector – in terms of reductions in energy consumption – relate to the implementation of carbon & energy management measures, lighting and building instrumentation & control measures . The largest group of savings – in terms of the potential energy bill savings – relate to the implementation of carbon and energy management programmes.

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

Measure type	Savings					
	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)	**Total capital cost of measure (£ thousands)**
Air conditioning and cooling	14,200	40	140	-	140	123,600
Building fabric	23,100	160	20	820	840	495,700
Building instrumentation and control	45,000	280	120	1,300	1,420	123,800
Building services distribution systems	9,400	30	100	-	100	62,600
Carbon and Energy Management	98,200	450	670	1,250	1,920	71,500
Hot water	11,300	80	10	390	410	53,800
Humidification	-	-	-	-	-	-
Lighting	68,700	200	690	-	690	206,600
Cooled storage	400	1	4	-	4	1,800
Small appliances	2,300	10	10	40	50	37,700
Space heating	25,500	180	20	940	960	165,900
Swimming pools	100	0	0	2	2	800
Ventilation	55,400	170	560	0	560	351,800
Total	**353,700**	**1,570**	**2,350**	**4,730**	**7,080**	**1,695,600**

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

1. Health sector

This report relates to the health sector (one of ten sectors covered in the Building Energy Efficiency Survey (BEES)). This section provides definitions for the three health sub-sectors (health centres, hospitals and nursing homes). It then sets the health 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 health sector.

Table 1.1: Table of health sub-sector definitions[6]

Sub-sector	Definition
Health centres	Refers to health care facilities that provide same-day healthcare appointments and surgical care including diagnostic and preventive procedures. This may include doctor and dentist's surgeries and outpatient rehabilitation/physical therapy offices.
Hospitals (consisting of NHS hospitals and private hospitals)	Refers to public sector, general medical and surgical hospitals (including critical access hospitals, children's hospitals and community or long stay hospitals), along with buildings used for the provision of private medical and surgical treatment. These facilities provide both acute and routine care services intended to treat patients for short periods of time, including emergency medical care, physician's office services, diagnostic care, ambulatory care, surgical care, and limited specialty services such as rehabilitation and cancer care.
Nursing homes	Refers to premises that house and provide residential accommodation, health care and assistance, in particular for the elderly and those with chronic illness or disability. Gross Floor Area should include all space within the building(s) including individual rooms or units, wellness centres, exam rooms, community rooms, small shops or service areas for residents and visitors (e.g. hair salons, convenience stores), staff offices, lobbies, atriums, cafeterias, kitchens, storage areas, hallways, basements, stairways, corridors between buildings, and lift shafts.

Health sector in the context of the wider non domestic stock

The health sector is a medium-sized segment of the non-domestic stock. It accounts for 2 per cent of the non-domestic stock in terms of premises count (28,900) and 6 per cent in terms of floor area (45 million m^2 GIA[7]).[8] In terms of energy consumption the sector consumed 17,380 GWh of total energy. This comprised 6,240 GWh of electrical energy and 11,140 GWh of non-electrical energy per year. This is equivalent to 7 per cent and 15 per cent of non-domestic stock totals respectively. This information is set out in Figure 1.1 to Figure 1.3.

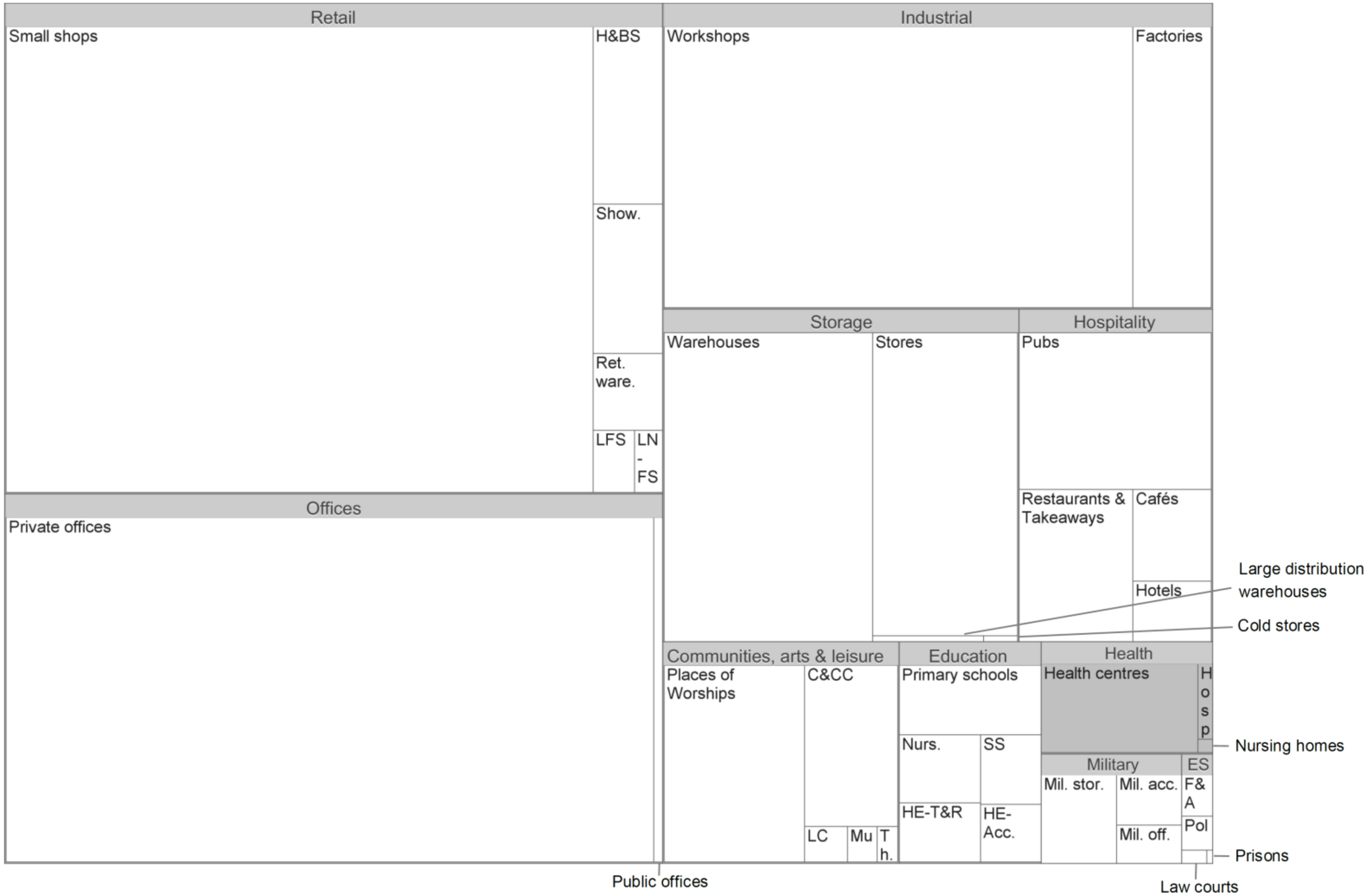
[6] These definitions were originally based on those used for US Energy Star scheme and then were adapted for the UK context.

[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 covered by BEES 2014–15

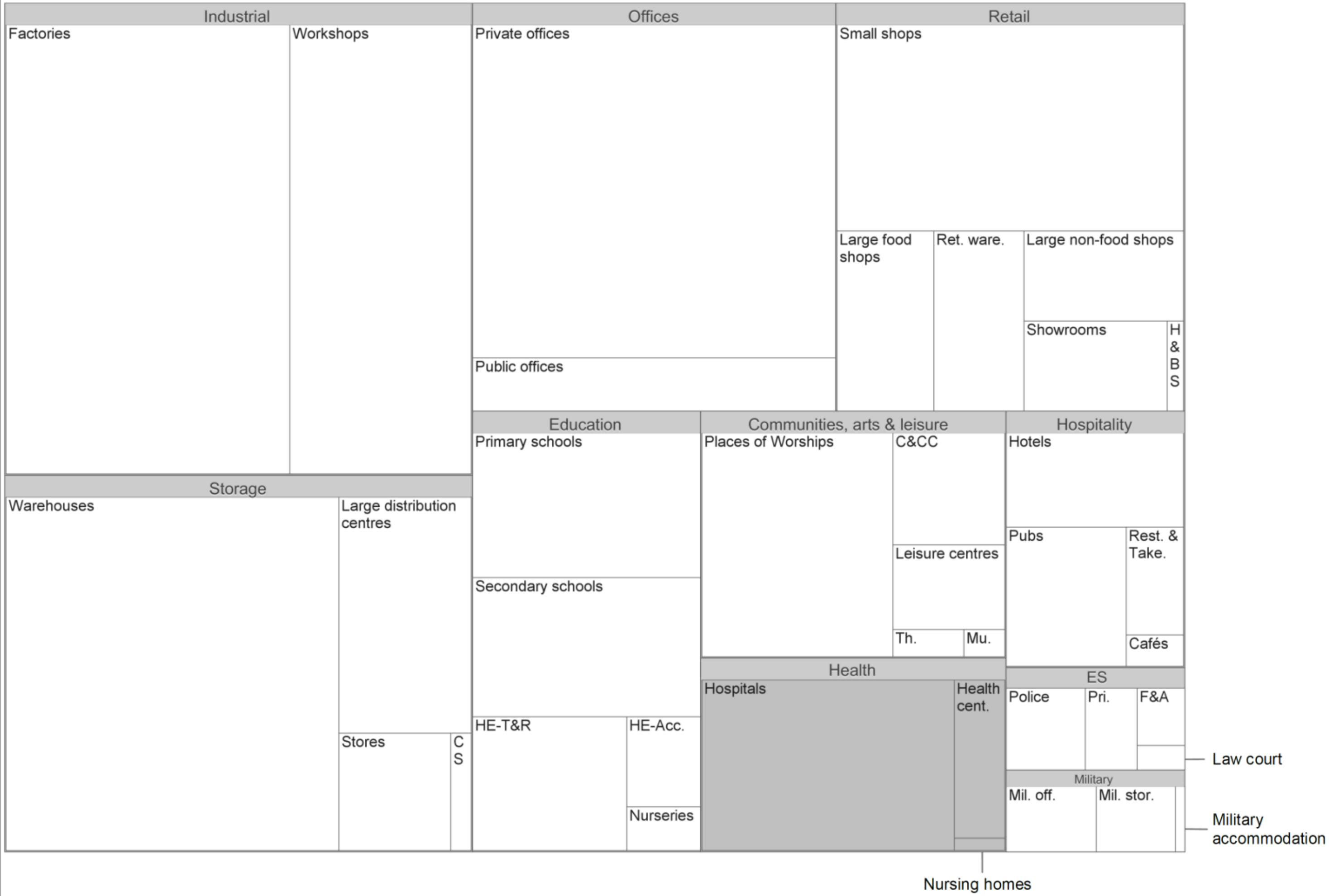
ID	Sub-sector
H&BS	Hairdressing & beauty salons
Show.	Showrooms
Ret. ware.	Retail warehouses
LFS	Large food shops
LN-FS	Large non-food shops
C&CC	Clubs & community centres
LC	Leisure centres
Mu.	Museums, Art galleries and Libraries
Th.	Theatres, cinemas and concert halls
Nurs.	Nurseries
SS	Secondary 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 covered by BEES 2014–15

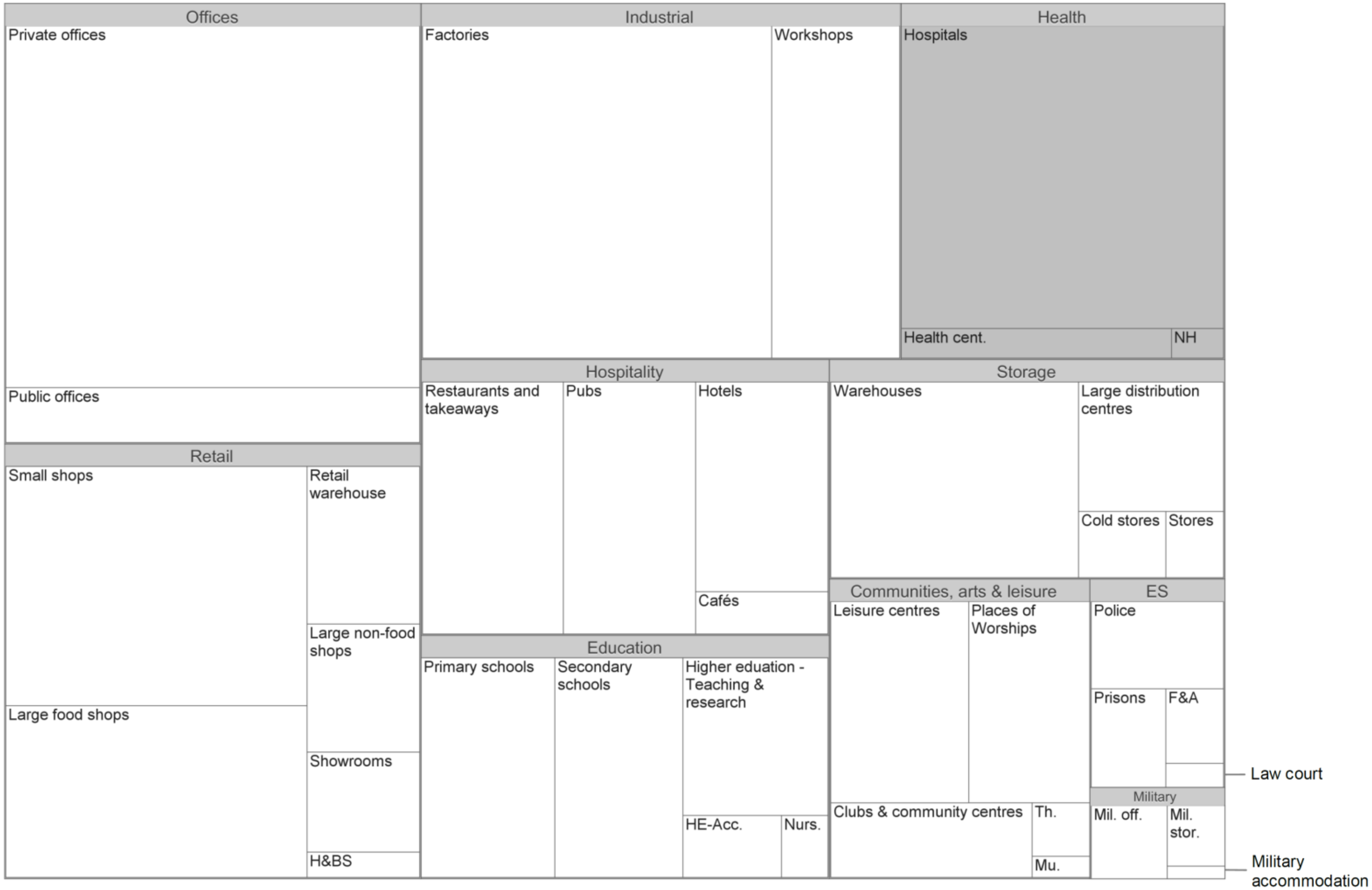
ID	Sub-sector
Ret. ware.	Retail warehouse
H&BS	Hairdressing & beauty salons
CS	Cold stores
HE-T&R	HE—Teaching and research
HE-Acc.	HE — Accommodation
C&CC	Clubs & community centres
LC	Leisure centres
Th.	Theatres, cinemas and concert halls
Mu.	Museums, Art galleries and Libraries
Health cent.	Health 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 covered by BEES 2014–15

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



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

General characteristics of the health sector

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

Health premises varied greatly in size and complexity from small health centres/clinics, to large university hospital buildings with a full range of clinical facilities, complex cooling and ventilation systems and site-wide district heating systems. Both public and private sector facilities were included in the study.

In health centres, the main activity was consultation rooms, with offices, waiting rooms and archives[9] common in the remaining space. In hospital premises, wards were the primary activity area with consulting rooms and offices also widespread; common areas, waiting rooms, patient waiting areas and catering facilities were also frequent occurrences. Nursing homes generally consisted of bedrooms and day facilities for residents, supported by catering and office areas for staff.

Within the health sector, a wide variety of energy intensive sector-specific equipment and activities were present (particularly in hospitals). These included rehabilitation facilities (e.g. hydrotherapy pools and gymnasiums), medical equipment such as MRI scanners, X-ray machines and autoclaves[10], and supporting infrastructure such as server rooms.

Summary statistics for the health sector

A number of standard characteristics for the health sector are set out in Table 1.3, Figure 1.4 and Figure 1.5; from premises and organisation size through to operating hours and premises tenure. These key characteristics for the health sector and how these vary across the health 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 health sector were split across two groups:

- Hospitals and nursing homes typically occupied a whole building and in the vast majority of cases had a floor area above 1,000 m^2, with many hospitals exceeding 10,000 m^2 in floor area. They were also, in general operating 24 hours a day. One of the areas where nursing homes and hospitals differed was that nursing homes tended to not consider energy usage reduction an area of high importance;
- Health centres also typically occupied a whole building but had a floor area of between 500 m^2 and 1,000 m^2. Health centres generally did not report that energy usage reduction was an area of high importance and operated between 9 and 15 hours a day.

The health sector organisation sizes were 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.

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[9] Archives are spaces used for the storage of documents e.g. patient records.

[10] An autoclave is a pressure chamber, used in medical applications to sterilise equipment.

Table 1.2: Organisation size tailoring by sub-sector

Sub-sector	Hospitals	Health centres	Nursing homes
Organisation size	Number of available beds	Number of patients	Number of bedrooms
Micro	1-49	Less than 999	No size banding used
Small	50-199	1,000-4,999	
Medium	200-499	5,000-7,499	
Large	500 or more	7,500 or more	

In broad terms there was a tendency for premises across each sub-sector with more than 500 beds and with 7,500 or more patients to be the most prevalent across the health sub-sectors.

Based on the sub-sector definitions of organisation size, most of the respondents identified themselves as being from 'large' organisations - 50 per cent in health centres and 46 per cent in hospitals were noted as being in the large category.

In terms of premises size, almost all hospitals (100 per cent) had a floor area of greater than 1,000 m^2 with many premises being above 10,000 m^2 (62 per cent). Nursing homes tended to have a floor area of between 1,000 m^2 and 4,999 m^2 (94 per cent). Health centres were often smaller, with the majority having a floor area below 1,000 m^2 (74 per cent). 37 per cent of health centres occupied premises between 500 m^2 and 999 m^2.

Across all sub-sectors premises tended to be owner occupied. That was the case for 76 per cent of hospitals, 71 per cent of nursing homes and 61 per cent of health centres.

Hospitals premises were typically occupied by organisations that reported to be actively managing their energy usage (71 per cent). In contrast, nursing homes and health centres reported to be more passive in their energy management with 73 per cent and 64 per cent stating they 'try to reduce energy use when we can but it is not an area of high importance' respectively.

In terms of building age there was a reasonably equal distribution across all the age of building bandings for each sub-sector.

Health sector premises in general were likely to occupy a whole building on a single building site. In hospital premises it was also not uncommon for a premises to occupy a whole building located on a site with multiple buildings operated by the same organisation (37 per cent). It is worth noting that in a small number of instances health centres (10 per cent) occupied only part of the building in which they were based.

Nursing homes and hospitals were continuously operating at peak operating hours (this is defined as hours when at least 50 per cent of the maximum number of staff on a typical day are present in the building). In comparison, health centres peak operating hours were likely to be between 9 and 15 hours a day (73 per cent).

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

Column percentages

	Health sub-sector			
	Health centres (%)	Hospitals (%)	Nursing homes (%)	**Health sector (%)**
Organisation size[11]				
Micro	1	-	7	0
Small	15	-	91	4
Medium	23	26	2	25
Large	50	46	-	46
Don't know	11	28	-	25
Not Asked	-	-	-	-
Total floor area (m^2)				
Less than 50	1	-	-	-
50-99	3	-	-	-
100-249	15	-	0	2
250-499	18	0	0	3
500-999	37	0	6	6
1,000-4,999	26	18	94	20
5,000-9,999	-	20	-	17
10,000 or more	-	62	-	52
Tenure				
Owned	61	76	71	74
Leased	39	24	29	26
Don't know	-	-	-	-
Energy management ambition[12]				
Active	22	71	17	63
Passive	64	28	76	34
None	14	1	7	3
Don't know	-	-	-	-
Age of building				
Pre-1900	10	5	13	6
1900-1939	8	9	14	9
1940-1985	30	41	11	39
1986-1990	15	25	17	24
1991-2006	30	17	17	19
2007 or later	7	3	5	3
Don't know	1	-	22	1

[11] Please note that a non-standard approach to organisation size is used in this sector as explained in Table 1.2.

[12] '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".

Table 1.3 continued.

	Health sub-sector			
	Health centres (%)	Hospitals (%)	Nursing homes (%)	**Health sector (%)**
Building structure				
Part of building	10	0	4	2
Whole building	88	63	96	67
Multiple buildings	1	37	-	31
Peak operating hours[13]				
8 or less	23	1	8	4
9-15	73	19	48	28
16-23	4	0	0	1
24	0	79	40	66
Don't know	0	1	4	1
Peak opening hours[14]				
8 or less	4	0	0	1
9-15	87	3	0	16
16-23	9	5	6	6
24	0	91	93	77
Don't know	0	1	4	1
Unweighted base	*52*	*57*	*57*	*166*

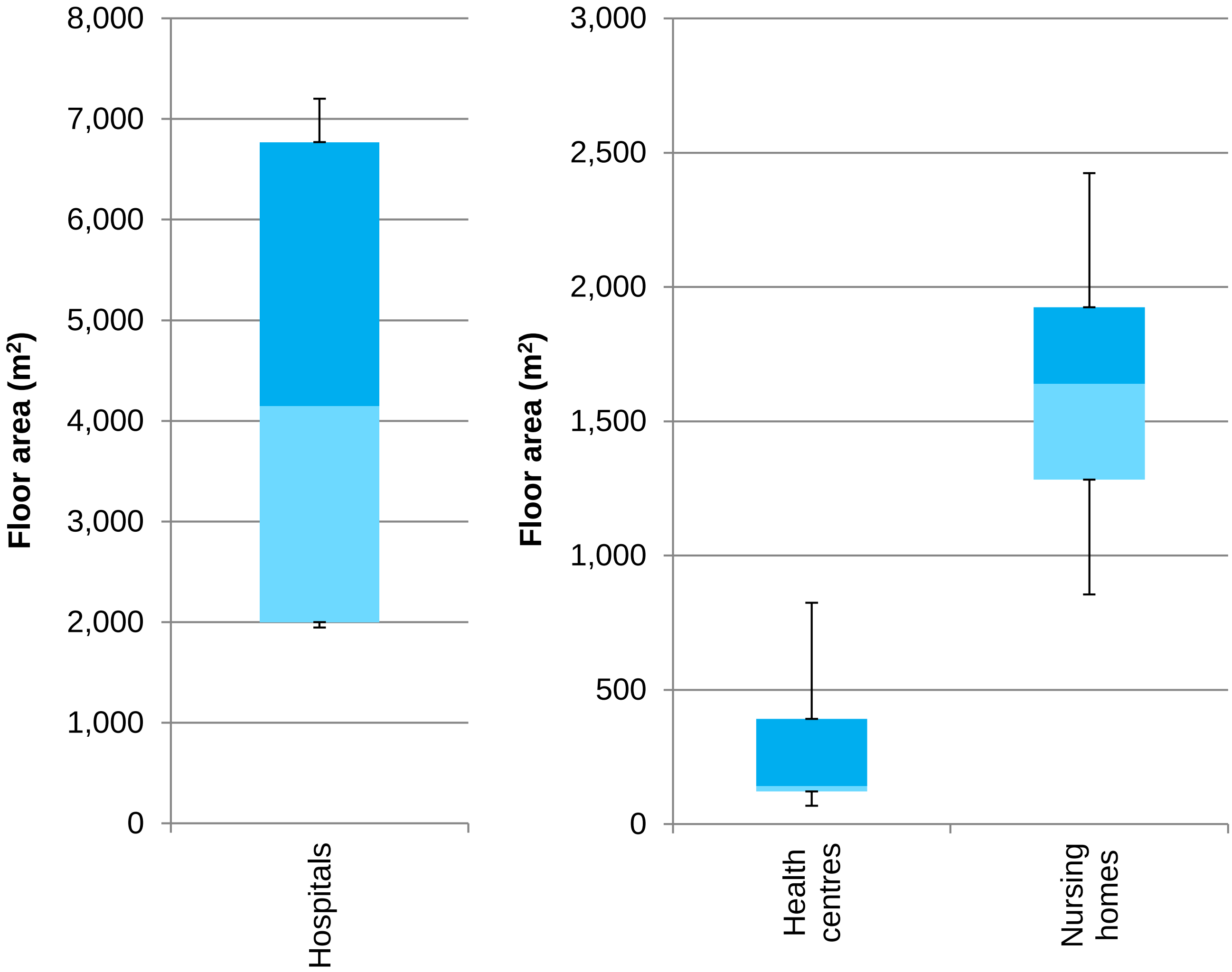
Source: Telephone survey or equivalent records for the sector, England and Wales

[13] 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)?".

[14] 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 hospitals had the largest median floor area in the health sector at 4,150 m^2, followed by nursing homes (1,640 m^2) and health centres (140 m^2). The distribution of floor area sizes for hospitals was also much wider than for other sub-sectors, with the central 50 per cent of records having floor areas between 2,000 m^2 and 6,770 m^2 compared with a range of 1,280 m^2 to 1,920 m^2 in nursing homes and 120 m^2 to 390 m^2 in health centres.

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

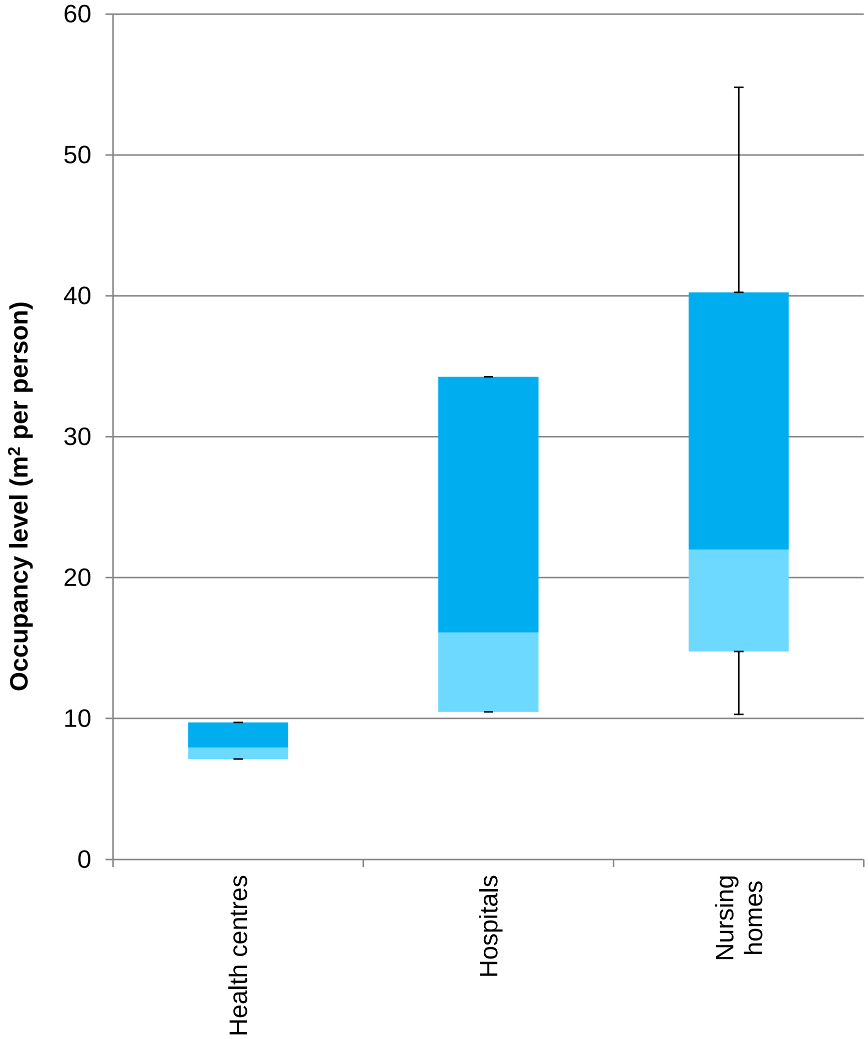


Note: In box and whisker plots, the blue columns, when combined, indicate the range of floor areas covered by the interquartile range of results (the middle 50 per cent of data points). The upper black bars extend to the 90th percentile, capturing a further 15 per cent of the total number of data points. 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.

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.[15] [16] Health centres show the highest median occupancy level of 8 m^2 per person. This compares with a median of 16 m^2 per person in hospitals and 22 m^2 per person in nursing homes.

Figure 1.5: Occupancy level by health sub-sector, 2014–15



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

[15] In the health sector, visitors refers to 'patients' in health centres and hospitals, and 'residents' in nursing homes.

[16] 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 health sector.

Greater detail on the BEES methodology in relation to the health 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 health 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;[17]
- 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.[18]

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 premises relying on telephone surveys and a limited number of site surveys. The non-domestic stock was broken down into 10 sectors and 38 sub-sectors.

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

The study has generated a database of 3,690 records. Each record may represent an entire building or a premises within a larger building. The findings in this report are based on data collected for the health sector through 166 telephone surveys and 13 site surveys during 2014–2015.

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

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

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[17] 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.

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

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

1. **Sample design -** BEES has been sampled and grossed primarily based on data from the Non-domestic National Energy Efficiency Data-framework (ND-NEED). This dataset uses the Valuation Office Agency's (VOA) property rating list. Where a sector was out of scope of the VOA database, alternative data sources were used. This gives a base record of address, floor area, building type, and energy use[19]. Using the Experian references in ND-NEED it was possible to add a contact telephone number. Analysis shows that the scope of BEES includes 89 per cent of premises floor area in England & Wales. The number of surveys per sub-sector was determined based on their overall size with a minimum of 50 surveys sought where possible. Overall 1 per cent of floor area has been surveyed based on the sub-sectors in scope.
2. **Data collection** – A sub-sector tailored telephone survey, supplemented with data from a more detailed site survey in a subset of cases, was used to gather the information required to model the energy end uses within these premises.
    - The telephone survey involved a single stage and took around 25 minutes to complete. It gathered basic information on the premises, its servicing and usage. It also included sub-sector specific key questions to gather further data on the most significant energy end uses. These questions were designed with input from expert interviewers and, if necessary, trial site surveys at the design stage of the research programme. The survey was conducted with the person responsible for energy management, building management or another suitable manager.
    - A limited number of site surveys were undertaken on the telephone survey sample. The candidates were selected based on a range of characteristics such as energy intensity, location and floor area size. The site surveys gathered detailed information on the energy end use consumption, activities (extent and intensity), abatement potential and the barriers and facilitators to implementing energy efficiency measures in the premises. The outputs were used to test the energy use and abatement models. Data collected on site was also used to correct and overwrite findings from the initial telephone survey. The data on barriers was collected via semi-structured face to face interviews.
3. **Data cleansing -** Prior to modelling, the data were cleansed firstly through record exclusion. Records were screened for outliers, then they were reviewed for quality. The outlier analysis was based on typical operating metrics, such as occupancy level (the number of square metres per person in a premises). Where extreme values were identified the record would be removed. The quality assurance process identified the proportion of questions for which a response was required to model energy use. Any records which failed to meet the minimum data quality thresholds, measured by the percentage of 'don't know' responses were excluded. Exclusion of these records was deemed necessary on the grounds that a significant prevalence of 'Don't know' responses was considered indicative of a respondent who lacked engagement or had a poor understanding of their premises' core services and equipment. Within the health sector, a total of 192 telephone survey or equivalent records were collected – following the record exclusion process a total of 166 records were retained for analysis. In this sector the share of records excluded was moderately low (14 per cent of total), as many of the records in the available sample yielded a low proportion of 'Don't know' responses, considered to indicate poor record reliability, while others did not have a reliable matched floor area.

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

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[20].
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.[21]
    - 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.

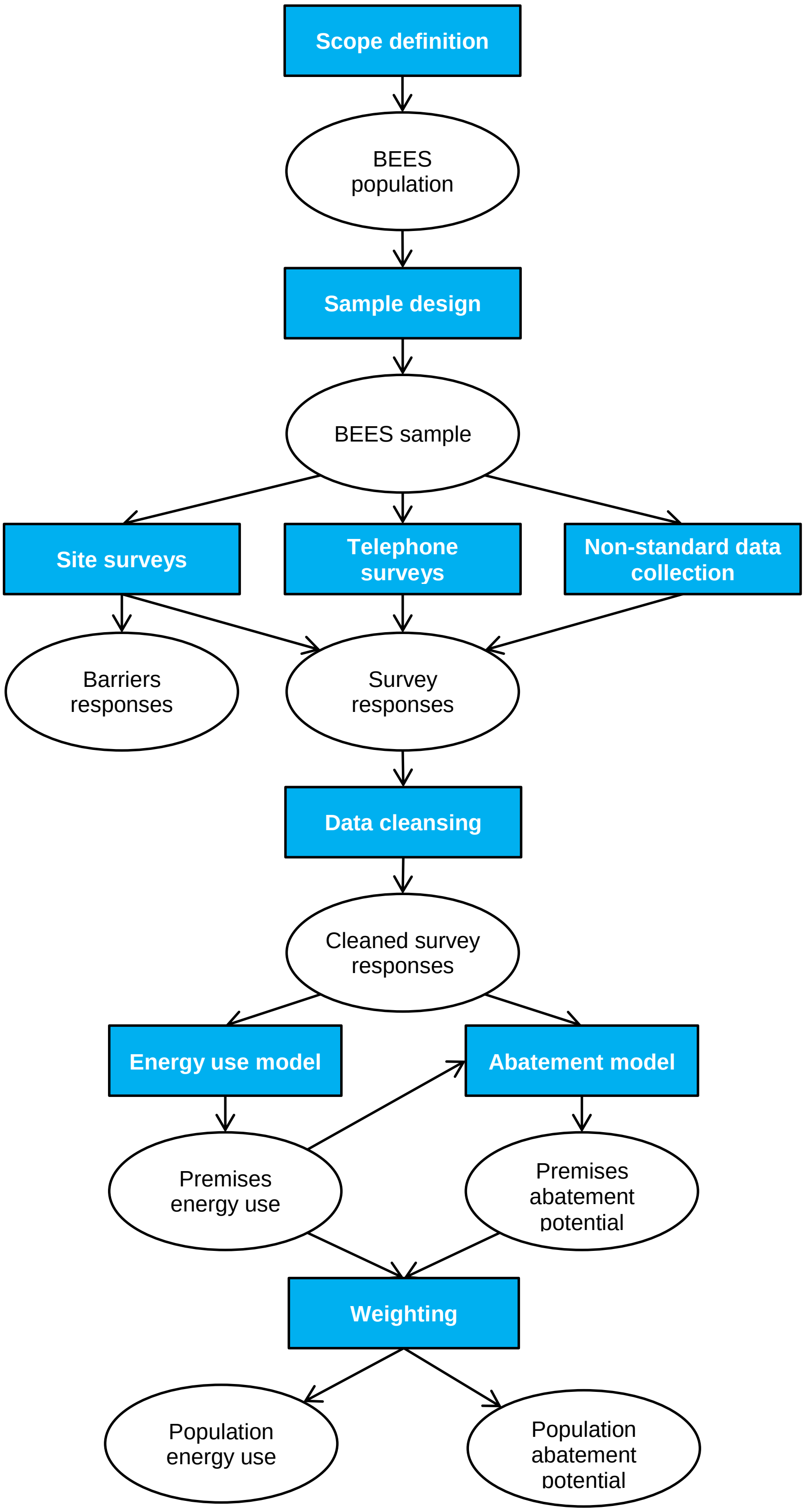
This approach was then tailored by sector. The impact of the change to the methodology within the health sector is covered in “Methodology challenges in the health sector”, which follows in this section, and in more detail in Appendix B.

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.

[20] 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.

[21] 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 health sector

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

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

1. **Design – sampling** No source dataset incorporating floor area or energy data was available for private hospitals. This meant that the team could not determine whether the sample was biased in terms of floor area or energy consumption. The respondents were also asked to provide their estimate of the premises floor area and energy consumption. These estimates were deemed to have low accuracy. As a result the private hospitals energy model was calibrated on the NHS hospital records which had a robust source of matched floor area and energy data. Originally, NHS hospitals and private hospitals were to be treated as separate sub-sectors, but they were merged for reporting purposes reducing the risk of inaccurate sub-sector figures.
2. **Design – sampling** When comparing the weighted floor area by available bed number within the premises for NHS hospitals with the Estates Return Information Collection (ERIC) data, an annual survey on the health sector, it showed that the BEES sample over represented the largest hospital buildings. The weighted sample floor area indicated that 64 per cent of the floor area was in premises with more than 500 beds, whilst ERIC states it is only 43 per cent. For private hospitals and health centres no comparison datasets were available and therefore it was not possible to determine if the concentration in the top activity banding is an indication of bias.
3. **Design – sampling** The survey process required the respondent to select a premises which includes patient wards, in order to ensure that the premises selected was a 24 hour facility providing patient care. As a result, a small element of the hospital estate may have been excluded, depending on the nature of each respondent site or premises. The likely exclusions as a consequence of this filtering process are central plant rooms and energy centres, incinerators, estates facilities, and some ancillary buildings such as offices, central laundries, medical records and staff accommodation. This means that there may be an underestimate of the scale and variety of energy uses in the hospital sector.
4. **Data processing** Medical equipment consumption was based on limited input data given the diversity of the load, which includes consumption of a range of specialist equipment relating to the provision of medical care. In the energy use model, medical load was estimated based on a simple allowance for a range of medical equipment types and data was gathered in the telephone survey on the freqency at which these were used. These allowances were corroborated with the small sample of site surveys. The modelling of this end use was simplistic and this affects the accuracy of the total energy consumption calculations.

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 health sector.

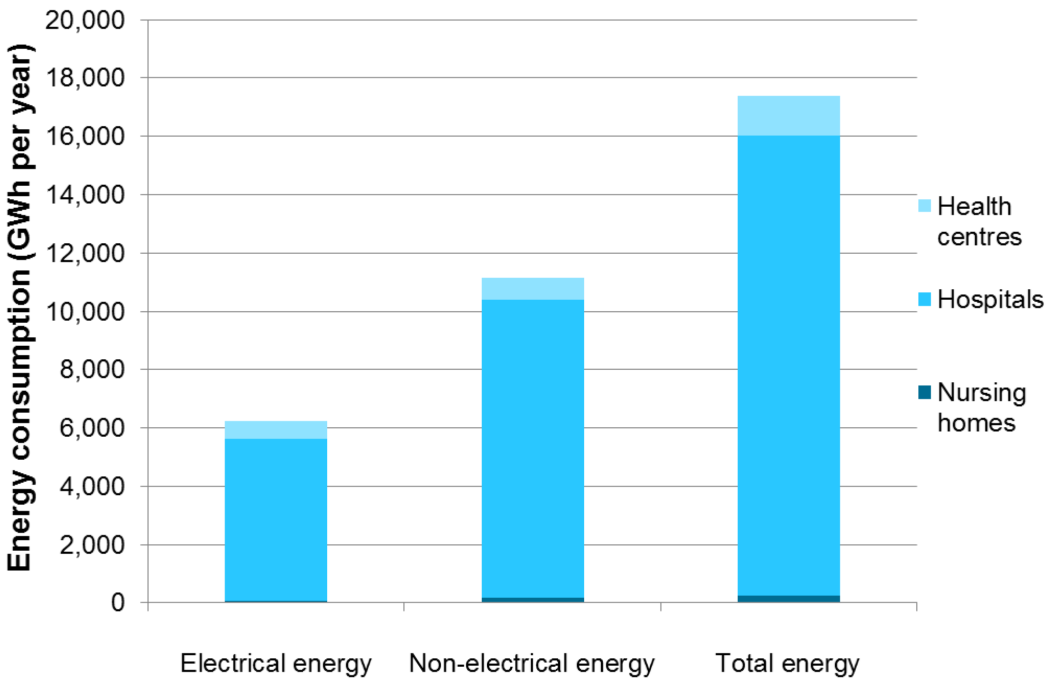
Energy consumption and greenhouse gas emissions in the health sector

The electrical and non-electrical energy consumption of the health sector is presented in Figure 3.1, broken down by the three health sub-sectors (health centres, hospitals and nursing homes).

The largest energy consumer in this sector was hospitals with a consumption of 15,780 GWh of energy (91 per cent of sector total). This was split between 5,550 GWh of electrical energy (89 per cent of sector total) and 10,230 GWh of non-electrical energy (92 per cent of sector total). The sub-sector is the largest consumer primarily because it had the largest floor area in the health sector and therefore was the most extensive (39 million m^2 for hospitals compared with 7 million m^2 for health centres and 0.6 million m^2 for nursing homes).

Health centres were the second largest consumer in the sector with a consumption of 1,340 GWh of energy (8 per cent of sector total). This consisted of 610 GWh of electrical energy consumption (10 per cent of sector total) and 730 GWh of non-electrical energy consumption (7 per cent of total). Nursing homes were the smallest consumer in the sector with 260 GWh of energy consumption, which was split into 80 GWh of electrical energy (1 per cent of sector total) and 180 GWh of non-electrical energy (2 per cent of sector total).

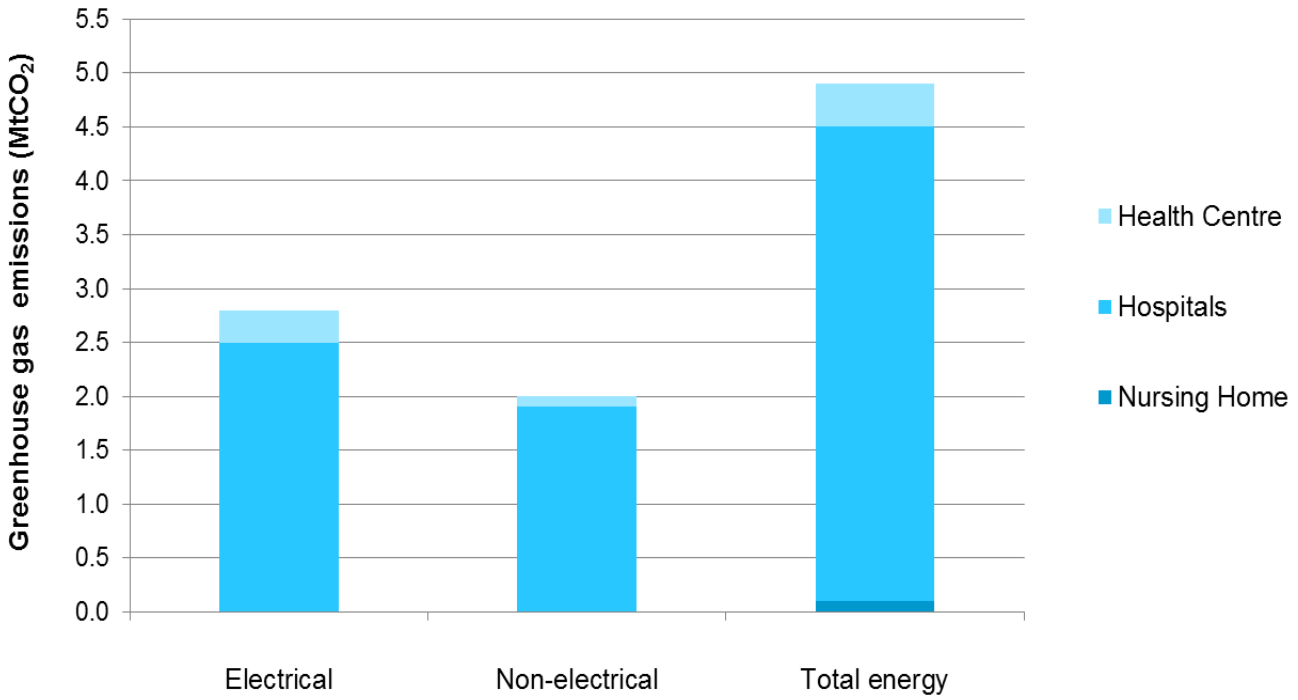
Figure 3.1: Electrical and non-electrical energy consumption by energy type and health sub-sector, 2014–2015



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

The greenhouse gas emissions for the health sector are presented in Figure 3.2.[22] The total greenhouse gas emissions from the health sector were deemed to be 4.9 $MtCO_2e$ per year. The annual emissions from electrical energy consumption were 2.8 $MtCO_2e$ and those from non-electrical energy consumption were 2.1 $MtCO_2e$.

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



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

Energy consumption by end use

The distribution of energy consumption by end use is presented in Figure 3.3 and Table 3.1.[23]

The energy use model defines 23 separate energy end uses in its analysis. These are derived by modelling the telephone survey inputs and calibrated using site survey data. For the purposes of presentation in Figure 3.3, 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 one custom category relevant to the sector (medical equipment). The simplified classification is shown against the more detailed classification results in Table 3.1.

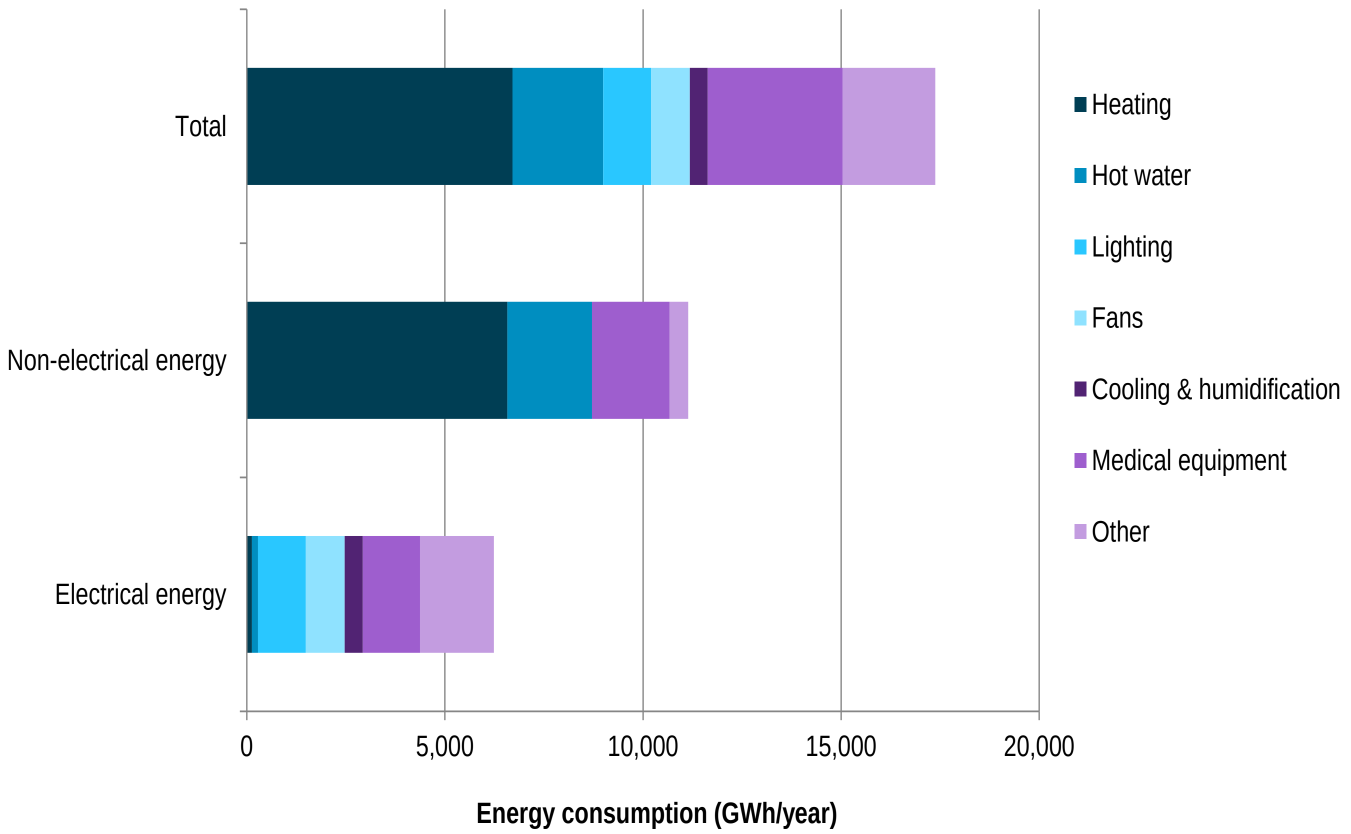
Further detail can be found in Appendix C on the 23 end uses and how these are re-categorised to the categories used in this sector report.

[22] 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.

[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.

The total energy consumption for the health sector was 17,380 GWh. The most significant end use was space heating (6,710 GWh, 39 per cent of total energy consumption), followed by medical equipment (3,410 GWh, 20 per cent of total). The most common end uses of electrical energy were medical equipment at 1,440 GWh (23 per cent of total), followed by internal lighting (1,210 GWh, 19 per cent). The next major end uses included fans (980 GWh, 16 per cent), small power (880 GWh, 14 per cent), and cooling & humidification (450 GWh, 7 per cent). The most significant non-electrical energy end uses were space heating at 4,330 GWh (59 per cent), followed by hot water (2,130 GWh, 19 per cent) and medical equipment (1,960 GWh, 18 per cent). Non-electrical energy consumption for heating was much higher than electrical energy consumption (6,580 GWh compared with 130 GWh).

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

Energy end use category (Simplified)	BEES end use category[24]	Electrical energy consumption (GWh/year)	Non-electrical energy consumption (GWh/year)	Total energy consumption (GWh/year)
Heating	Space heating	130	6,580	6,710
Hot water	Hot water	150	2,130	2,290
Lighting	Lighting - internal	1,210	-	1,210
Fans	Fans	980	-	980
Cooling & humidification	Space cooling	450	-	450
Medical equipment	Medical equipment	1,440	1,960	3,410
Other	Pumps	110	-	110
	Catering	300	390	690
	Cooled storage	50	-	50
	Controls	70	-	70
	Lighting - external	60	-	60
	Vertical transport	70	-	70
	Lighting - display	-	-	-
	Entertainment equipment	250	-	250
	Pool/leisure	1	10	10
	Small power	880	-	880
	ICT equipment	60	-	60
	Laundry	20	70	90
	Other	-	-	-
Total		**6,240**	**11,140**	**17,380**
Unweighted base		*166*	*162*	*166*

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

Health 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] Figures 3.4 to 3.6 present the distribution of energy intensity for all modelled records in each sub-sector within the health sector, in terms of total energy intensity, electrical energy intensity and non-electrical energy intensity respectively.[26] In this report all intensity figures (excluding box plots) have been

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

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

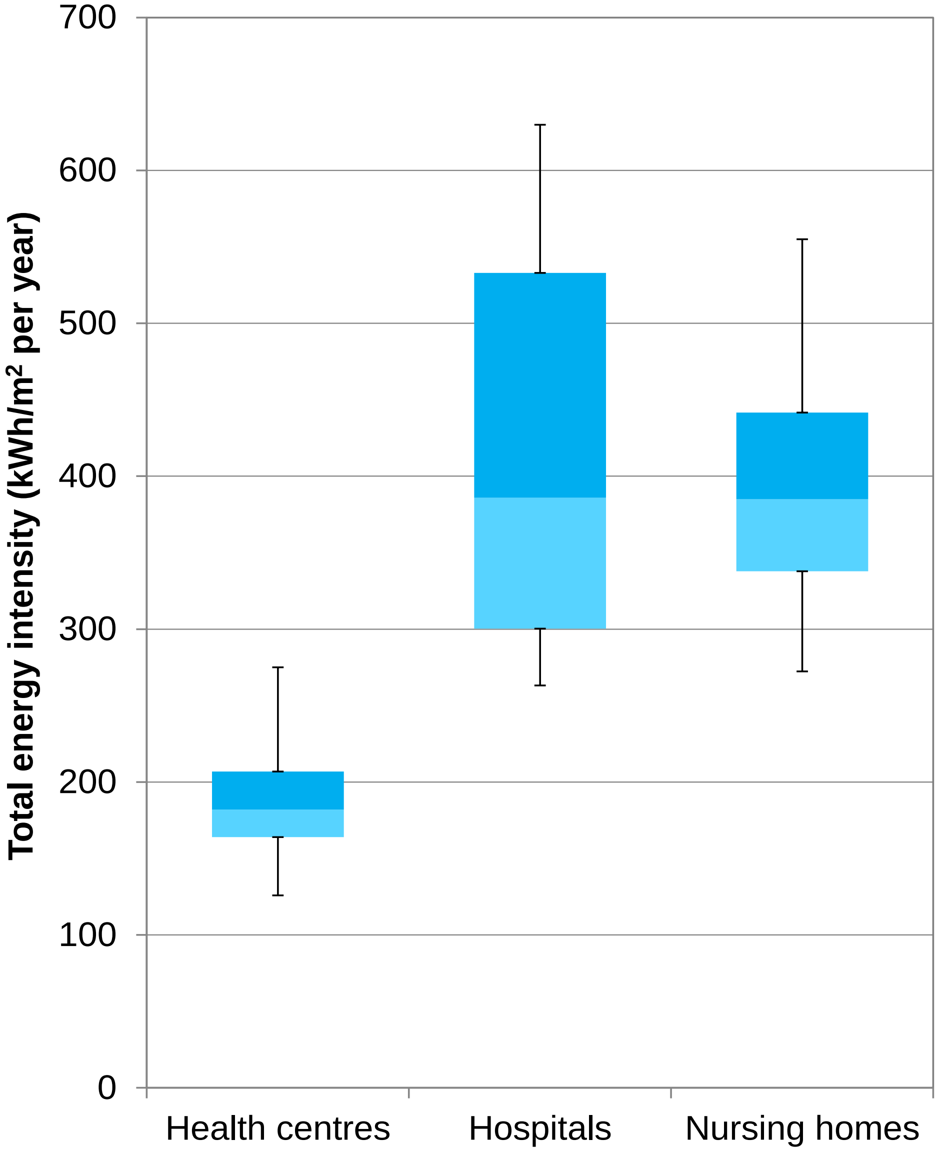
[26] Please note mean energy intensities are calculated by summing the total consumption associated with an end use and dividing it by the sub-sectors total floor area. The energy intensities for non-electrical uses are therefore based on the total population and do not make an allowance for where the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

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

Hospitals displayed the highest median total energy intensity (386 kWh/m^2), closely followed by nursing homes (385 kWh/m^2).

Hospitals typically displayed the highest median electrical energy intensity (124 kWh/m^2). The second most energy intensive sub-sector in terms of electrical energy was nursing homes (83 kWh/m^2). Nursing homes displayed the highest median non-electrical energy intensity of 292 kWh/m^2, followed by hospitals (255 kWh/m^2).

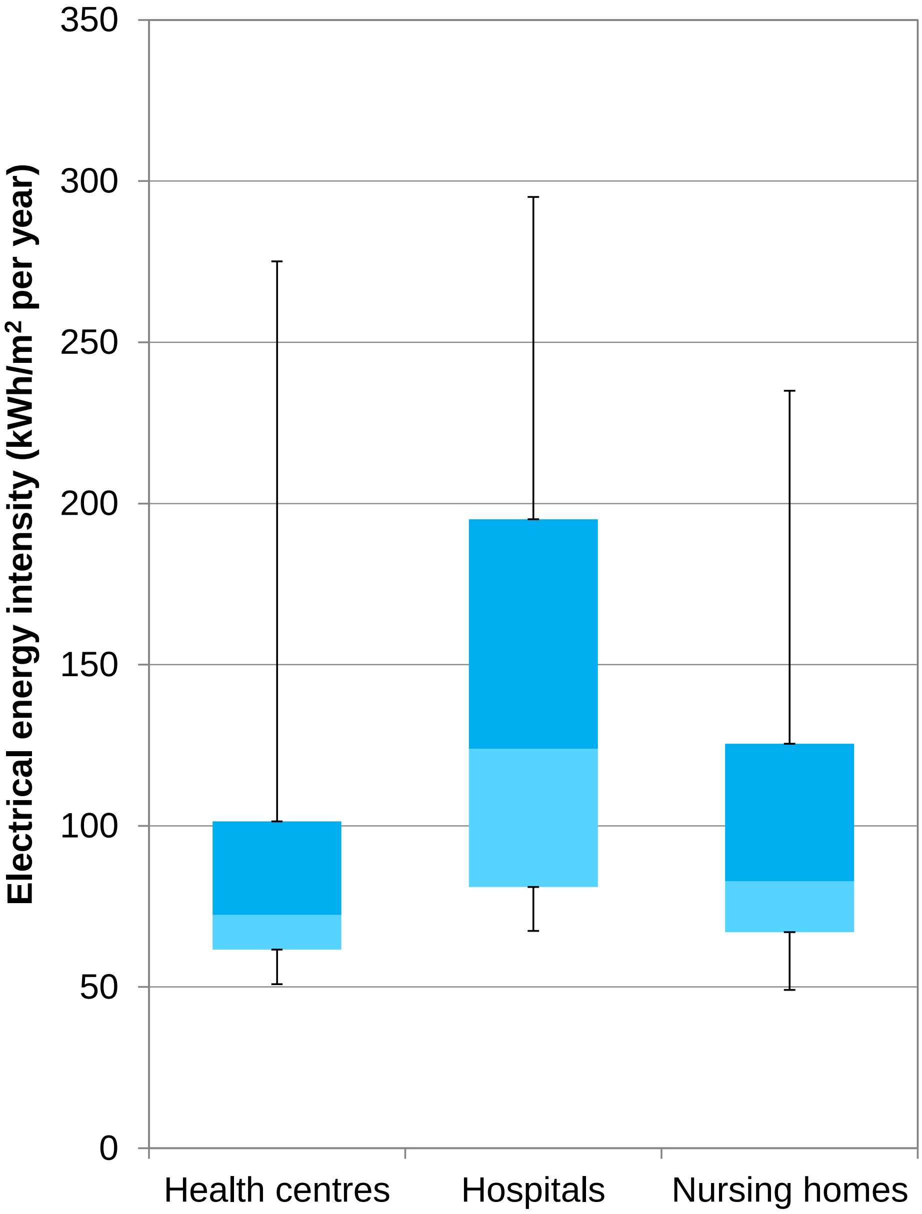
Figure 3.4: Distribution of total energy intensity by health sub-sector, 2014–15



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.

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

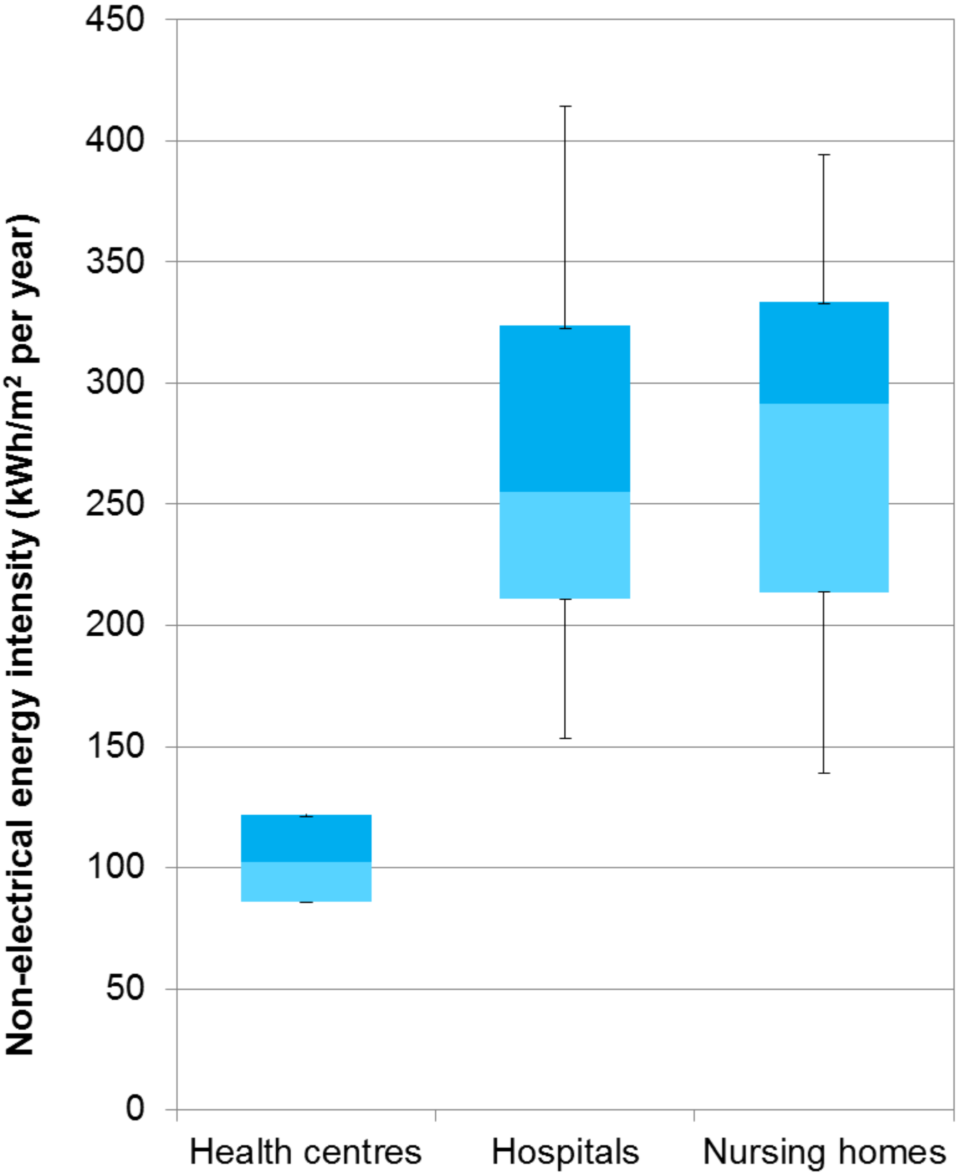
Figure 3.5: Distribution of electrical energy intensity by health sub-sector, 2014–15



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.

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

Figure 3.6: Distribution of non-electrical energy intensity by health 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.

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

Health 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 health sector. Further data is provided in Appendix C where energy consumption and energy intensity is provided separately for electrical and non-electrical energy end use breakdowns by sub-sector.

Heating energy intensity was notably higher in hospitals and nursing homes than in health centres. This was primarily due to hospitals' and nursing homes' 24 hour operation and high internal temperatures in ward areas, compared to health centres which typically operate weekday hours. Hot water intensity in hospitals and nursing homes was also high, driven by washing requirements for patients and high demand associated with clinical facilities such as operating theatres.

Medical equipment was an important end use in the sector. In order to estimate this intensity, the telephone survey collected data on the prevalence of a range of common energy intensive equipment and operating theatres. Due to the complexity and multi departmental nature of hospitals it was not possible to determine the operational hours of the different items, and assumptions had to be used; these numbers are therefore presented at a lower confidence level.

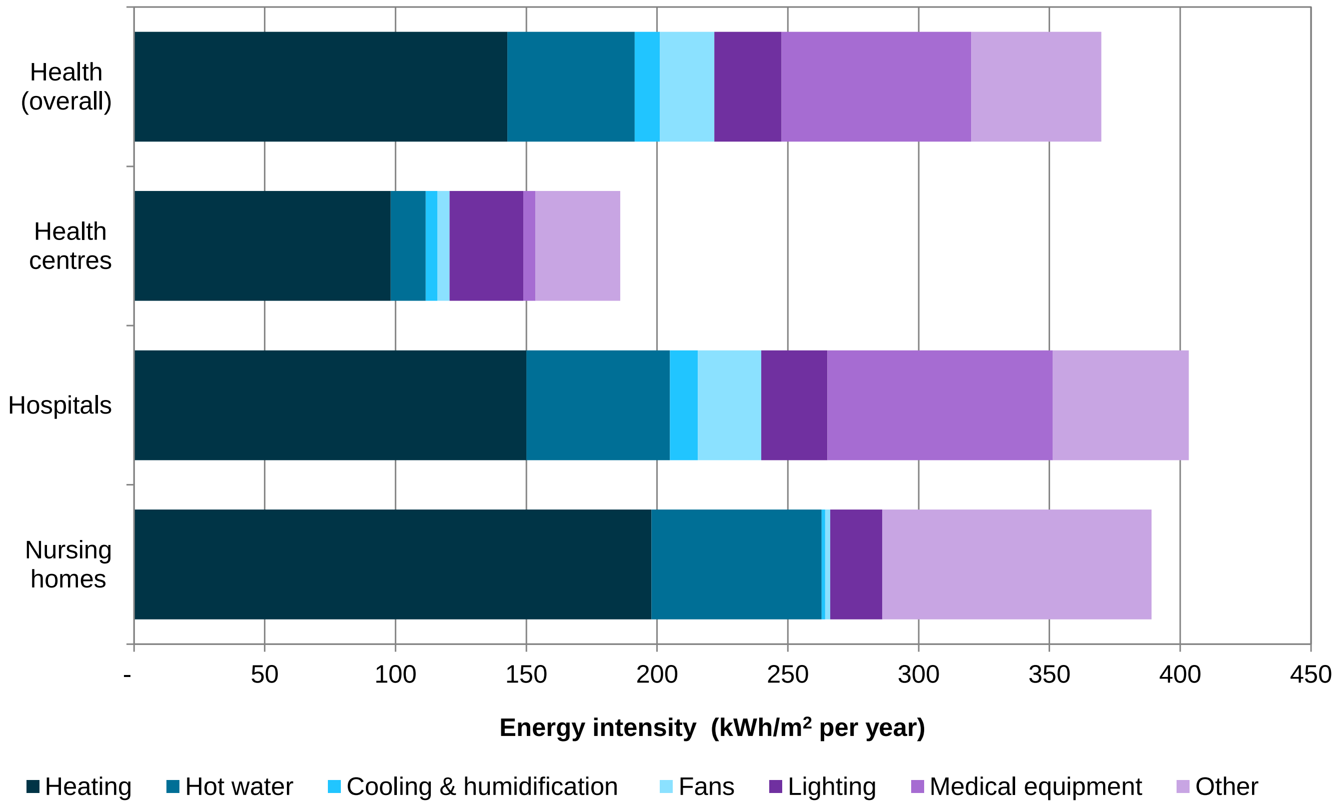
Cooling & humidification and fans were significant end uses in hospitals. This is because these premises are often located in large deep plan buildings[27] where natural ventilation cannot be used to adequately ventilate and condition internal spaces. Specialist facilities such as operating theatres and laboratories also require sophisticated mechanical ventilation systems. Conversely, nursing homes and health centres tended to be in smaller buildings where natural ventilation was common.

Lighting energy intensity was significant in all sub-sectors. In health centres the intensity was high; site surveys indicated a tendency for consulting rooms and small office spaces to be overlit, resulting in high energy intensity despite shorter operating hours. In hospitals, there were fewer areas with high lighting levels, and larger spaces such as wards and corridors were less likely to be overlit, reducing overall intensity despite the long hours of use. Site survey results also identified that large-scale programmes to replace lamps in lighting fittings have been undertaken or commenced in NHS hospitals in recent years, which also reduced intensity in this sub-sector.

Catering was present in many of the buildings in the health sector, and this makes up a significant element of the "other" end use identified in the BEES study. This was particularly the case for nursing homes.

[27] A deep plan building is a building in which the horizontal distance from the external wall is many times greater than the floor to floor height. Buildings of this sort generally require mechanical ventilation as natural ventilation is less effective. If there are high incidental heat gains, or the width is very large, then additional air-conditioning may be required.

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



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

4. Abatement potential

In this section, abatement potential[28] for the health sector is considered. Abatement potential is calculated on 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[29], while the benefits were only based on the incremental reduction in energy consumption[30]. Replacement of systems which were not at the end of their life were therefore included, but will be more expensive, as the impact on energy consumption is likely to be smaller for new equipment, while the full capital costs are taken into account. This means that a measure may be cost-effective if the system is replaced at the end of its life – especially as at the end of life the cost of the more energy efficient alternative would be compared to replacement with a less efficient alternative - but, the same measure may not be cost-effective if the system is replaced earlier in its life. Replacing measures at the end of life will be less costly for organisations, but it would take longer for the full potential to be realised. While the costs include an allowance for installation costs and hassle costs, this may not 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

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

[29] 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.

[30] 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 health sector throughout England and Wales.

Total technical abatement potential for health sector

The abatement potential for each sub-sector where it is available is shown in Table 4.1 and Figure 4.1. The total abatement potential was between 40 and 50 per cent of total energy consumption[31]. Each sub-sector can achieve between 30 to 42 per cent savings in electrical energy consumption and 41 to 56 per cent savings in non-electrical energy consumption. This could be achieved at an overall capital expenditure of £1.7 billion.

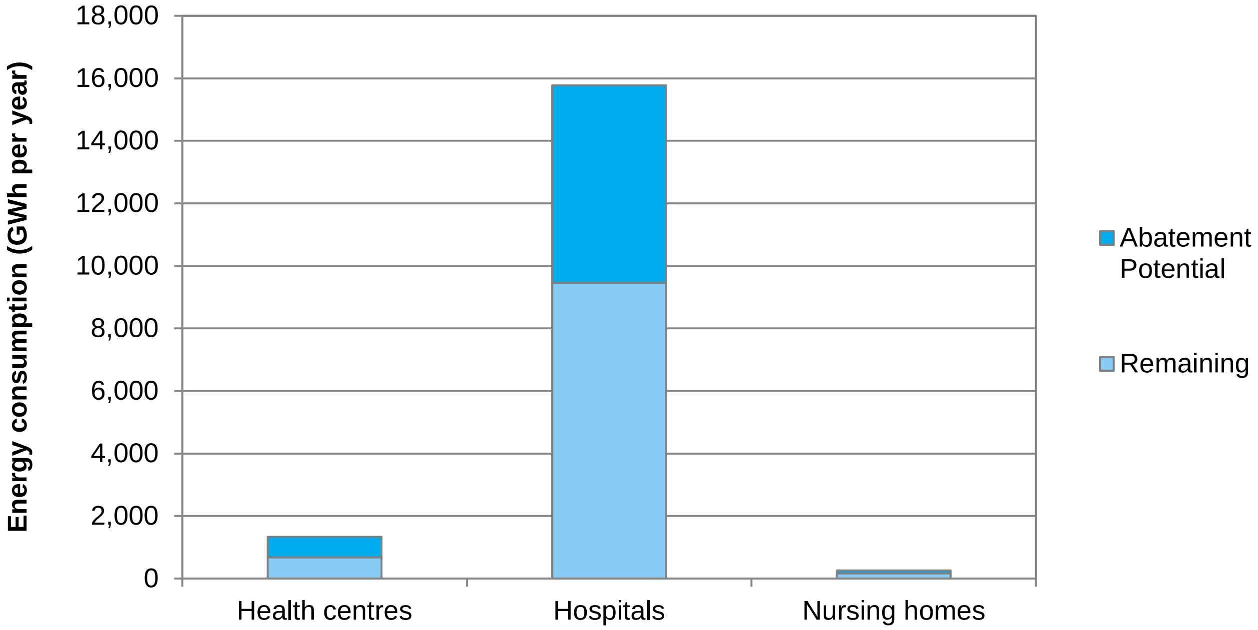
Table 4.1: Total abatement potential by health sub-sector, 2014–15

Sub-sector	Capital Expenditure required to deliver abatement potential (£ thousands)	Baseline energy consumption (Energy Use model)		Total abatement potential		
		Annual electrical energy consumption (GWh)	Annual non-electrical energy consumption (GWh)	Annual electrical energy savings (GWh)	Annual non-electrical energy savings (GWh)	Overall reduction (per cent)
Health centres	236,300	610	730	260	410	50
Hospitals	1,437,300	5,550	10,230	2,070	4,240	40
Nursing homes	21,900	80	180	20	80	40
Total	**1,695,600**	**6,240**	**11,140**	**2,350**	**4,730**	**41**

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

[31] 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: Abatement potential by health sub-sector, 2014–15

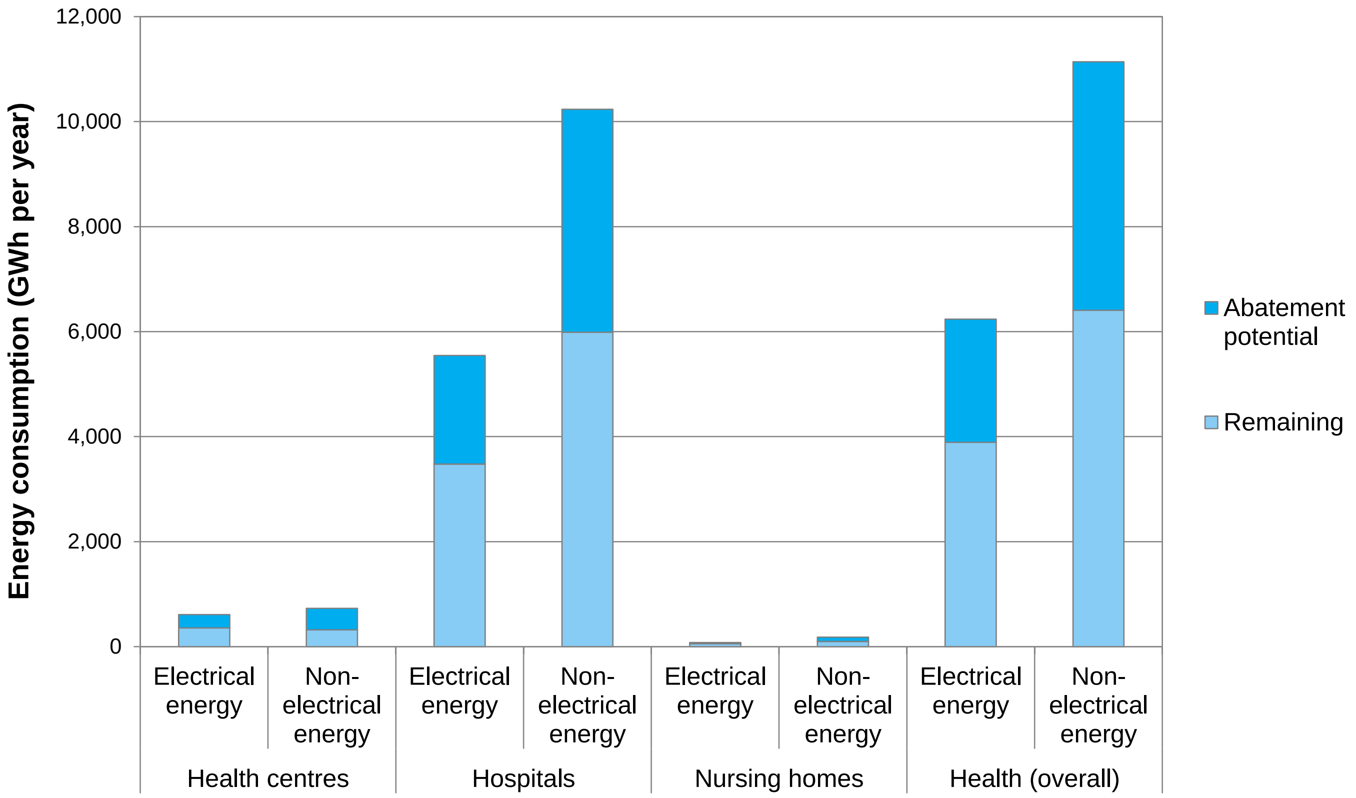


Source: Abatement model results by sub-sector, England and Wales

Figure 4.2 shows that the abatement potential in 2014–15 varied by sub-sector: health centres had the largest proportional scope for reduction (50 per cent of total energy consumption overall). This compared with 40 per cent in both hospitals and nursing homes. The relatively low reductions for hospitals was due in part to the high level of medical equipment energy use in this sub-sector and the limitations in the abatement model relating to the calculation of medical equipment energy abatement measures. The only measures assumed to be applicable to medical equipment were general carbon and energy management measures. 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 more abatement potential associated from 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 the associated savings from related abatement measures, including building instrumentation and controls.

Figure 4.2: Abatement potential by energy type and health 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.[32] 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 costs from a societal perspective, we have supplemented this by providing the simple private payback periods for each measure group to help show how attractive these measures might be for individual organisations on the basis of how long it takes to recoup the costs of measures undertaken from the energy savings generated. Note that the payback period reflects the gross bill savings of the measure alone, rather than the bill savings that would be achieved by the measure if all other measures were installed.

The total abatement potential of the socially cost effective measure groups was 4,430 GWh, of which 1,500 GWh was electrical energy consumption and 2,930 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 4,020 GWh, of which 1,480 GWh was electrical energy consumption and 2,540 GWh non-electrical energy consumption. Within each group of measures there will be some measures that are more cost-effective than others for each sub-sector. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole. Similarly the aggregation of measure groups from the sub-sector level to the sector level may hide measure groups that are cost effective in a particular sub-sector, but not for the sector as a whole.

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

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

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

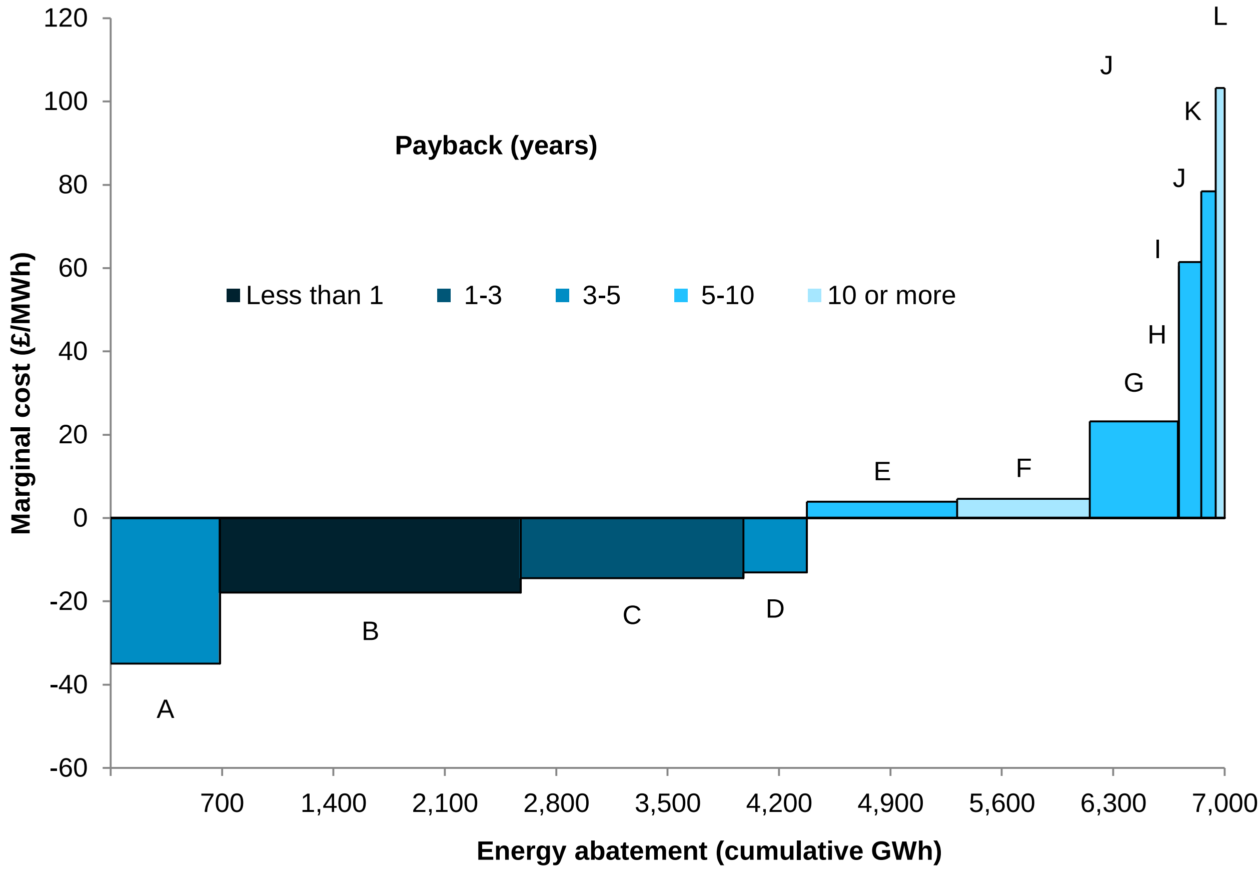
Figure 4.3 shows the marginal abatement cost and total abatement potential of each measure type for the health sector. This shows how different measures contribute to the overall abatement potential (x-axis) and the net unit cost to society of implementing the measures (y-axis).

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

Lighting upgrades to LEDs were identified in the majority of the surveys, despite the commencement of NHS programmes to replace lamps in light fittings, as discussed in section 3: Health sub-sector energy end use breakdowns. On a few sites there were significant boiler replacements opportunities due to the age of the current plant. There was also scope for improved use of zonal heating and cooling control and investment in staff awareness and training on energy consumption.

In some cases, site surveys identified opportunities and potential different to that identified in the modelled output for a record. Typically this would be the case where an exceptional site characteristic had been identified related to information which had not been gathered in the telephone survey. On one premises, there was extensive use of natural daylight which meant that lighting upgrade savings had been overstated. On another premises there were portions of the building that were unoccupied and hence the savings potential was lower than originally modelled.

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 Lighting [MAC: £-45 per MWh. GWh: 690]

B Carbon and Energy Management [MAC: £-18 per MWh. GWh: 1,920]

C Building instrumentation and control [MAC: £-14 per MWh. GWh: 1,420]

D Hot water [MAC: £-13 per MWh. GWh: 410]

E Space heating [MAC: £4 per MWh. GWh: 960]

F Building fabric [MAC: £5 per MWh. GWh: 840]

G Cooled storage [MAC: £23 per MWh. GWh: 4]

H Ventilation [MAC: £23 per MWh. GWh: 560]

I Swimming pools [MAC: £60 per MWh. GWh: 2]

J Air conditioning and cooling [MAC: £61 per MWh. GWh: 140]

K Building services distribution systems [MAC: £78 per MWh. GWh: 100]

L Small appliances [MAC: £103 per MWh. GWh: 50]

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

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

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

Measure type	Savings					Total capital cost of measure (£ thousands)
	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	
Air conditioning and cooling	14,200	40	140	-	140	123,600
Building fabric	23,100	160	20	820	840	495,700
Building instrumentation and control	45,000	280	120	1,300	1,420	123,800
Building services distribution systems	9,400	30	100	-	100	62,600
Carbon and Energy Management	98,200	450	670	1,250	1,920	71,500
Hot water	11,300	80	10	390	410	53,800
Humidification	-	-	-	-	-	-
Lighting	68,700	200	690	-	690	206,600
Cooled storage	400	1	4	-	4	1,800
Small appliances	2,300	10	10	40	50	37,700
Space heating	25,500	180	20	940	960	165,900
Swimming pools	100	0	0	2	2	800
Ventilation	55,400	170	560	0	560	351,800
Total	**353,700**	**1,570**	**2,350**	**4,730**	**7,080**	**1,695,600**

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 sector for electrical energy intensity and non-electrical energy intensity by sub-sector are provided, and the the telephone survey response rates by sub-sector.

Confidence intervals

Table A.1: Confidence intervals for electrical energy intensity

	Mean (kWh/m^2)	Confidence interval (kWH/m^2)
Health centres	85	± 16
Hospitals	142	± 18
Nursing homes	120	± 27
Health	**133**	**± 15**

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

	Mean (kWh/m^2)	Confidence interval (kWH/m^2)
Health centres	101	± 18
Hospitals	262	± 23
Nursing homes	269	± 39
Health	**237**	**± 23**

Response rates

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

	Health centres (%)	Hospitals (%)	Nursing homes (%)	**Health sector (%)**
Completed interview	11	9	10	10
Still live[34]	50	22	68	43
Screening failure/other non-response[35]	0	0	1	0
Refusal	10	3	10	7
Other non-response	3	2	4	3
Invalid contact details	27	63	8	36

[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: Health method challenges and data collection

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

Health sector methodology challenges

In the case of the health 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: Health sector approach challenges

Stage	Challenge	Response	Impact
Design - sampling	No source dataset incorporating floor area or energy data was available for private hospitals.	The sample for private hospitals was taken from a directory of private hospitals in the UK, and respondents were asked for their floor area and energy data in the telephone survey.	The team could not stratify the sample in order to ensure that a mixture of large/medium/small floor area and high/medium/low energy intensity records were included in the telephone survey.
Design - sampling	When comparing the weighted floor area by available bed numbers within the premises for NHS hospitals with the Estates Return Information Collection (ERIC) data, an annual survey on the health sector, it showed that the BEES sample over-represented the largest hospital buildings. The weighted sample floor area indicated that 64 per cent of the floor area was in premises with more than 500 beds, whilst ERIC states it is only 43 per cent.	The results for NHS hospitals (part of the 'hospital's sub-sector) can therefore be caveated with a known degree of bias.	A source of bias has been identified but the impact has not been quantified therefore it can only be noted at this stage.

Stage	Challenge	Response	Impact
Design - sampling	The BEES survey process requires the respondent to select a premises which includes patient wards, in order to ensure that the premises selected is a 24 hour facility providing patient care. As a result, a small element of the hospital estate may have been excluded, depending on the nature of each respondent site or premises. Likely exclusions as a consequence of this filtering process are central plant rooms and energy centres, incinerators, estates facilities, and some ancillary buildings such as offices, central laundries, medical records and staff accommodation.	Without robust statistics to support the make-up of the excluded building types, there was no way to directly address this issue in the modelling.	The overall energy end use breakdown within the hospitals and health centres sub-sectors may feature some end uses less prominently than in reality. For example, laundry facilities may be under-represented.
Design - sampling	No comprehensive, reliable sampling frame incorporating floor area data was available for nursing homes.	Nursing homes were contacted from a list obtained from the Nursing Homes Association. Floor area for each record was estimated based on number of bedrooms, derived from the total area for floor homes which had provided a total floor area for their building.	The lack of a reliable floor area figure also affected confidence in model calibration procedures.
Data collection	There was very limited accuracy in estimation of medical equipment loads in hospitals based on telephone survey data. The telephone survey only collected data on the number of a selection of key items of equipment and number of operating theatres. Hours of use were only collected for the main operating theatres.	A dedicated medical equipment spreadsheet tool was used to estimate medical equipment loads based on the limited data from the site surveys and direct research on equipment ratings. A fixed rating for each reported item had to be used e.g. 60kW per MRI scanner present.	At individual record level, the medical equipment estimates are presented with low confidence. As a result higher individual and overall variances were anticipated in hospitals than in many other sub-sectors and this was observed in the data in the majority of cases. Private hospitals reported higher

Stage	Challenge	Response	Impact
	In practice, such equipment can be obtained in a wide range of power ratings. Within the limitations of the project it was not possible to identify a key metric (such as floor area, number of staff) and an appropriate scaling factor (e.g. 1 computer per staff member) in the telephone survey as a basis for scaling the total load for each equipment item. This was due to the highly specialist nature of different areas/departments present, and the fact that a facility (e.g. sterile services) may serve a greater area than just the building identified in the telephone survey.	Assumed hours of use (linked to building hours, normal daytime hours or 24/7) were employed for each item.	quantities of specialist medical equipment relative to floor area. As a consequence their energy consumption for medical equipment was much higher. It is possible that the equipment is used less often, and that the model is exaggerating consumption in this sub-sector.
Data collection	The size and complexity of NHS hospitals and private hospitals created challenges for the site survey method, as full equipment inventories and usage information could not be obtained. In particular, obtaining power ratings for medical equipment were challenging to gather.	Prioritisation of highly energy intensive equipment and sampling approaches were undertaken where necessary for the completion of site audits. Where site surveys yielded insufficient information to inform model calibration, estimates of equipment ratings were required.	The site survey process did not yield confirmation of typical ratings for all the high energy equipment types identified in the sub-sector specific questions for hospitals. When analysing the telephone survey responses, estimates for equipment ratings and hours of use were required in order to complete the modelling process.
Data processing	NHS hospital and private hospital premises were often multi-building campuses, such that match data sources could not be related directly to the premises the respondent selected for the telephone survey.	Where respondents identified the presence of more than one building in the telephone survey, these records were isolated during the calibration analysis.	The calibration process suffered some limitations in this sub-sector due to match data uncertainty. Calibration of the model was undertaken based on the records with the greatest match data confidence i.e. those

Stage	Challenge	Response	Impact
			where energy data could be linked specifically to the premises in the telephone survey.
Data processing	Uptake of site surveys was limited in nursing homes.	Low confidence levels were attributed to end use energy predictions in this sub-sector.	This reduced the extent to which modelling assumptions could be verified, reducing confidence in end use energy predictions.
Data processing	Nursing homes calibration analysis was restricted by three issues: 1: Floor areas were derived based on the number of bedrooms 2: Limited matched energy data provided was estimated by respondents and heavily rounded; quality of estimates was suspect 3: Only two site surveys could be scheduled; both of these were for young people’s care homes which were not “typical” of nursing homes in general	On review of the available dataset, a decision was made to calibrate the energy model based on the Display Energy Certificate data for nursing homes, which is considered robust. Neither the record floor area or respondent energy data estimates collected in the BEES survey were considered reliable for calibration purposes. This gives confidence in the overall model output for electrical and thermal energy use, but limits confidence in end use energy estimates.	Nursing homes were relatively simple premises to model, and the pre-calibration model estimate was noted to be close to the DEC median value without adjustment. However, it should be noted that the breakdown of energy by end use has not been verified against site survey data, so this is presented with lower confidence than data for sub-sectors following the ’standard’ approach.

Telephone survey and site survey data collection

Table B.2 shows that 166 telephone survey or equivalent records and 13 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
Health centres	61	62	0	62	52	23	5	4
Hospitals	70	72	0	72	57	32	8	7
Nursing homes	50	58	-	58	57	25	3	2
Health sector	**181**	**192**	**0**	**192**	**166**	**27**	**16**	**13**

Source: Telephone survey or equivalent records, England and Wales

[36] See section 2: Method 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 health 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.
7	**Humidification**	All humidification plant used to provide humidification for general building services including ventilation and air conditioning but excluding special energy uses such as swimming pool de-humidification.
8	**Lighting – internal**	All general internal lighting including task lights and emergency lights.

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

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

The energy end uses have been grouped for the purpose of presentation in the report. The groupings are set out in Table C.2 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
	Medical equipment	Medical equipment
	Central catering	Other
	Distributed catering	Other
	Small power	Other
	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
	Medical equipment	Medical equipment
	Catering	Other
	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 health sub-sector and for the sector combined. Tables C.5 and C.6 show energy intensity by end use for each health sub-sector and for the sector combined.

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

Simplified end use category	**BEES end use category**	**Electrical energy consumption (GWh per year)**			
		Health centres	Hospitals	Nursing homes	**Health sector**
Heating	Space heating	60	60	10	130
Hot water	Hot water	20	120	10	150
Cooling & humidification	Space cooling	30	420	1	450
Fans	Fans	30	950	1	980
Lighting	Lighting - internal	200	990	10	1,210
Medical equipment	Medical equipment	30	1,410	0	1,440
Other	ICT equipment	2	60	1	60
	Cooled storage	20	30	0	50
	Small power	150	730	1	880
	Pumps	10	100	2	110
	Controls	8	60	1	70
	Humidification	-	-	-	-
	Laundry	0	9	10	20
	Lighting - display	-	-	-	-
	Lighting - external	-	60	3	60
	Entertainment lighting	-	-	-	-
	Vertical transport	9	60	1	70
	Distributed catering	20	140	1	160
	Central catering	1	120	20	140
	Entertainment equipment	20	230	1	250
	Lab equipment	-	-	-	-
	Pool/leisure	-	1	-	1
	Other	-	-	-	-
Total		**610**	**5,550**	**80**	**6,240**
Unweighted base		*52*	*57*	*57*	*166*

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

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

Simplified end use category	BEES energy end use category	Non-electrical energy consumption (GWh per year)			
		Health centres	Hospitals	Nursing homes	**Health sector**
Heating	Space heating	650	5,810	120	6,580
Hot water	Hot water	80	2,030	30	2,130
Catering	Catering	1	360	30	390
Medical equipment	Medical equipment	-	1,960	-	1,960
Other	Pool/leisure	-	10	-	10
	Laundry	-	70	-	70
Total		**730**	**10,230**	**180**	**11,140**
Unweighted base		*48*	*57*	*57*	*162*

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

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

Simplified end use category	BEES end use category	Electrical energy intensity (kWh/m^2 per year)			
		Health centres	Hospitals	Nursing homes	**Health sector**
Heating	Space heating	8	2	19	3
Hot water	Hot water	3	3	17	3
Cooling & humidification	Space cooling	4	11	1	10
Fans	Fans	5	24	2	21
Lighting	Lighting - internal	28	25	20	26
Medical equipment	Medical equipment	5	36	0	31
Other	ICT equipment	0	1	2	1
	Cooled storage	3	1	1	1
	Small power	20	19	1	19
	Pumps	2	3	3	2
	Controls	1	1	1	1
	Humidification	-	-	-	-
	Laundry	0	0	19	0
	Lighting - display	-	-	-	-
	Lighting - external	-	1	4	1
	Entertainment lighting	-	-	-	-
	Vertical transport	1	2	2	2
	Distributed catering	2	4	2	3
	Central catering	0	3	24	3
	Entertainment equipment	2	6	2	5
	Lab equipment	-	-	-	-
	Pool/leisure	-	0	-	0
	Other - normal	-	-	-	-
	Total	**85**	**142**	**120**	**133**
Unweighted base		*52*	*57*	*57*	***166***

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

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

Simplified end use category	BEES energy end use category	Non-electrical energy intensity (kWh/m^2 per year)			
		Health centres	Hospitals	Nursing homes	**Health sector**
Heating	Space heating	90	148	179	140
Hot water	Hot water	11	52	48	45
Catering	Catering	0	9	42	8
Medical equipment	Medical equipment	-	50	0	42
Other	Pool/leisure	-	0	-	0
	Laundry	-	2	-	1
	Total	**101**	**262**	**269**	**237**
Unweighted base[37]		*52*	*57*	*57*	***166***

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 health 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).

Health centres

In health centres there was an annual abatement potential of 260 GWh of electrical energy and 410 GWh of non-electrical energy (equivalent to 150 ktCO_2e combined). This equates to a 42 per cent and 56 per cent reduction on energy consumption respectively. The capital cost to achieve this is £236m. The annual savings delivered would be £36m.[38] These figures are grouped according to measure types in D.2. The total abatement potential of the socially cost effective measure groups was 120 GWh, all of which was electrical energy consumption. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. The total abatement potential relating to measure groups with a private payback of 3 years or less was 290 GWh, of which 180 GWh was electrical energy consumption and 110 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.1).

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

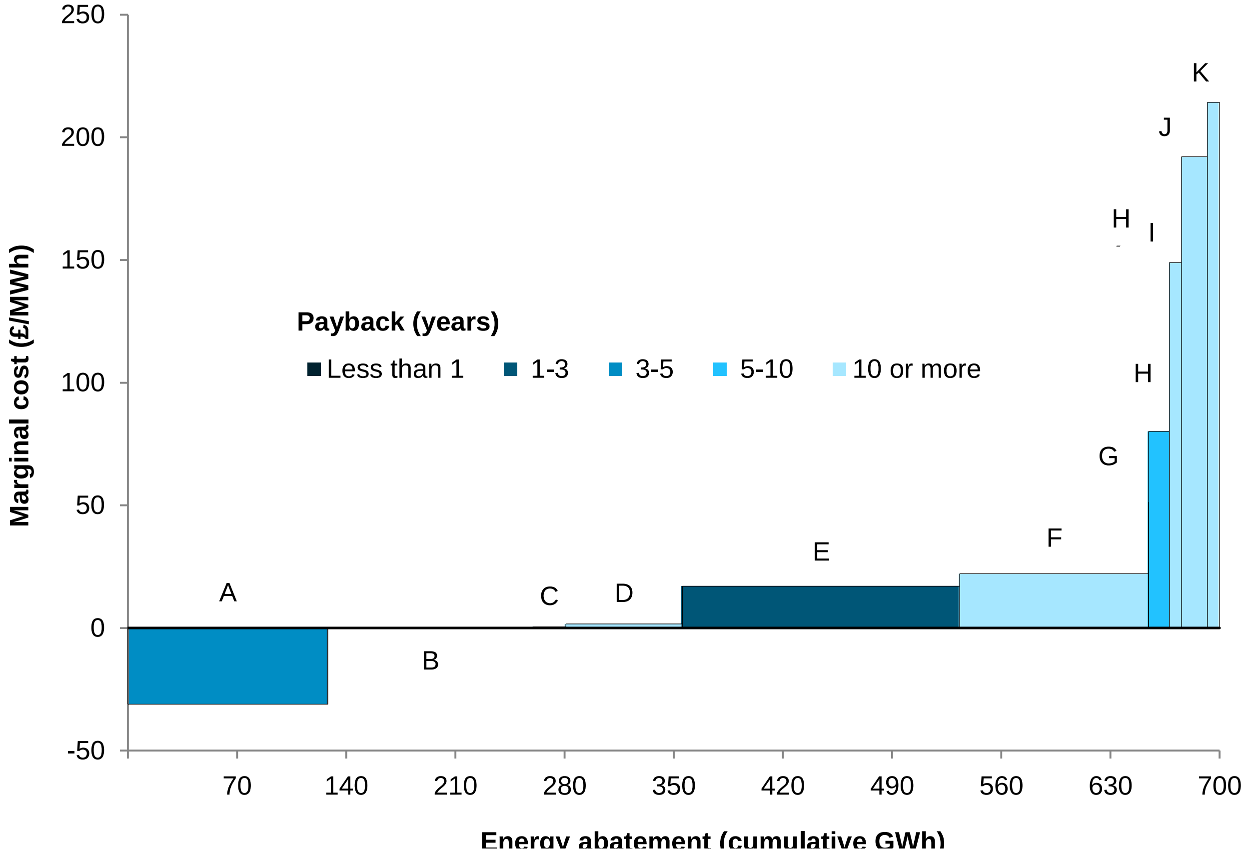
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving (ktCO_2e)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Payback period (years)**[39]
Air conditioning and cooling	700	2	7	-	7	13,000	19
Building fabric	2,200	10	5	70	70	34,500	10
Building instrumentation and control	4,200	30	20	110	130	24,600	4
Building services distribution systems	1,200	4	10	-	10	8,800	5
Carbon and energy management	8,900	40	60	110	170	19,200	2
Hot water	700	4	3	20	20	6,100	7
Humidification	-	-	-	-	-	-	-
Lighting	12,100	30	120	-	120	41,500	3
Cooled storage	0	0	0	-	0	0	5
Small appliances	600	2	6	1	7	10,100	12
Space heating	3,400	20	7	110	120	51,300	13
Swimming pools	-	-	-	-	-	-	-
Ventilation	1,600	5	20	-	20	27,100	11
Total	**35,700**	**150**	**260**	**410**	**660**	**236,300**	‘’

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 health 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: £-31 per MWh. GWh: 120]

B Building instrumentation and control . [MAC: £0 per MWh. GWh: 130]

C Hot water [MAC: £1 per MWh. GWh: 20]

D Building fabric [MAC: £2 per MWh. GWh: 70]

E Carbon and Energy Management [MAC: £17 per MWh. GWh: 170]

F Space heating [MAC: £22 per MWh. GWh: 120]

G Refrigeration [MAC: £51 per MWh. GWh: 0]

H Building services distribution systems [MAC: £80 per MWh. GWh: 10]

I Air conditioning and cooling [MAC: £149 per MWh. GWh: 7]

J Ventilation [MAC: £192 per MWh. GWh: 20]

K Small appliances [MAC: £214 per MWh. GWh: 7]

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

Hospitals

In hospitals there was an annual abatement potential of 2,070 GWh of electrical energy and 4,240 GWh of non-electrical energy (equivalent to 1,400 $ktCO_2e$ combined). This equates to a 37 per cent and 41 per cent reduction on energy consumption respectively. The capital cost to achieve this is £1.4bn. The annual savings delivered would be £314m.[40] These figures are grouped according to measure types in Table D.3.The total abatement potential of the socially cost effective measure groups was 3,920 GWh, of which 1,270 GWh was electrical energy consumption and 2,620 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 3,540 GWh, of which 1,260 GWh was electrical energy consumption and 2,280 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 hospitals, 2014–15

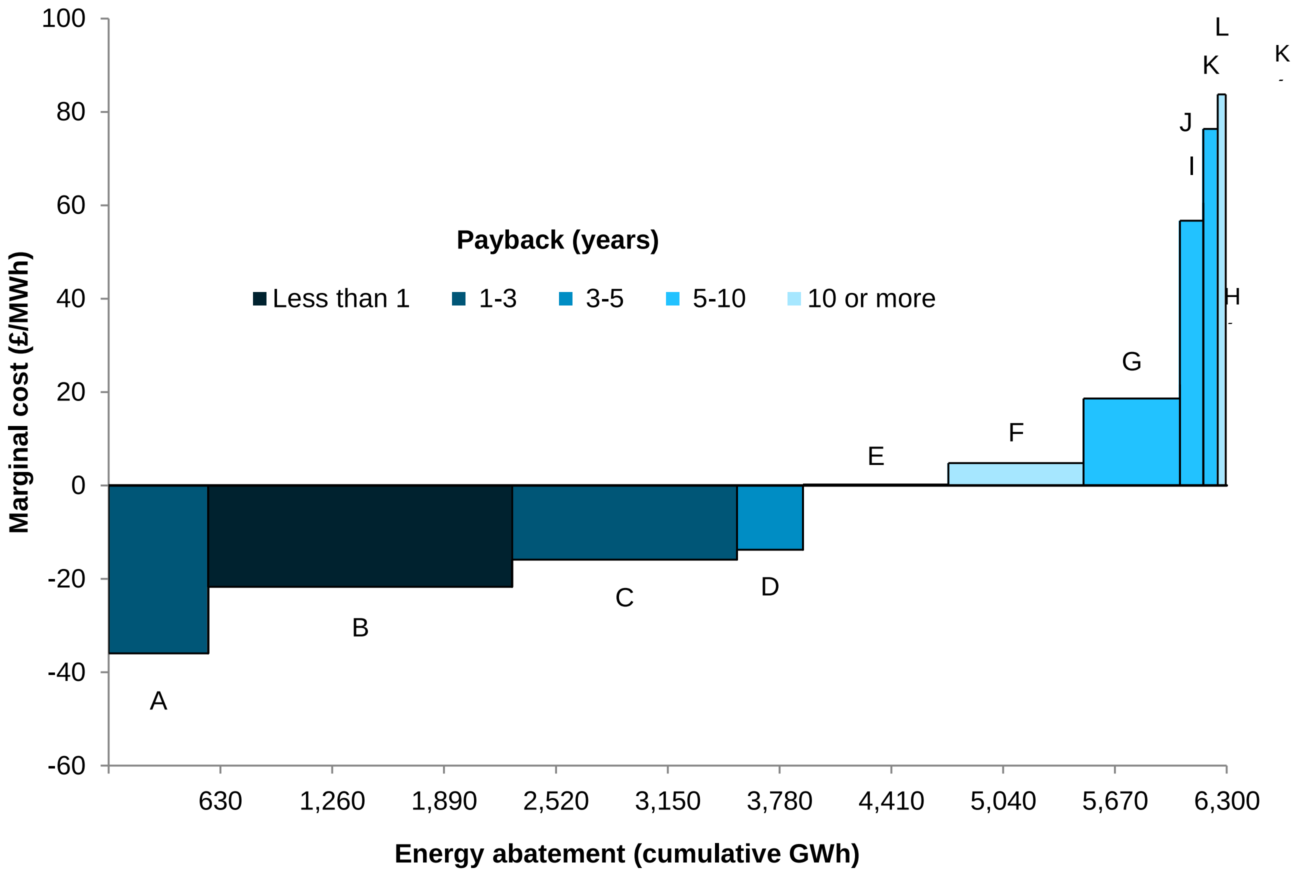
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousand)**	**Pay-back period (years)**[41]
Air conditioning and cooling	13,500	40	140	-	140	110,300	9
Building fabric	20,700	140	20	750	760	456,800	12
Building instrumentation and control	39,900	250	100	1,160	1,270	97,400	2
Building services distribution systems	8,200	30	80	-	80	52,700	5
Carbon and energy management	88,000	400	600	1,120	1,720	51,000	1
Hot water	10,300	70	10	370	380	46,300	4
Humidification	-	-	-	-	-	-	-
Lighting	55,800	160	560	-	560	161,400	2
Cooled storage	300	1	3	-	3	1,300	4
Small appliances	1,600	9	6	40	50	26,600	10
Space heating	21,600	150	8	820	820	109,000	4
Swimming pools	100	0	0	2	2	800	8
Ventilation	53,800	160	540	-	540	323,900	3
Total	**313,600**	**1,400**	**2,070**	**4,240**	**6,310**	**1,437,300**	‘’

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 hospitals, 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: £-36 per MWh. GWh: 560]

B Carbon and Energy Management [MAC: £-22 per MWh. GWh: 1,720]

C Building instrumentation and control [MAC: £-16 per MWh. GWh: 1,270]

D Hot water [MAC: £-14 per MWh. GWh: 380]

E Space heating .[MAC: £0 per MWh. GWh: 820]

F Building fabric [MAC: £5 per MWh. GWh: 760]

G Ventilation [MAC: £19 per MWh. GWh: 540]

H Refrigeration [MAC: £22 per MWh. GWh: 3]

I Air conditioning and cooling [MAC: £57 per MWh. GWh: 140]

J Swimming pools [MAC: £60 per MWh. GWh: 2]

K Building services distribution systems [MAC: £76 per MWh. GWh: 80]

L Small appliances [MAC: £84 per MWh. GWh: 50]

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

Nursing homes

In nursing homes there was an annual abatement potential of 30 GWh of electrical energy and 80 GWh of non-electrical energy (equivalent to 20 $ktCO_2e$ combined). This equates to a 30 per cent and 44 per cent reduction on energy consumption respectively. The capital cost to achieve this is £22m. The annual savings delivered would be £4m[42]. These figures are grouped according to measure types in Table D.4. The total abatement potential of the socially cost effective measure groups was 80 GWh, of which 20 GWh was electrical energy consumption and 60 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 20 GWh was electrical energy consumption and 50 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 nursing homes, 2014–15

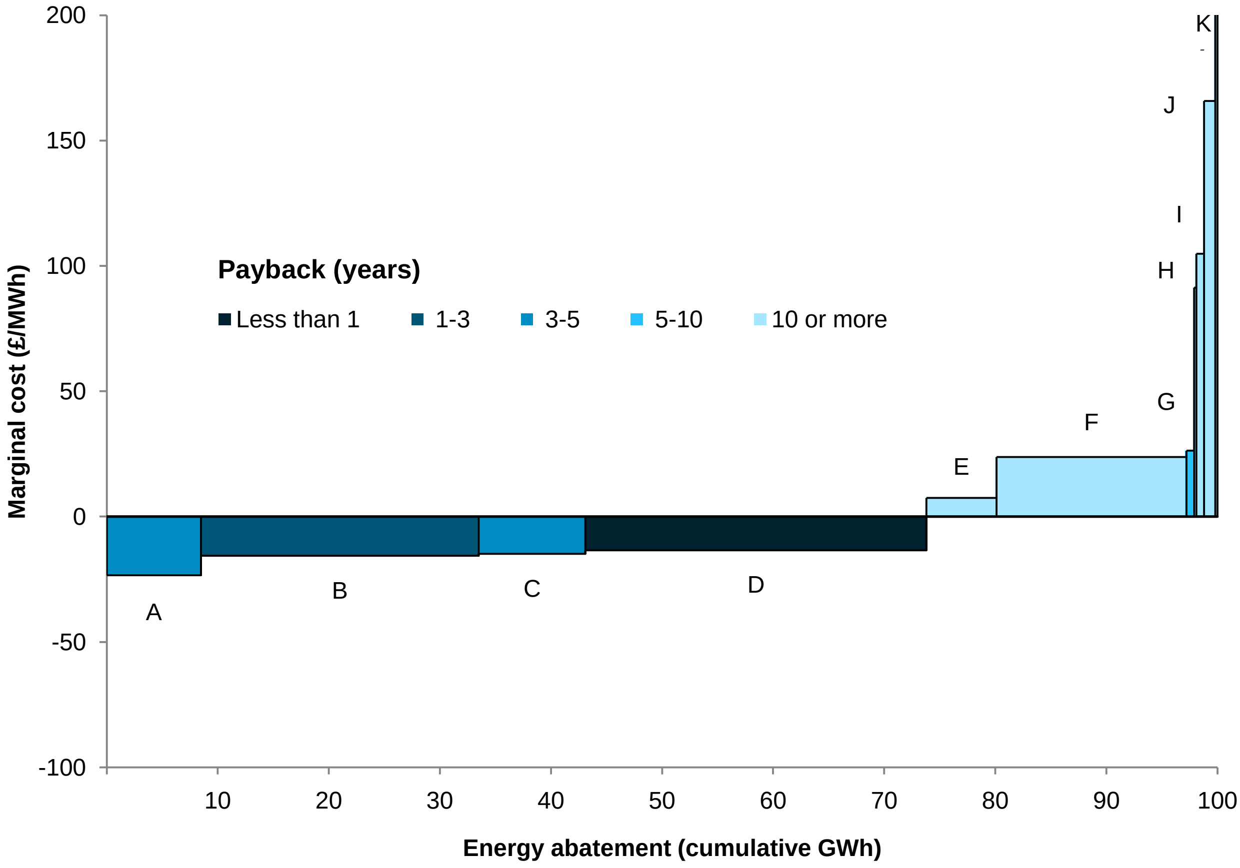
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Pay-back period (years)**[43]
Air conditioning and cooling	0	0	0	-	0	300	31
Building fabric	200	1	1	6	7	4,500	13
Building instrumentation and control	800	5	3	20	30	1,900	2
Building services distribution systems	0	0	0	-	0	1,000	14
Carbon and energy management	1,400	7	8	20	30	1,300	1
Hot water	300	2	1	9	10	1,400	4
Humidification	-	-	-	-	-	-	-
Lighting	900	3	9	-	9	3,700	3
Cooled storage	100	0	1	-	1	400	5
Small appliances	100	0	0	1	1	1,100	14
Space heating	600	3	1	20	20	5,600	10
Swimming pools	-	-	-	-	-	-	-
Ventilation	100	0	1	0	1	800	10
Total	**4,400**	**20**	**30**	**80**	**110**	**21,900**	‘’

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 nursing homes, 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: £-23 per MWh. GWh: 9]
B Building instrumentation and control [MAC: £-16 per MWh. GWh: 30]
C Hot water [MAC: £-15 per MWh. GWh: 10]
D Carbon and Energy Management [MAC: £-14 per MWh. GWh: 30]
E Building fabric [MAC: £8 per MWh. GWh: 7]
F Space heating [MAC: £24 per MWh. GWh: 20]
G Refrigeration [MAC: £27 per MWh. GWh: 1]
H Air conditioning and cooling [MAC: £93 per MWh. GWh: 0]
I Ventilation [MAC: £104 per MWh. GWh: 1]
J Small appliances [MAC: £166 per MWh. GWh: 1]
K Building services distribution systems [MAC: £671 per MWh. GWh: 0]

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

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