Department for
Business, Energy
& Industrial Strategy

Building Energy Efficiency Survey: Military sector, 2014–15

November 2016

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.

[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 Military 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.

Military sector overview

The Military sector consisted of Military accommodation, Military offices and Military storage premises; for the purpose of this study, it did not include Military premises that were present in other building types. The Military sector had a total floor area of 18 million m^2 of which 12 million m^2 was reported under BEES (1 per cent of the total non-domestic stock) across 12,400 premises (1 per cent of the total non-domestic stock). The Military sector's electrical energy consumption was 690 GWh (0.8 per cent of the total non-domestic stock) and non-electrical energy consumption was 1,150 GWh (1.5 per cent of total non-domestic stock).

The findings in this report are based on data collected through 64 telephone surveys used in the energy use and abatement models and 9 site surveys in 2014–15.[4]

Key findings

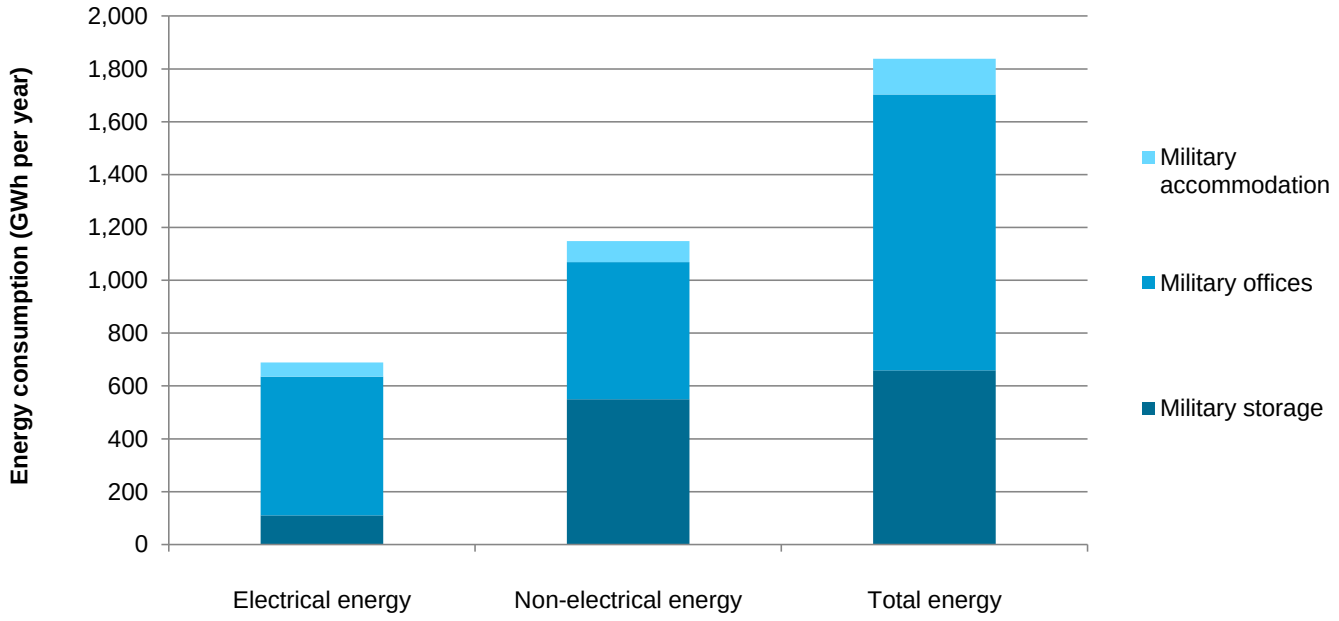
Energy consumption in the Military sector, 2014–15

- According to modelled data based on telephone survey responses, the sector consumed 1,840 GWh of total energy. This comprised 690 GWh of electrical energy and 1,150 GWh of non-electrical energy per year (Figure 0.1).
- The largest energy consumer in this sector was Military offices, with 1,040 GWh total energy consumption (57 per cent of sector total). Military storage was the second largest consumer, with 660 GWh total energy consumption (36 per cent).
- The difference in absolute consumption between the sub-sectors matched to some extent with their overall size. Military storage and Military offices were the largest sub-sectors in terms of energy consumption, while also representing 95 per cent of the sector's overall floor area. In contrast, Military accommodation premises represented 5 per cent of the sector's floor area (the smallest of the three sub-sectors) and 7 per cent of the sector's energy consumption - also the smallest.
- Military accommodation had the highest median total energy intensity (211 kWh/m^2), followed by Military offices (161 kWh/m^2) and Military storage (144 kWh/m^2).
- Military offices typically displayed the highest median electrical energy intensity (65 kWh/m^2). The second most energy intensive sub-sector in terms of electrical energy was Military accommodation (49 kWh/m^2). Military accommodation displayed the highest median non-electrical energy intensity of 145 kWh/m^2, followed by Military storage (125 kWh/m^2) and Military offices (97 kWh/m^2).

[4] Data for the military sector was collected via questionnaires completed by military Facility Management Contractors with an understanding of energy management. Further detail is provided in section 2 of this report.

- The energy consumption of the Military sector was broken down into specific 'end uses'. The most significant end use was space heating (1,050 GWh, 57 per cent of total energy consumption), followed by internal lighting (290 GWh, 16 per cent of total).

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



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

Abatement potential in the Military sector, 2014–15

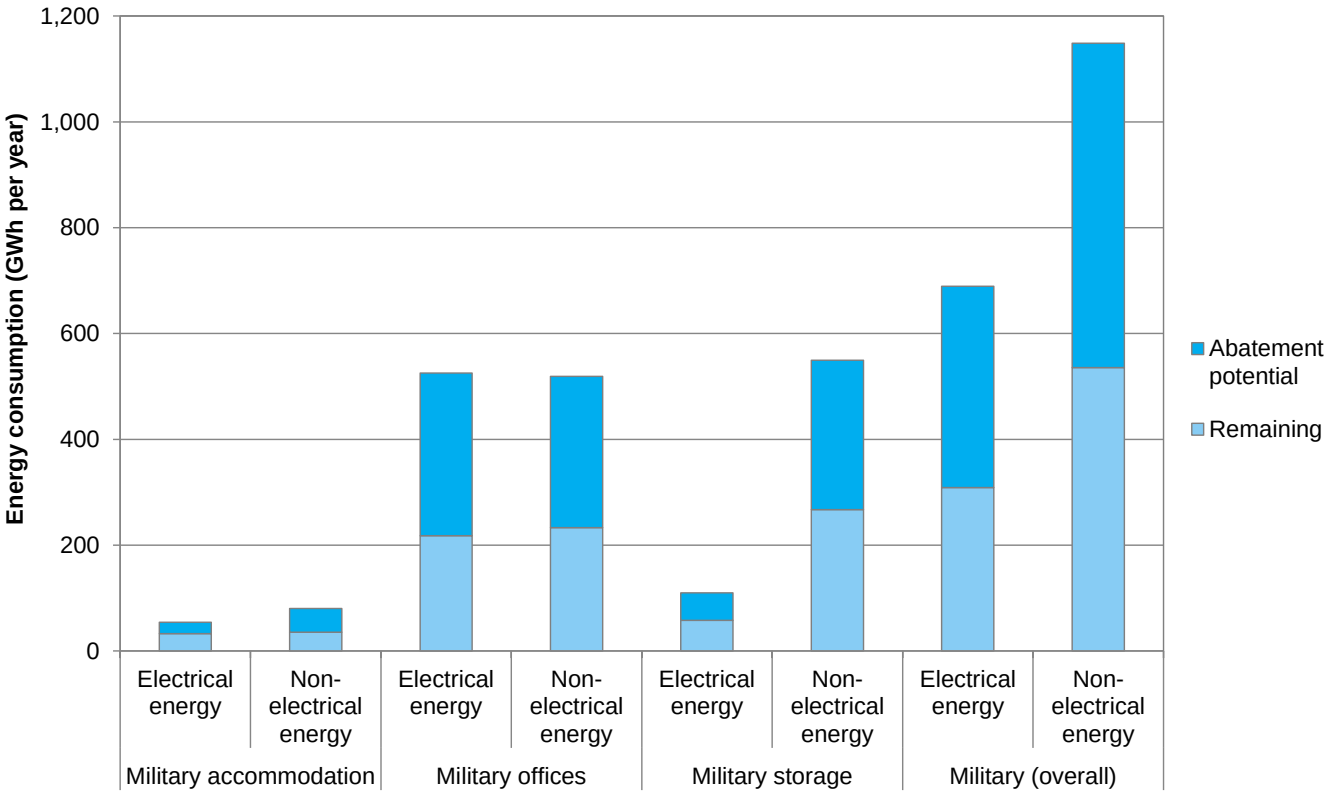
- According to modelled data based on telephone survey responses, Figure 0.2 shows abatement potential for the sector, broken down by sub-sector and fuel type. This represents the total abatement potential that is technically available, which relates to the possible reductions in energy consumption following 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 Military sector was 990 GWh of total energy consumption (54 per cent reduction on total consumption). This comprised 380 GWh of electrical energy (a 55 per cent reduction) and 610 GWh of non-electrical energy (a 53 per cent reduction).
- This could be achieved at a capital cost of £310 million. The socially cost effective potential was 610 GWh of total energy consumption which consisted of 270 GWh of electrical energy consumption and 340 GWh of non-electrical energy consumption. Organisations are more likely to be influenced by the payback period for improvement: overall there were 590 GWh of total energy savings with a private payback period[5] of 3

[5] Payback is calculated by dividing the capital installation cost associated with a measure by the annual financial savings achieved based on energy cost reductions accounting for any annual operational costs.

years or less (270 GWh of electrical energy abatement and 320 GWh of non-electrical energy abatement).

- The sub-sector with the largest relative and absolute abatement potential was Military offices, which could reduce consumption by 590 GWh which spilts between 310 GWh of electrical energy (58 per cent reduction on consumption) and 290 GWh of non-electrical energy (55 per cent reduction on consumption).
- The proportional abatement potential available in Military offices was higher than that estimated for the office sector, a separate sector of the non-domestic stock in BEES with an estimated 33 per cent reduction for electrical energy and 49 per cent reduction for non-electrical energy.

Figure 0.2: Abatement potential by energy type and Military 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 Military sector – in terms of reductions in energy consumption – relate to the implementation of carbon & energy management measures, lighting upgrades and space heating measures. The largest group of savings – in terms of the potential energy bill savings – related to the implementation of lighting upgrades[6].

[6] The BEES report findings have been compared to a parallel study conducted by the Military as part of the DIO EUS BEIM programme (Defence Infrastructure Organisation, Energy Utilities and Sustainability, Built Environment Improvement Measures). This project found that the capital cost for energy efficiency measures was substantially greater than in typical commercial environments. This was due in large part to restrictions on staff and requirements for security clearance. As a result

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

Measure type	Savings					Total capital cost of measure (£ thousands)
	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	
Air conditioning and cooling	1,500	4	20	-	20	16,200
Building fabric	3,700	20	2	140	140	71,600
Building instrumentation and control	4,600	20	10	130	140	15,100
Building services distribution systems	2,400	8	20	-	20	14,200
Carbon and energy management	13,300	50	90	190	270	13,900
Hot water	600	3	0	20	20	4,000
Humidification	-	-	-	-	-	-
Lighting	17,100	60	170	-	170	50,300
Cooled storage	100	0	1	-	1	400
Small appliances	2,100	7	20	2	20	27,100
Space heating	3,500	10	0	140	140	49,600
Swimming pools	-	-	-	-	-	-
Ventilation	4,400	10	50	-	50	47,300
Total	**53,400**	**180**	**380**	**610**	**1000**	**309,700**

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

BEES costs, which are based on more typical commercial environments, may underestimate the cost of implementing measures in this sector.

1. Military sector

This report relates to the Military sector (one of 10 sectors covered in the Building Energy Efficiency Survey (BEES)). This section provides definitions for the three Military sub-sectors (Military accommodation, Military offices and Military storage). It then sets the Military 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 Military sector.

Table 1.1: Table of Military sub-sector definitions[7]

Sub-sector	Definition
Military offices	Office provision both cellular and open plan depending on function.
Military storage	Storage and warehousing for non-specialist materials, hazardous materials, explosive materials, Military vehicle garages, bulk vehicle storage and railway & locomotive sheds.
Military accommodation	Single Living Accommodation (SLA) generally consisting of blocks of single occupancy bedrooms with en suite provision (shower, basin and WC) and communal facilities (utility, drying, snack and common rooms). Home to servicemen and women during their training or posting to a unit.

Military premises that were not reported under BEES included the following activities: air traffic control, armouries, catering, hangars, medical, reserve forces & cadets, schools, testing, training, welfare, workshops and places of worship. These amounted to a floor area of 7 million m^2 GIA[8].

Military sector in the context of the wider non domestic stock

The Military sector is a small segment of the non-domestic stock. It accounts for 1 per cent of the non-domestic stock in terms of premises count (24,200) and 1 per cent in terms of floor area (11.5 million m^2).[9]

In terms of energy consumption the sector consumed 1,840 GWh of total energy. This comprised 690 GWh of electrical energy and 1,150 GWh of non-electrical energy. This is equivalent to 1 per cent of the non-domestic stock total (1 per cent for electrical and 2 per cent for non-electrical energy). This information is set out in Figure 1.1 to Figure 1.3.

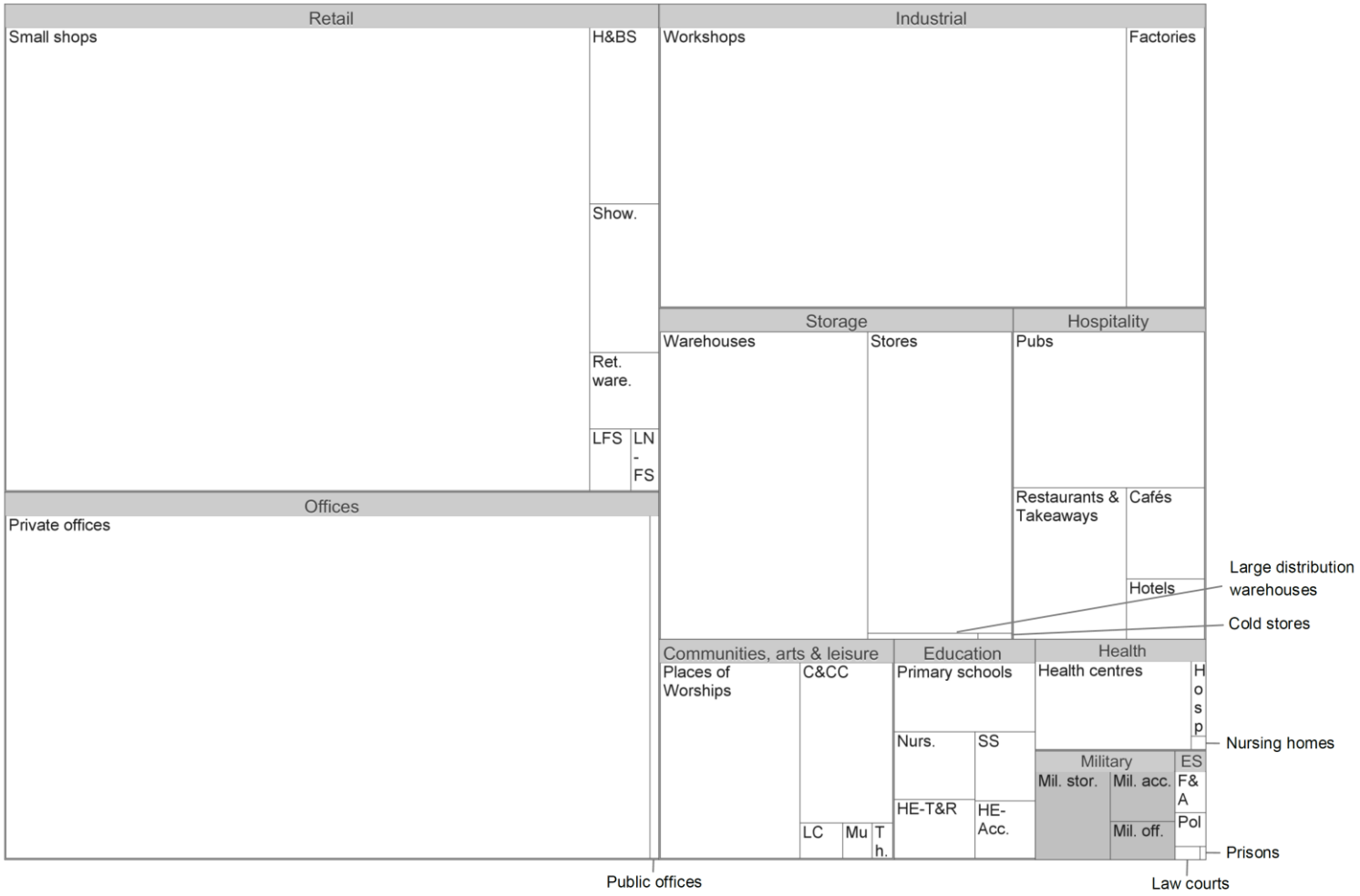
[7] These definitions were provided by the Military.

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

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

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

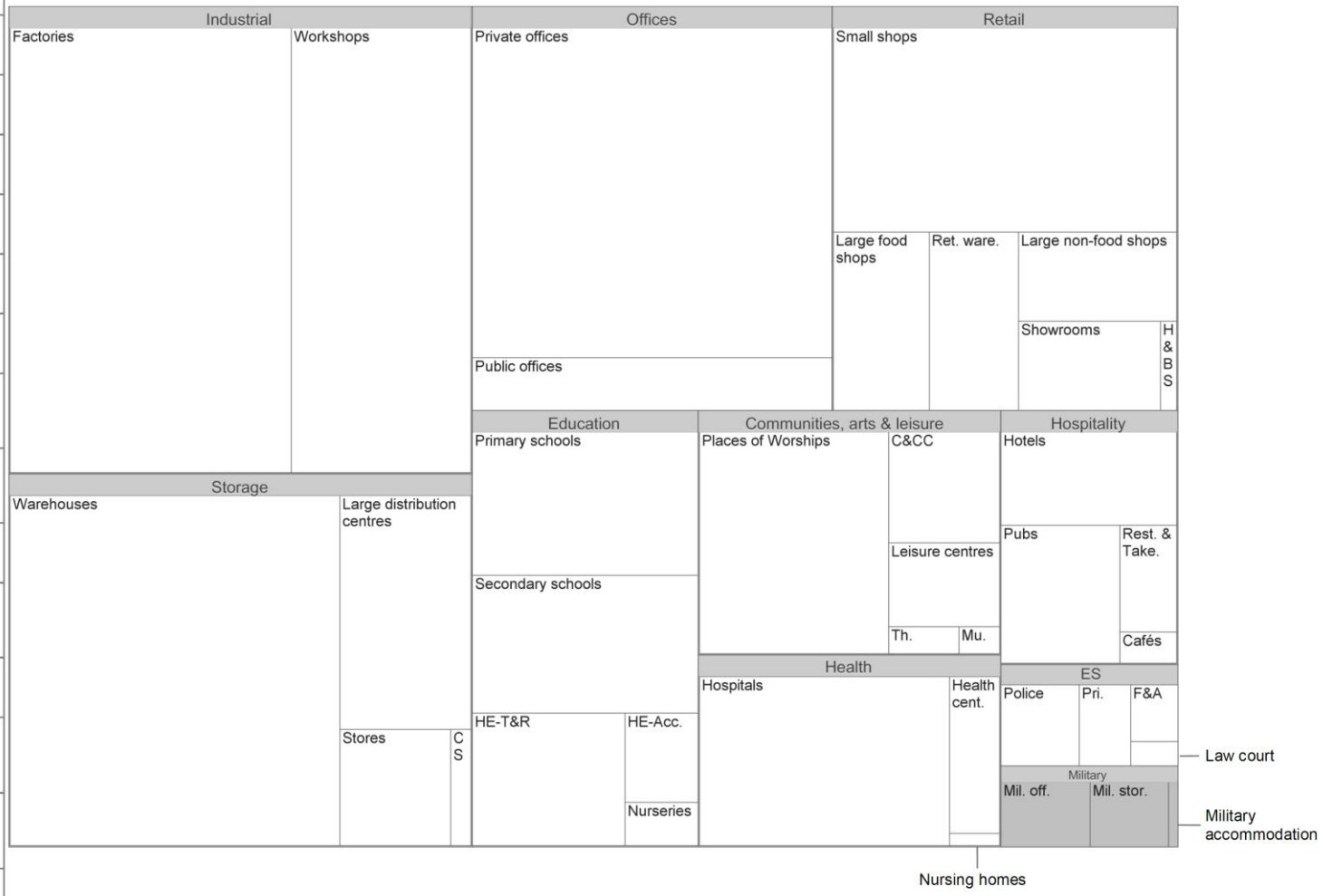
ID	Sub-sector
H&BS	Hairdressing & beauty salons
Show.	Showrooms
Ret. ware.	Retail warehouses
LFS	Large food shops
LN-FS	Large non-food shops
C&CC	Clubs & community centres
LC	Leisure centres
Mu.	Museums, Art galleries and Libraries
Th.	Theatres, cinemas
Nurs.	Nurseries
SS	Secondary schools
HE-T&R	HE—Teaching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



Source: Population table

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

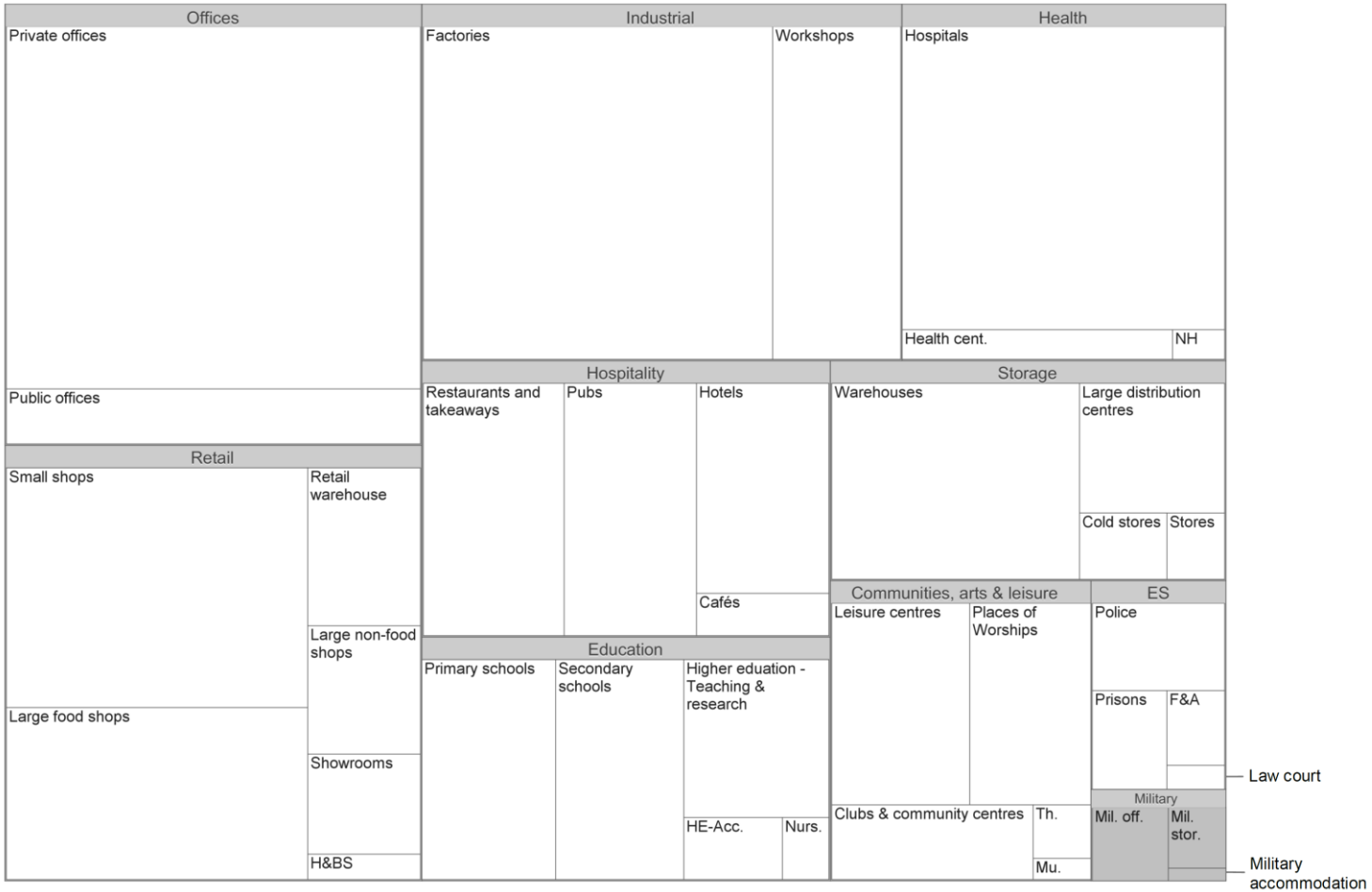
ID	Sub-sector
Ret. ware.	Retail warehouse
H&BS	Hairdressing & beauty salons
CS	Cold stores
HE-T&R	HE—Teaching and research
HE-Acc.	HE — Accommodation
C&CC	Clubs & community centres
LC	Leisure centres
Th.	Theatres, cinemas and concert halls
Mu.	Museums, Art galleries and Libraries
Health cent.	Health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



Source: Population table

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

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



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

General characteristics of the Military sector

The survey records relate to a whole premises within the Military estate.

The Military estate includes a very broad range of premises types. Within the context of the BEES study, it was necessary to simplify the sector to three sub-sectors for the three most prevalent building types in the Military building stock, based on floor area. These were Military accommodation, Military offices and Military storage premises.

Military accommodation premises were primarily composed of bedrooms, typically with communal eating and washing facilities. Most included catering facilities for the occupants. Many of these premises were relatively modern and a significant proportion included ventilation and comfort cooling.

Military offices premises were similar to the wider non-domestic office stock. These premises were primarily composed of office and meeting room areas, supported by staff rest facilities, and mechanical ventilation and air conditioning were relatively common. Energy intensive activities included server rooms and catering.

Military storage premises were dominated by storage space, with basic heating and lighting systems.

Summary statistics for the Military sector

A number of standard characteristics for the Military sector are set out in Table 1.2, Figure 1.4 and Figure 1.5; from premises and organisation size through to operating hours and premises tenure. These key characteristics for the Military sector and how these vary across the Military 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 Military sector could be categorised into three main groups:

- Military accommodation, premises typically open for 24 hours per day, occupying the full extent of a building and more than 1,000 m^2 in floor area;
- Military offices, operating over standard office hours (9-15 hours per day), occupying whole buildings or multiple buildings and more than 1,000 m^2 in floor area;
- Military storage, premises typically more than 1,000 m^2 in floor area and operating for 8 hours or fewer per day.

As expected, all Military premises were part of a ‘large’ organisation (one employing more than 250 members of staff).

Military accommodation, storage and offices typically occupied large premises with a floor area of greater than 1,000 m^2(over 90 per cent of the floor area of each of these sub-sectors was accounted for by large premises). There were no Military accommodation premises in the sample occupying premises smaller than 250 m^2.

With regards to tenure, over 93 per cent of the overall Military premises were owner occupied. All Military storage premises were owner occupied. The lowest owner occupation rate was Military offices, of which 88 per cent was owner occupied and 11 per cent leased. The Military accommodation sub-sector had a similar fraction of leased property, at 8 per cent.

The majority of Military accommodation and storage premises described themselves as "actively seeking ways to reduce energy use". Military offices showed the lowest prevalence of active energy management ambition, at 61 per cent.

In terms of building age, all Military premises in the sample were built after 1900. The sub-sector with the most modern buildings was Military offices, of which 70 per cent of floor area was built between 1991 and 2006 and 28 per cent built before 1985. The majority of Military storage premises (92 per cent) were built before 1985. The remaining 8 per cent were built between 1991 and 2006. Within Military accommodation premises the most typical age banding (representing 39 per cent of the total floor area) were those premises built between 1991 and 2006.

Typically premises across all sub-sectors occupied either a whole building or multiple buildings. The only sub-sector in which premises occupying part of a building were found was Military offices, where 1 per cent of the total floor area comprised these premises types. 42 per cent of the floor area in the Military offices sub-sector was within 'multiple building' sites.

The peak operating hours[10] varied between sub-sectors. The majority of Military offices had peak operating hours of between 9-15 hours per day (81 per cent). Military accommodation premises demonstrated a split operating profile, with 44 per cent of premises having peak operating hours of 9-15 per day, and 43 per cent between 16-23 hours per day. Peak operating hours for Military storage premises were more varied, with 51 per cent opening for 8 or fewer hours per day and 32 per cent for 9-15 hours per day.

Military premises also demonstrated varied opening hours[11]. The majority of Military offices had opening hours of 9-15 hours (62 per cent) or 24 hours (20 per cent). Military accommodation demonstrated similar opening hours, with 68 per cent open 24 hours per day, and 23 per cent between 9-15 hours. Military storage premises generally had opening hours of fewer than 15 hours per day (65 per cent).

[10] For this query, 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)?"

[11] This was defined as the total number of hours that the premises was 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).

Table 1.2: Range of building and premises characteristics by Military sub-sector by percentage of floor area, 2014–15

Column percentages

	Military sub-sector			
	Military accommodation (%)	Military offices (%)	Military storage (%)	**Militarysector (%)**
Organisation size				
Micro (0-9)	-	-	-	-
Small (10-49)	-	-	-	-
Medium (50-249)	-	-	-	-
Large (250+)	100	100	100	100
Don't know	-	-	-	-
Total floor area (m^2)				
Less than 50	-	-	-	-
50-99	-	0	0	0
100-249	-	1	2	1
250-499	0	1	1	1
500-999	7	6	2	5
1,000-4,999	69	26	58	42
5,000-9,999	24	29	36	32
10,000 or more	-	37	-	19
Tenure				
Owned	92	88	100	93
Leased	8	11	-	6
Don't know	-	1	-	1
Energy management ambition[12]				
Active	82	61	63	63
Passive	18	39	37	37
None	-	-	-	-
Do not know	-	-	-	-
Age of building				
Pre-1900	-	-	-	-
1900-1939	3	9	40	23
1940-1985	27	19	52	34
1986-1990	19	0	-	1
1991-2006	39	70	8	41
2007 or later	12	0	-	1
Don't know	-	1	-	1

[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 1.2 continued.

	Military sub-sector			
	Military accommodation (%)	Military offices (%)	Military storage (%)	**Military (overall) (%)**
Building structure				
Part of building	-	1	-	1
Whole building	82	57	63	61
Multiple buildings	18	42	37	38
Peak operating hours[13]				
8 or less	4	19	51	32
9-15	44	81	32	58
16-23	43	-	-	2
24	-	-	-	-
Don't know	9	-	16	8
Opening hours[14]				
8 or less	-	11	33	20
9-15	23	62	32	47
16-23	-	7	-	4
24	68	20	18	21
Don't know	9	-	16	8
Unweighted base	*24*	*24*	*16*	*64*

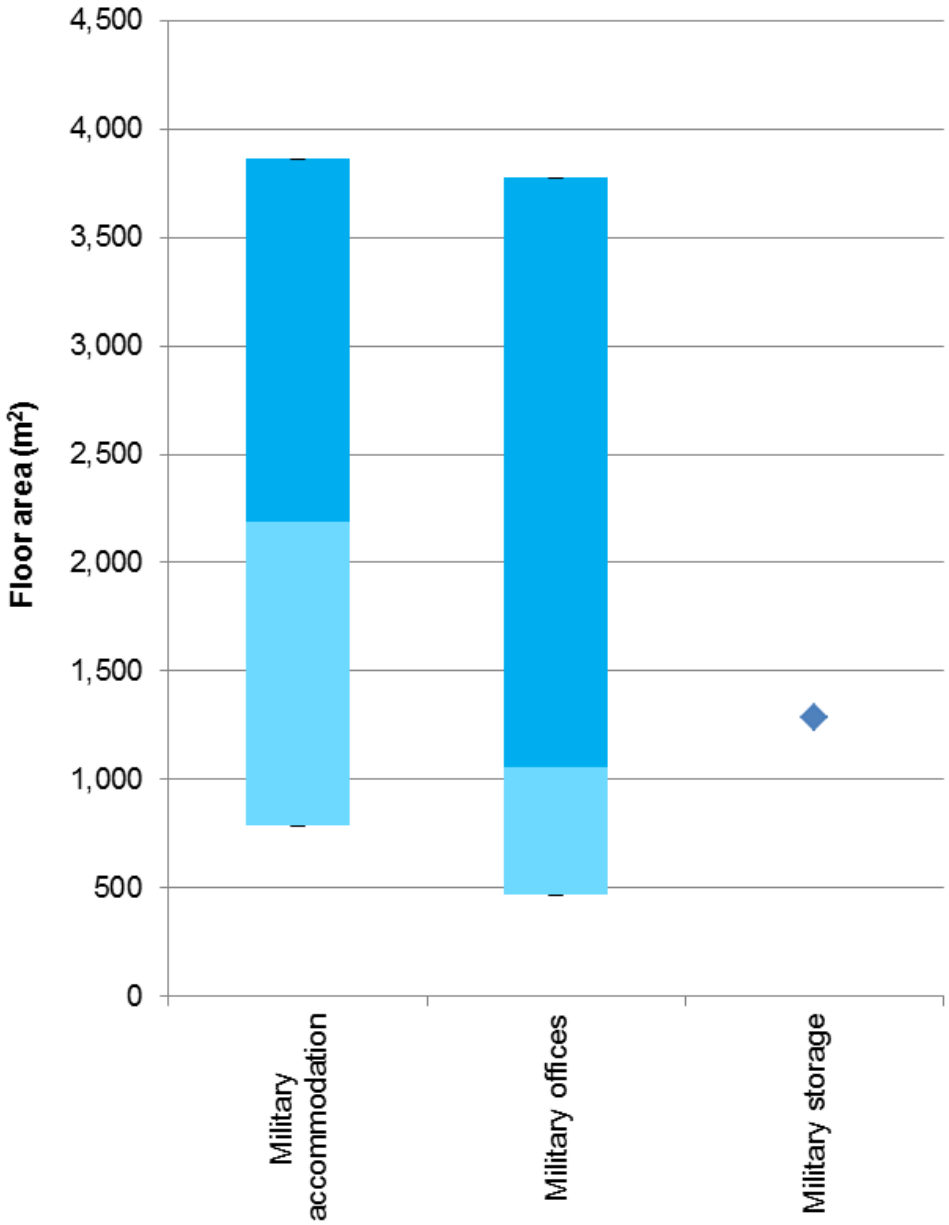
Source: Telephone survey or equivalent records for the sector, England and Wales

Figure 1.4 shows the distribution of premises sizes, in terms of floor area, by sub-sector. The plot shows that Military accommodation premises had the largest median floor area in the Military sector at 2,190 m^2, followed by Military storage (1,290 m^2) and Military offices (1,060 m^2). The distribution of floor area sizes was broadly consistent between the three sub-sectors.

[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 was 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: Premises size by Military sub-sector, 2014–15

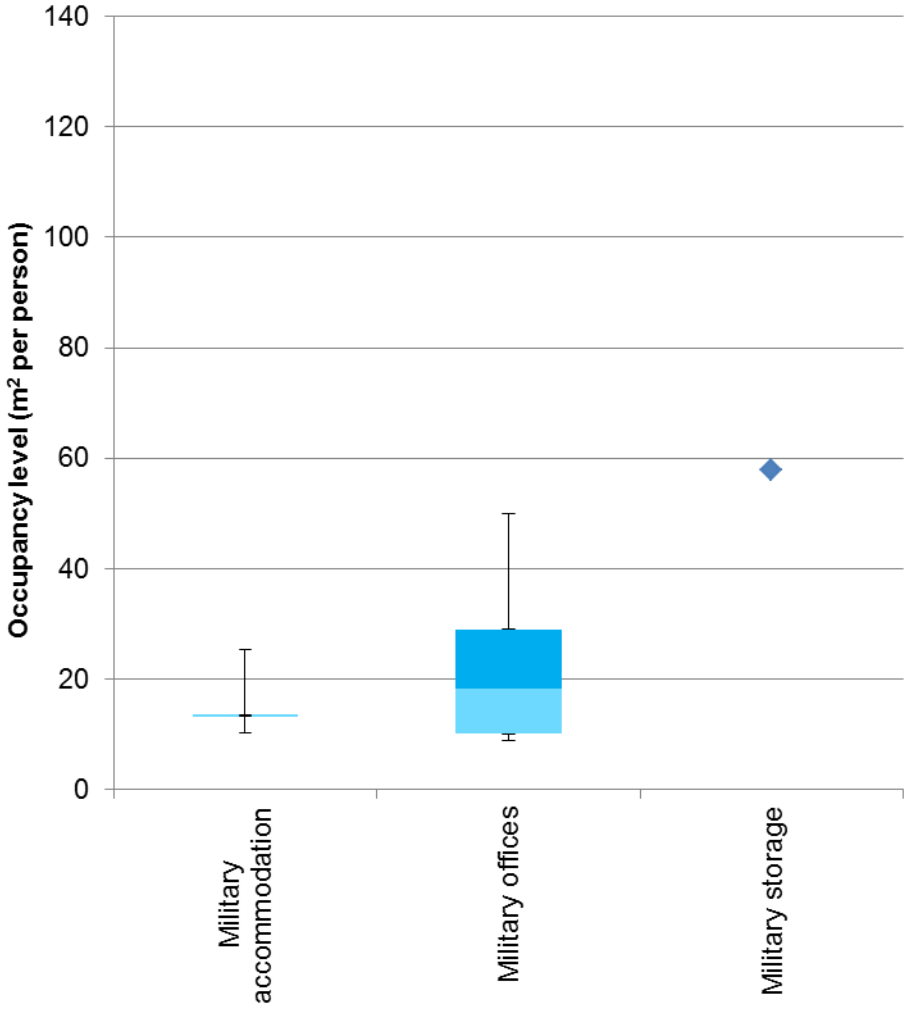


Note: In box and whisker plots, the blue columns, when combined, indicate the range of floor areas covered by the interquartile range of results (the middle 50 per cent of data points). No 10th and 90th percentiles are shown in this sector as all sub-sectors are based on less than 50 cases

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. Military accommodation shows the highest median occupancy level of 14 m^2 per person.[15] This compares with a median of 18 m^2 per person in Military offices and 58 m^2 per person in Military storage.

Figure 1.5: Occupancy level by Military 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). No 10th and 90th percentiles are shown in this sector as all sub-sectors are based on less than 50 cases

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

[15] 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 Military sector.

Greater detail on the BEES methodology in relation to the Military 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 Military 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;[16]
- 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.[17]

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

Standard approach

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

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

The study has generated a database of 3,690 records. Each record may represent an entire building or a premises within a larger building. The findings in this report are based on data collected for the Military sector through 64 telephone surveys and 9 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 premises 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 on the premises.

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[16] The current non-domestic stock el (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.

[17] 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[18]. 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

[18] 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.

floor area.

4. Secondly, record amendment was conducted on the remaining data. The remaining records were reviewed and in some cases data amended to overcome isolated yet important instances of 'Don't know'. These amendments were applied to the telephone survey dataset. Where telephone survey records contained a 'Don't know', the response was estimated where possible based on the most likely response based on what was typical for the premises, or was proxied based on other question responses[19].
5. **Data processing** – Two models were used to process the cleaned telephone survey outputs. The **energy use model** was used to estimate the energy use in each premises, and the **abatement model** was used to estimate the cost and abatement potential of different abatement measures if they were to be installed in that premises. These models are outlined below, for more details see the technical annex. It should be noted that all processed outputs relate to the time when the original data was collected.[20]
    - The energy use model used an energy calculator to estimate a premises energy consumption, split by end use and fuel type, based on the cleaned telephone survey responses. A calibration process was carried out for each sub-sector to map telephone survey responses to different values of parameters in the energy calculator. This calibration was based on alternative data sources, previous knowledge of the sub-sector and the site surveys. The energy use mode did not take dynamic effects or building geometry into account, given the nature of the telephone survey data.
    - The abatement model used the cleaned telephone survey outputs and a set of relatively simplistic measure applicability rules to assess whether or not different abatement measures were applicable to a particular premises. The effect of applicable measures was estimated by changing relevant parameters in the energy calculator and recalculating the energy consumption of the premises.
6. **Weighting –** All the data generated was weighted upwards to represent the sub-sector population, based on the likelihood the premises was selected and on the overall share of floor area in the achieved sample.

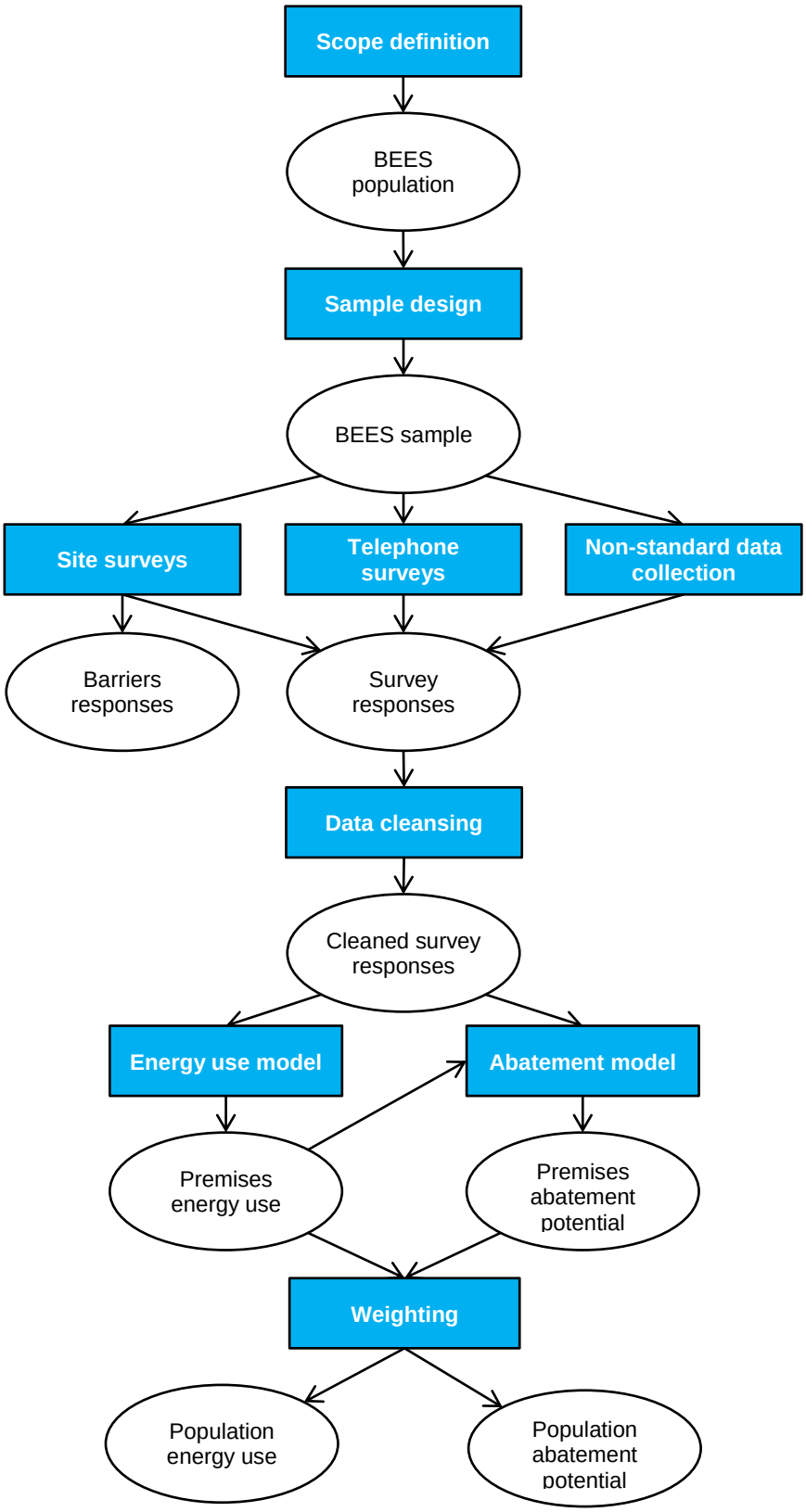
This approach was then tailored by sector. The impact of the change to the methodology within the Military sector is covered in "Methodology challenges in the Military sector", which follows in this section, and in more detail in Appendix B.

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.

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

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

Figure 2.1: Methodology flowchart



Methodology challenges in the Military sector

For all Military sub-sectors a customised approach was required due to the fact that no data on Military premises was available in the public domain. A summary of further specific issues encountered is set out below and a full description is included in Appendix B.

- **Sample Design** No comprehensive listing of Military premises could be provided, so random sampling was not possible. The sample was selected through collaboration with Military maintenance contractors, and the Military property gazetteer was used as a reference source for the total floor area of the sector.
- **Sample Design** The Military building stock includes a full range of premises types, but the BEES study was only able to analyse the three most common types covering over 70 per cent of the stock – offices, storage and accommodation. The results presented here effectively treated the Military sector as being comprised entirely of offices, storage and accommodation.
- **Data collection** It was observed that facilities management of Military premises was sub-contracted to regional contractors. In order to collect telephone survey data these contractors were approached directly and a single contact provided multiple records in each region. The team successfully engaged with three facilities management contractors to provide telephone survey data for BEES. In each case, telephone survey responses were provided by one individual. They provided responses for all premises that they were responsible for in that region. The reliance on a single point of contact meant that the quality of responses was of lower than typical. This is because these respondents tended to populate fields with similar responses in order to provide data quickly. In reality, these simplified responses were shown to miss information where site surveys were undertaken. Examples of information that was simplified included occupancy hours, which is influences who intensively a premises is being used . Furthermore, only two facilities management contractors were willing to support the site surveys, which meant it was only possible to determine what had been accurately submitted for these two contractors This introduced an element of systematic bias within the sample although the impact of this bias is unknown.
- **Data processing** The availability of metered energy data for individual premises within the Military estate was very limited and very little premises-level energy data was generally available to assist in model calibration activities. because it was not possible to reconcile energy model results with metered data. Typically, the reconciliations are an important step in ensuring the model is correctly calculating consumption. This therefore reduced confidence in energy end use and overall energy estimates in the Military sector,

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 Military sector.

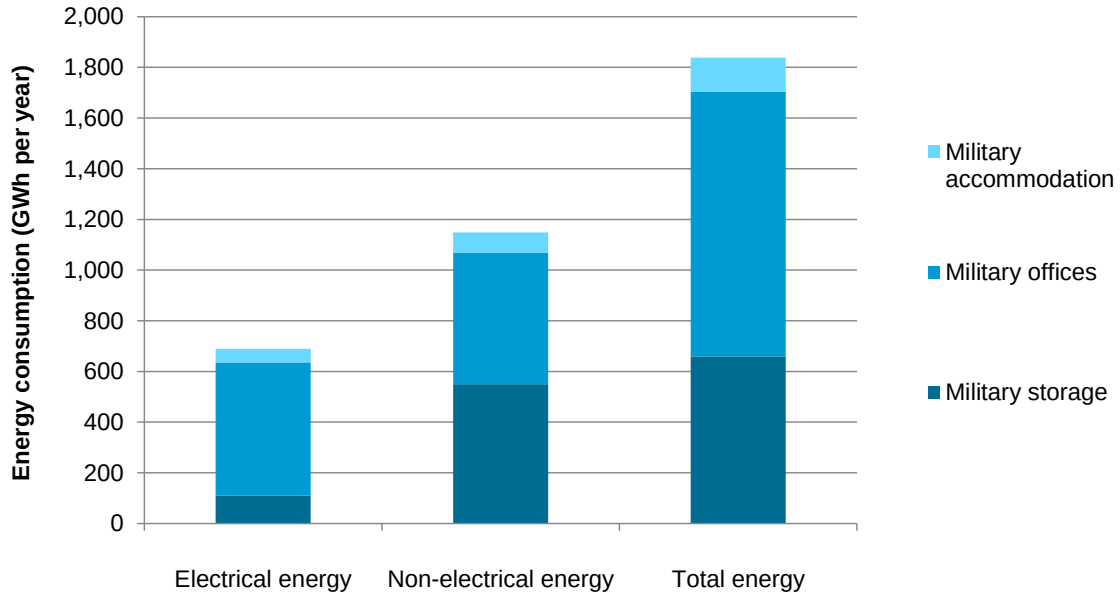
Energy consumption and greenhouse gas emissions in the Military sector

The total energy consumption, electrical and non-electrical energy consumption of the Military sector is presented in Figure 3.1, broken down by the three Military sub-sectors (Military offices, Military storage and Military accommodation).

The Military sector consumed 1,840 GWh of energy. This consisted of 690 GWh of electrical energy and 1,150 GWh of non-electrical energy per year (Figure 3.1). The largest consumer Military offices, with a consumption of 1,040 GWh (57 per cent of total). This was split between 530 GWh of electrical energy (77 per cent of sector total) and 520 GWh of non-electrical energy (45 per cent of sector total). This was partly due to this sub-sector being the largest in the Military sector (5.9 million m^2 compared with 5.1 million m^2 for Military storage and 0.6 million m^2 for Military accommodation).

Military storage premises were the second largest consumer in the sector, with a consumption of 660 GWh (36 per cent of total). This consisted of 110 GWh of electrical energy consumption (16 per cent of sector total) and 550 GWh of non-electrical energy consumption (48 per cent of sector total). Military accommodation premises were the smallest consumer in the sector with 130 GWh of total energy consumption (7 per cent of total), which was split into 50 GWh of electrical energy (7 per cent of sector total) and 80 GWh of non-electrical energy (7 per cent of sector total).

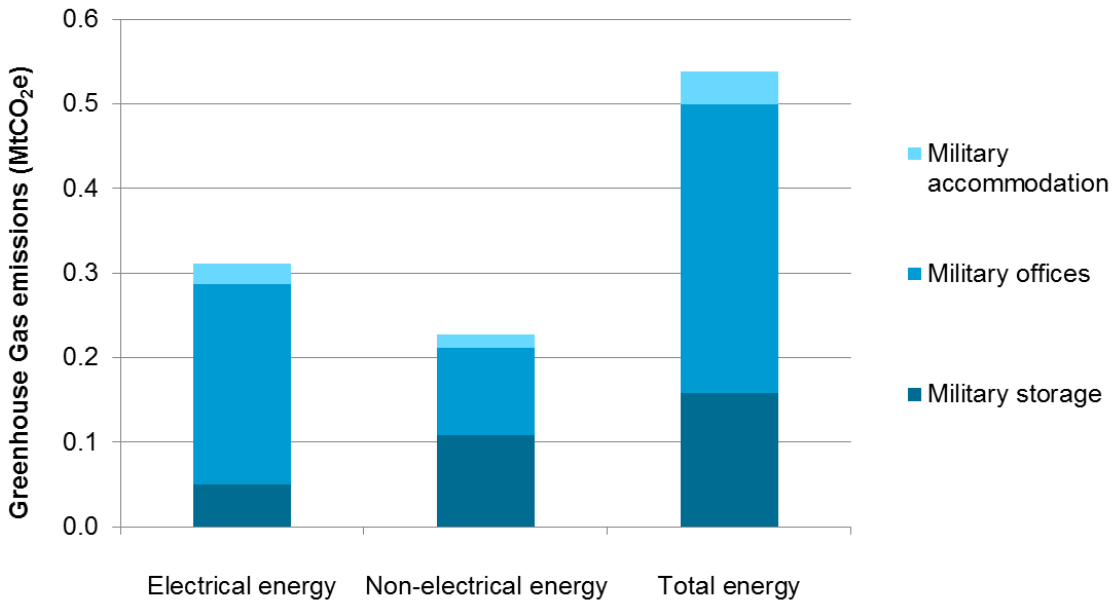
Figure 3.1: Electrical and non-electrical energy consumption by energy type and Military sub-sector, 2014–15



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

The greenhouse gas emissions for the Military sector are presented in Figure 3.2.[21] The total greenhouse gas emissions from the Military sector were deemed to be 0.5 $MtCO_2e$ per year. The annual emissions from electrical energy consumption were 0.3 $MtCO_2e$ and those from non-electrical energy consumption were 0.2 $MtCO_2e$.

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



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

Energy consumption by end use

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

The energy use model defined 23 separate energy end uses in its analysis. These were derived by modelling the telephone survey inputs and were calibrated using site survey data. For the purposes of presentation in Figure 3.3, 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 (small power). The simplified classification is shown against the more detailed classification results in

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

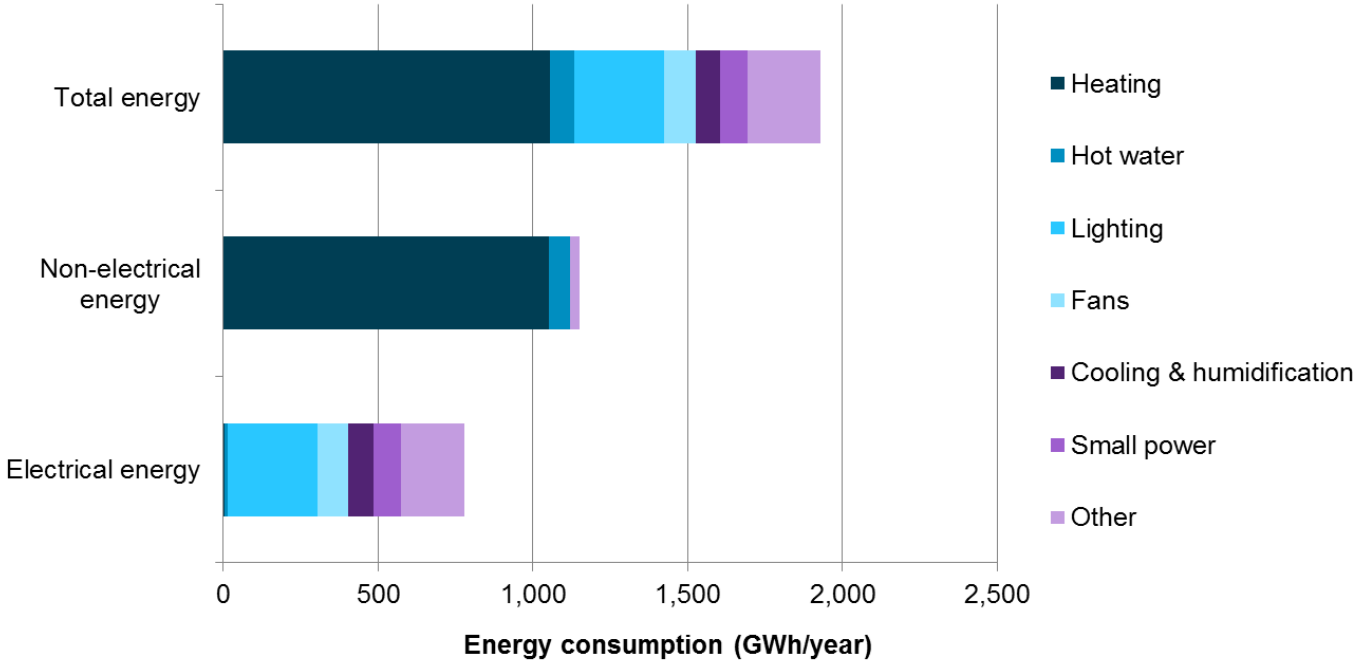
[22] In the context of the BEES study, small power represents office equipment (comprising computers, printers and ancillary desktop equipment). Other plug-in loads are disaggregated into entertainment equipment, catering, pool/leisure equipment etc.

Table 3.1.

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

The total energy consumption for the Military sector was 1,840 GWh. The most significant end use was space heating (1,050 GWh, 57 per cent of total energy consumption), followed by internal lighting (290 GWh, 16 per cent of total). The most common end uses of electrical energy were internal lighting at 290 GWh (42 per cent of total), followed by fans (100 GWh, 14 per cent). The next major end uses included small power (90 GWh, 13 per cent), space cooling (80 GWh, 12 per cent) and catering (40 GWh, 6 per cent). The most significant non-electrical energy end uses were space heating at 1,050 GWh (91 per cent) followed by hot water (70 GWh, 6 per cent) and catering (30 GWh, 3 per cent). Non-electrical energy consumption for space heating was much higher than electrical energy consumption (1,050 GWh compared with 4 GWh).

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

Energy end use category (Simplified)	BEES end use category[23]	Electrical energy consumption (GWh/year)	Non-electrical energy consumption (GWh/year)	Total energy consumption (GWh/year)
Heating	Space heating	4	1,050	1,050
Hot water	Hot water	10	70	80
Lighting	Lighting - internal	290	-	290
Fans	Fans	100	-	100
Cooling & humidification	Space cooling	80	-	80
Small power	Small power	90	-	90
Other	Medical equipment	-	-	-
	Pumps	20	-	20
	Catering	40	30	70
	Cooled storage	4	-	0
	Controls	9	-	10
	Lighting - external	6	-	10
	Vertical transport	1	-	0
	Lighting - display	1	-	0
	Entertainment equipment	10	-	10
	Pool/leisure	-	-	-
	ICT equipment	4	-	0
	Laundry	4	-	0
	Other	20	-	20
Total		**690**	**1,150**	**1,840**
Unweighted base		*24*	*24*	*16*

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

Military 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.[24] Figure 3.4 to Figure 3.6 present the distribution of energy intensity for all modelled records in each sub-sector within the Military sector, in terms of total energy intensity, electrical energy intensity and non-electrical energy intensity respectively. [25] In this report all intensity figures (excluding box plots) have been calculated using the total sector or sub-sector floor area regardless or whether they have a particular energy source or end-use.

Figure 3.4 shows that Military accommodation had the highest median total energy intensity (211 kWh/m^2), followed by Military offices (161 kWh/m^2) and Military storage (144 kWh/m^2).

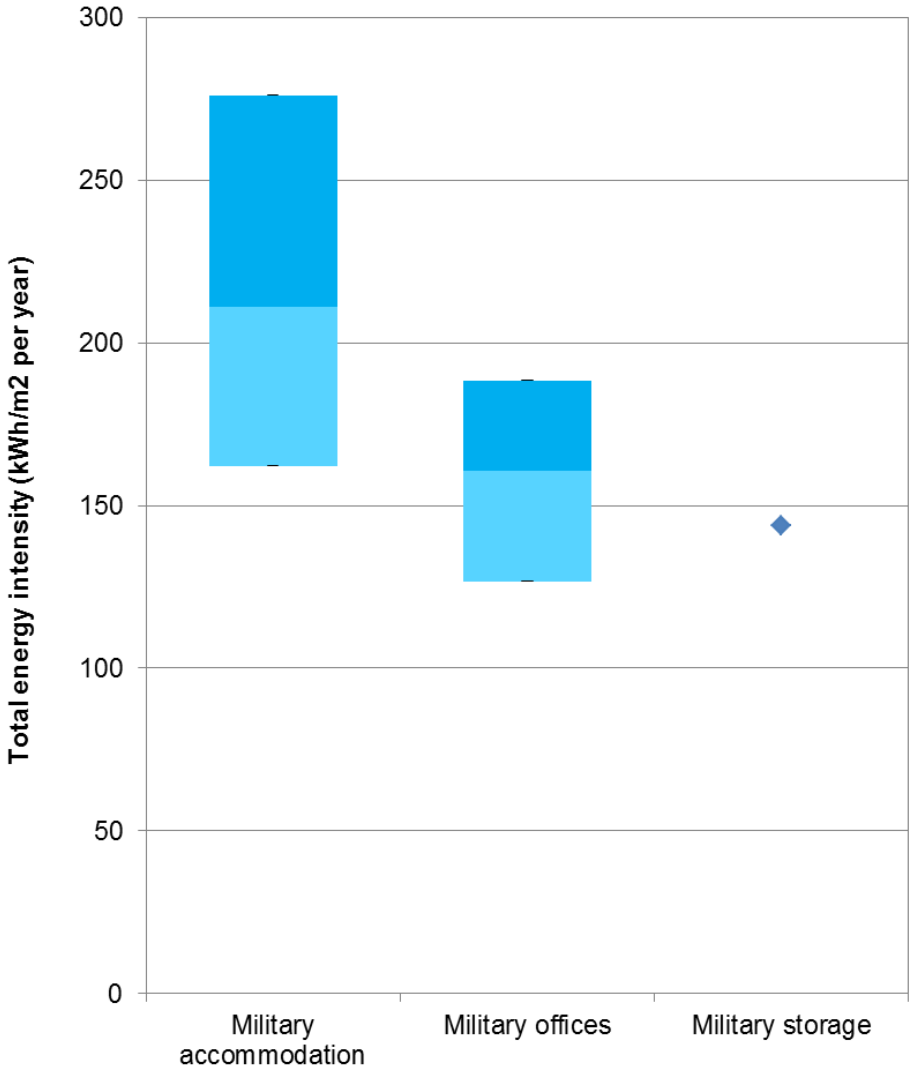
[23] The end uses are defined in Appendix C.

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

[25] 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.

Figure 3.5 and Figure 3.6 show that Military offices typically displayed the highest median electrical energy intensity (65 kWh/m^2). The second most energy intensive sub-sector in terms of electrical energy was Military accommodation (49 kWh/m^2). Military accommodation displayed the highest median non-electrical energy intensity of 145 kWh/m^2, followed by Military storage (125 kWh/m^2) and Military offices (97 kWh/m^2).

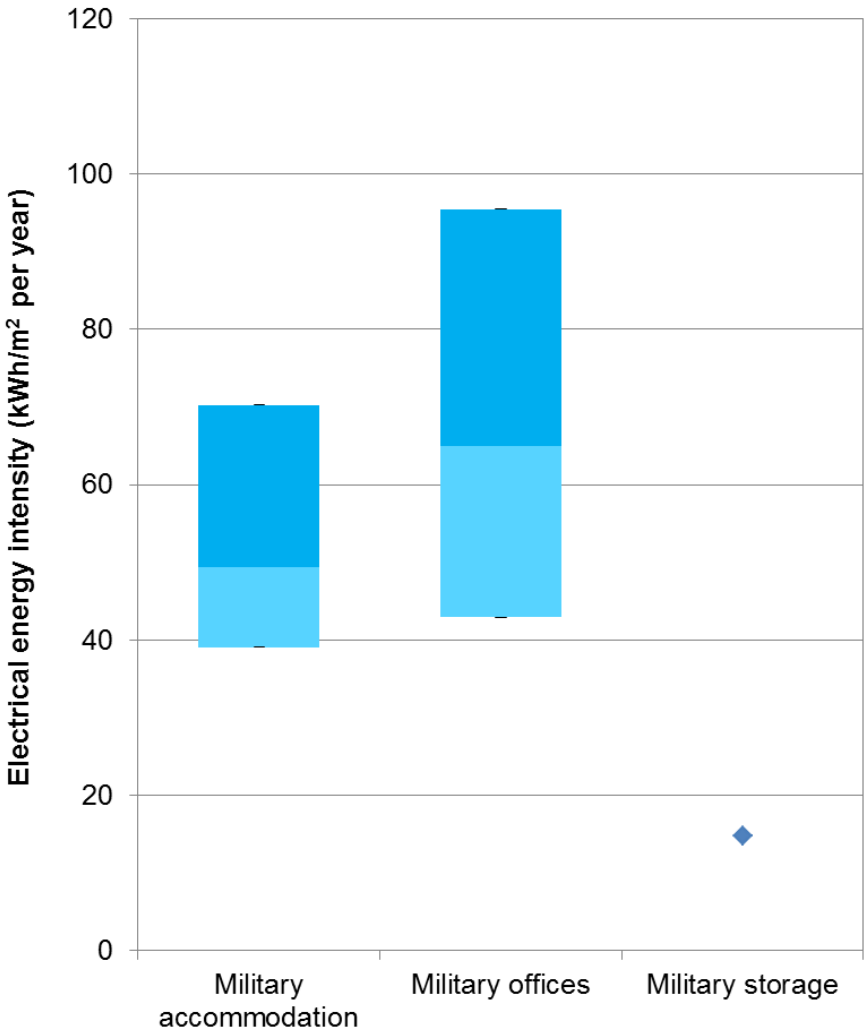
Figure 3.4: Distribution of total energy intensity by Military sub-sector, 2014–15



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). No 10th and 90th percentiles are shown in this sector as all sub-sectors are based on less than 50 cases.

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

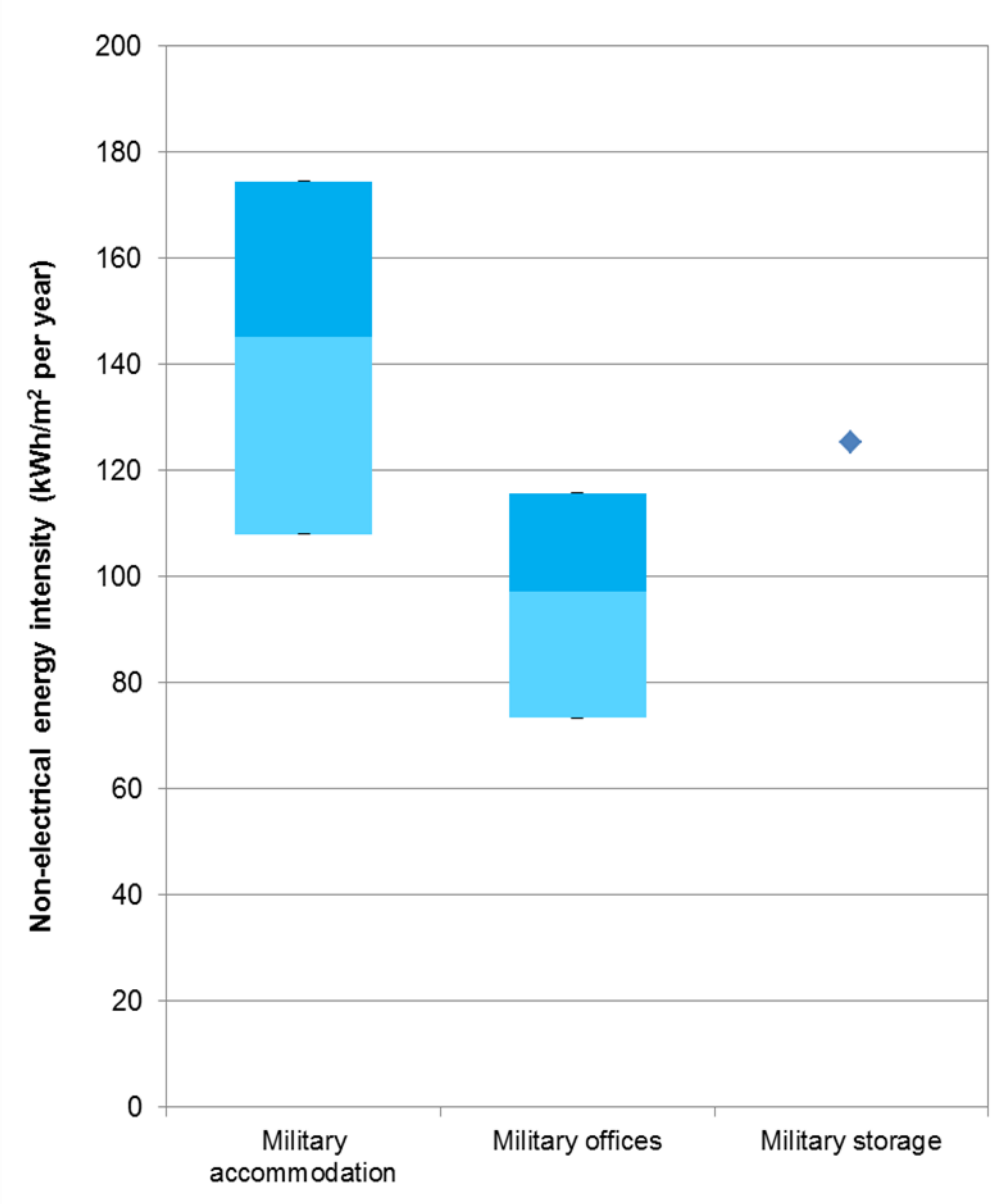
Figure 3.5: Distribution of electrical energy intensity by Military sub-sector, 2014–15



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). No 10th and 90th percentiles are shown in this sector as all sub-sectors are based on less than 50 cases.

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

Figure 3.6: Distribution of non-electrical energy intensity by Military 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

Military 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 Military sector[26]. Further data is provided in Appendix C where energy intensity and energy consumption is provided separately for electrical and non-electrical energy end use breakdowns by sub-sector. Some end uses, e.g. heating, hot water and catering, may be a mix of electrical and non-electrical energy.

Heating energy was the largest contributor to the sector's energy intensity. Military accommodation and storage premises exhibited higher heating energy intensity; in the case of accommodation this was due to relatively long hours of occupancy, whilst in the case of storage premises high ceilings increased the heated volume significantly. Military offices tended to have lower heating energy intensity: these premises tended to operate during weekday office hours only in most cases. Hot water energy intensity was considerable in Military accommodation, driven by showers and washing. In Military offices and Military storage premises hot water energy intensity was low, reflecting handwashing and use in staff kitchenettes only in most cases.

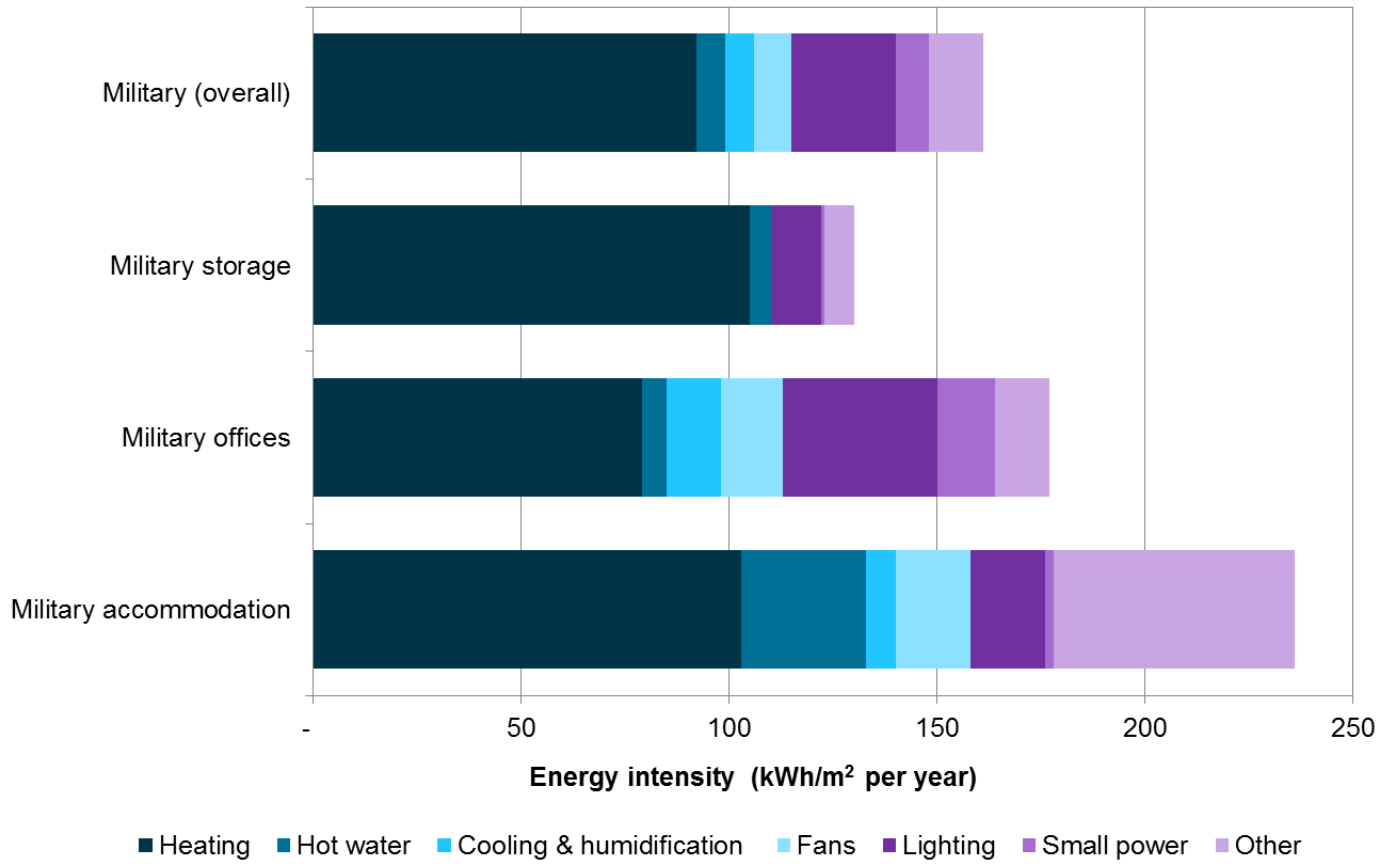
Energy intensity for fans and cooling & humidification was highest in Military offices and Military accommodation. Much of the Military's accommodation was in modern large blocks in a similar format to student accommodation; these were more likely to include comfort cooling and mechanical ventilation than the traditional barracks.

Lighting energy intensity was highest in Military offices where higher lighting levels are required; in accommodation light levels are much lower but the hours of use are significant. Site surveys identified very basic lighting provision in a number of storage facilities, resulting in low energy intensity due to low light levels. Unoccupied storage facilities also contributed to low lighting energy intensity, as lighting could be switched off much of the time.

Small power energy intensity was significant only in the Military offices sub-sector where desk based office equipment is common. The greatest contributor to the "other" end use category was catering energy in Military accommodation premises.

[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.

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



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

4. Abatement potential

In this section, abatement potential[27] for the Military 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 calculate 95 individual measures, but these have been grouped into larger categories. Within each group of measures there will be some measures that are more cost-effective than others for the sector and sub-sectors. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole.

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

The costs were based on standardised absolute installation costs[28], while the benefits were only based on the incremental reduction in energy consumption[29]. Replacement of systems which were not at the end of their life was therefore included. This will be more expensive than end of life replacement, as the impact on energy consumption is likely to be smaller for where equipment is newer, while the full capital costs are taken into account. This means that a measure may be cost-effective if the system is replaced at the end of its life - especially as at the end of life the cost of the more energy efficient alternative would be compared to replacement with a less efficient alternative - but, the same measure may not be cost-effective if the system is replaced earlier in its life. Replacing measures at the end of life will be less costly for organisations, but it would take longer for the full potential to be realised. While the costs include an allowance for installation costs and hassle costs, this may not include all the wider disruption costs that may be faced by organisations upgrading equipment; for example it does not factor in the costs of relocating staff if it is not possible for staff to work on site while work is underway. In the military sector, the additional security restrictions also increase the costs of installation relative to industry averages, but this has not been included in this analysis. The

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

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

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

extent to which organisations face these costs will depend on whether upgrades are scheduled as part of a wider refurbishment. [30]

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 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 Military sector throughout England and Wales.

Total technical abatement potential for Military 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 49 and 57 per cent of total energy consumption[31]. Each sub-sector can achieve between 39 to 58 per cent savings in electrical energy consumption and 52 to 56 per cent savings in non-electrical energy consumption. This could be achieved at an overall capital expenditure of £310 million.

Table 4.1: Abatement potential by Military sub-sector, 2014–15

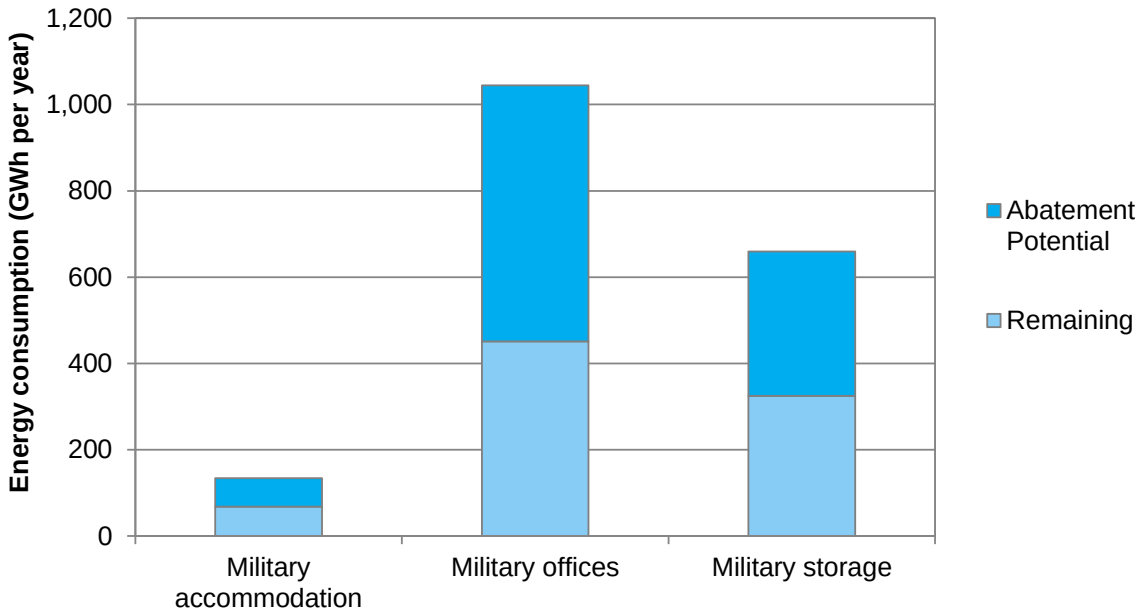
	Capital Expenditure required to deliver abatement potential (£ thousands)	**Baseline energy consumption (Energy Use model)**		**Total abatement potential**		
Sub-sector		Annual electrical energy consumption (GWh)	Annual non-electrical energy consumption (GWh)	Annual electrical energy savings (GWh)	Annual non-electrical energy savings (GWh)	Overall reduction (per cent)
Military accommodation	19,900	50	80	20	50	49
Military offices	203,000	530	520	310	290	57
Military storage	86,700	110	550	50	280	51
Total	**309,700**	**690**	**1,150**	**380**	**610**	**54**

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

[30] The findings for the military sector have been compared to a parallel study conducted by the Military as part of the DIO EUS BEIM programme (Defence Infrastructure Organisation, Energy Utilities and Sustainability, Built Environment Improvement Measures). This project found that the capital cost for energy efficiency measures was substantially greater than in typical commercial environments. This was due in large part to restrictions on staff and requirements for security clearance. As a result BEES costs, which are based on more typical commercial environments, may underestimate the cost of implementing measures in this sector.

[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 Military sub-sector, 2014–15



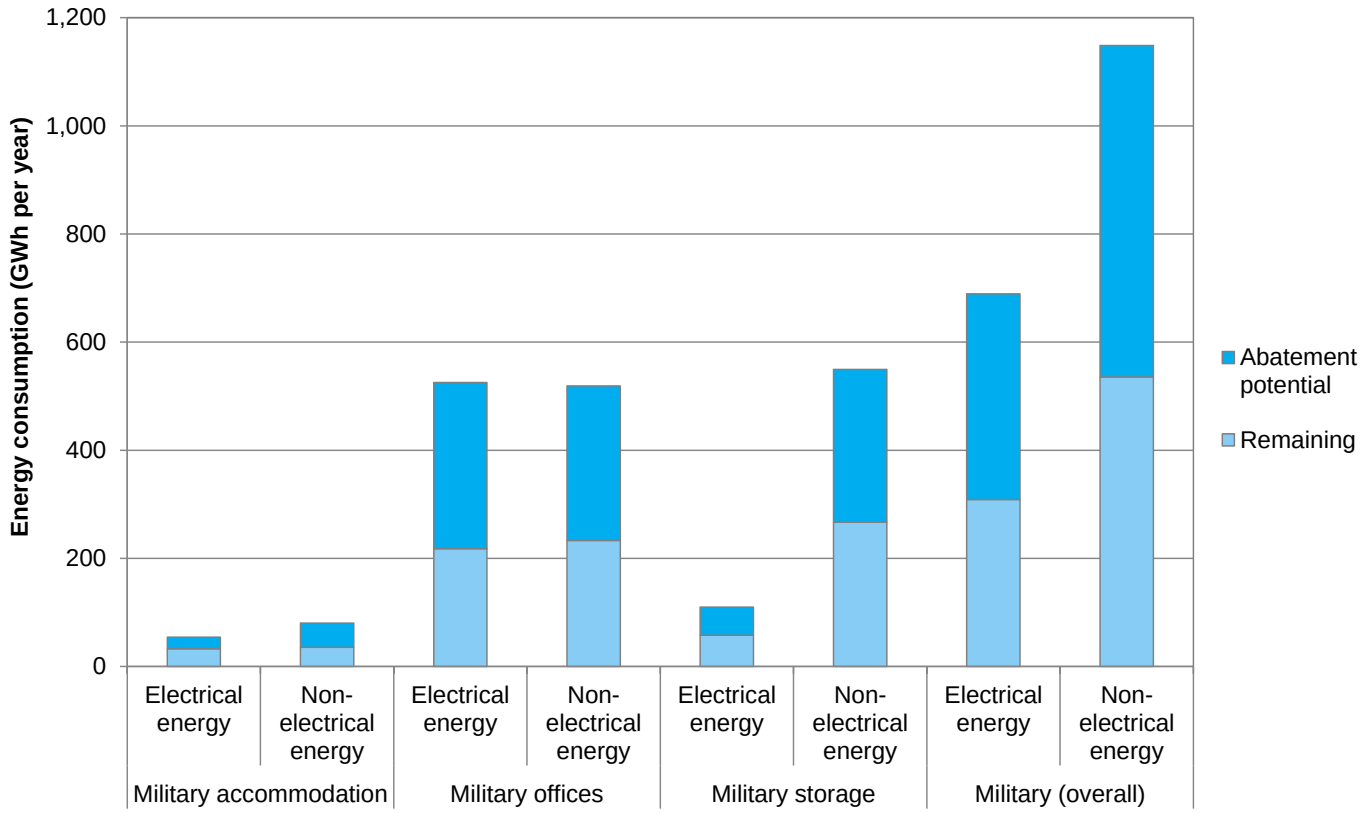
Source: Abatement model results by sub-sector, England and Wales

Figure 4.2 shows that the total technical abatement potential in 2014–15 varied by sub-sector: Military offices had the largest absolute and proportional scope for reduction (57 per cent overall). This compared with 51 per cent in Military storage and 49 per cent in Military accommodation.

The results were separated into electrical and non-electrical energy. On a percentage basis there was marginally more abatement potential associated from savings in electrical energy use. This is likely due to the high prevalence of compact fluorescent tube lighting, particularly in Military offices, and the associated savings from related abatement measures. Further detail of the abatement potential for each sub-sector is provided in Appendix D.

The proportional abatement potential available in Military offices was higher than that estimated for the office sector, a separate sector of the non-domestic stock in BEES with an estimated 33 per cent reduction for electrical energy and 49 per cent reduction for non-electrical energy. Similarly the storage sector was estimated to have an abatement potential equivalent to a 33 per cent reduction in electrical energy consumption and 47 per cent reduction in non-electrical energy consumption – lower than the percentage reduction for the Military storage sector. This is likely due to the presence of typically older building service plant in Military premises, providing greater potential for energy savings.

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

The total abatement potential of the socially cost effective measure groups was 610 GWh, of which 270 GWh was electrical energy consumption and 340 GWh non-electrical energy consumption. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. The total abatement potential relating to measure groups with a private payback of 3 years or less was 590 GWh, of which 270 GWh was electrical energy consumption and 320 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, building instrumentation and control and carbon and energy management. These measure groups also had relatively low payback periods, suggesting they may be more likely to get taken up, but recognising that take-up will also depend on the extent to which there are barriers.

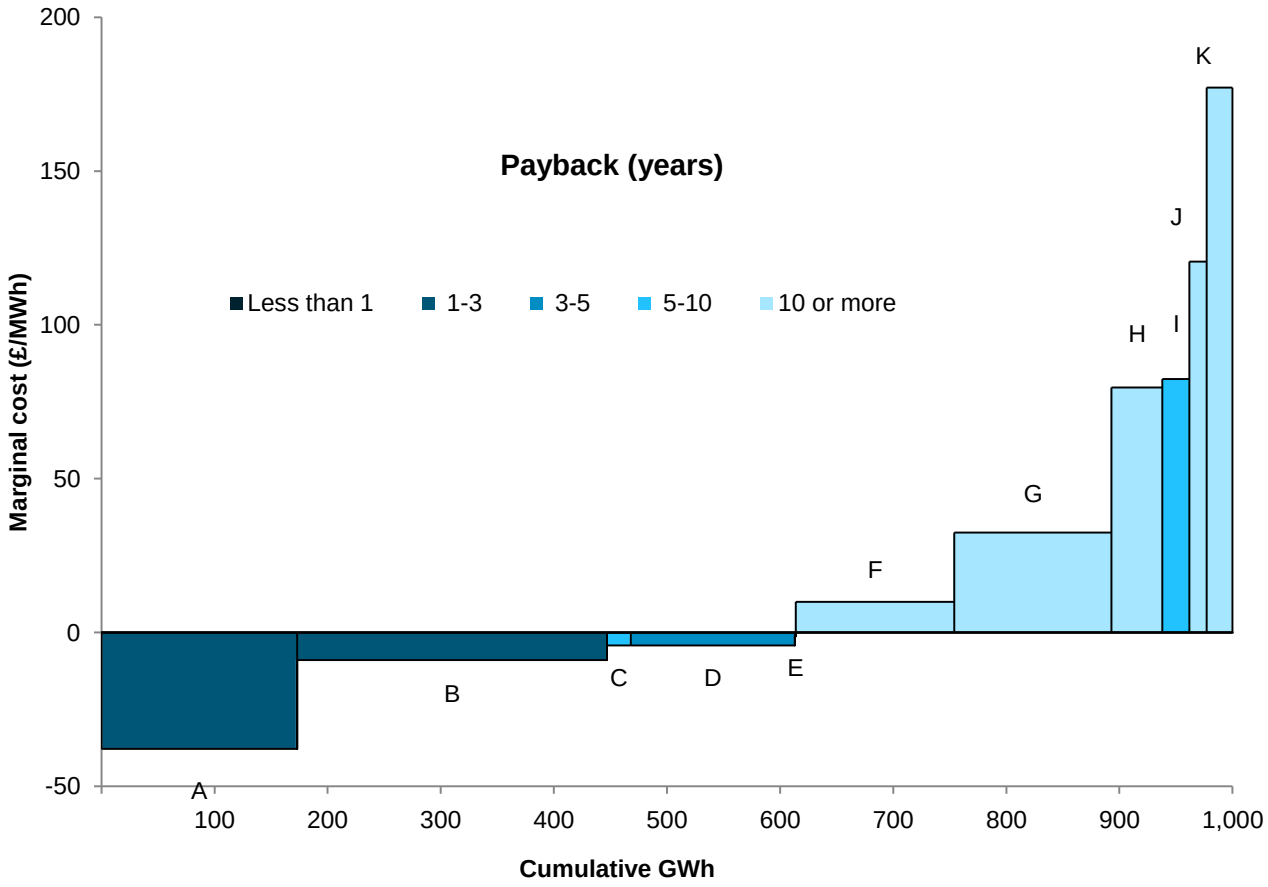
These modelled findings corresponded broadly with opportunities identified in the site surveys. Typically site surveys identified potential savings associated with heating controls upgrades (space temperature control, thermostatic radiator valves, improved heating zoning), lighting upgrades and building management system recommissioning / upgrade.

In terms of carbon and energy management measures it was found that on some premises the lights were often left on – this was particularly acute for large storage hangars, where the relative occupancy was very low. In addition, hangar doors were left open whilst heating systems were engaged and multiple heaters were employed in drying rooms operating 24 hours a day, when a single heater would suffice.

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

In some cases site surveys identified additional potential to that calculated in the modelled output for a record. Typically this would be the case where an exceptional characteristic about the premises had been identified at the site visit, which related to information not collected as part of the telephone survey. An example of this would be sites where pipes used to distribute heating were passing through mothballed areas and should be isolated to reduce radiant losses.

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: £-38 per MWh. GWh: 170]

B Carbon and Energy Management [MAC: £-9 per MWh. GWh: 270]

C Building instrumentation and control [MAC: £-4 per MWh. GWh: 140]

D Hot water [MAC: £-4 per MWh. GWh: 20]

E Cooled storage [MAC: £-1 per MWh. GWh: 1]

F Building fabric [MAC: £10 per MWh. GWh: 140]

G Space heating [MAC: £32 per MWh. GWh: 140]

H Ventilation [MAC: £80 per MWh. GWh: 50]

I Building services distribution systems [MAC: £82 per MWh. GWh: 20]

J Air conditioning and cooling [MAC: £121 per MWh. GWh: 20]

K Small appliances [MAC: £177 per MWh. GWh: 20]

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 savings were associated with carbon and energy management, lighting, space heating, building fabric and building instrumentation and control measures. The most significant available savings - in terms of annual energy bill savings - were associated with lighting upgrades, carbon and energy management programmes and ventilation measures.

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

Measure type	Savings					Total capital cost of measure (£ thousands)
	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	
Air conditioning and cooling	1,500	4	20	-	20	16,200
Building fabric	3,700	20	2	140	140	71,600
Building instrumentation and control	4,600	20	10	130	140	15,100
Building services distribution systems	2,400	8	20	-	20	14,200
Carbon and energy management	13,300	50	90	190	270	13,900
Hot water	600	3	0	20	20	4,000
Humidification	-	-	-	-	-	-
Lighting	17,100	60	170	-	170	50,300
Cooled storage	100	0	1	-	1	400
Small appliances	2,100	7	20	2	20	27,100
Space heating	3,500	10	0	140	140	49,600
Swimming pools	-	-	-	-	-	-
Ventilation	4,400	10	50	-	50	47,300
Total	**53,400**	**180**	**380**	**610**	**1000**	**309,700**

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)
Military accomodation	94	± 24
Military offices	89	± 20
Military storage	22	±8
Military	**60**	**± 16**

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

	Mean (kWh/m^2)	Confidence interval (kWh/m^2)
Military accommodation	140	± 17
Military offices	88	± 15
Military storage	108	± 33
Military	**100**	**± 16**

Response rates

Response rates are not shown for the Military sector as these sub-sectors were entirely sampled through direct contacts provided by the Ministry of Defence.

Appendix B: Military method challenges and data collection

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

Military sector methodology challenges

In the case of the Military 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: Military sector approach challenges

Stage	Challenge	Response	Impact
Sample source data	NEED did not contain a sample source for Military estate.	The MOD was not able to provide a premises level register. Only aggregate statistics could be provided on prominence of different premises types by floor area bandings.	The team could not select the sample directly. There was a reliance on the Military team to select premises which fit each quota.
Sample design	The Military estate comprises a near complete range of non-domestic premises; within BEES our modelling approach had to target discrete sub-sectors.	The Military's estate data was examined. Offices, storage and accommodation were identified as the premises types making up the majority of the stock in terms of floor area. These three sub-sectors were targeted in the BEES analysis.	A proportion of the Military estate (circa 30 per cent) was not sampled or modelled in the BEES study. These premises are not accounted for in the final results which effectively treat the Military sector as comprising only of offices, storage and accommodation.
Sample design	NEED did not contain a sample source for the Military estate.	Military was not able to provide a premises level register. Only aggregate statistics could be provided on prominence of different premises types by floor area bandings.	The team was not able to adopt standard floor area bandings as used elsewhere in the study. The team had limited understanding of the quality of data held in the source database.

Stage	Challenge	Response	Impact
Data collection	Energy management is handled through regional facilities management contracts.	The team successfully engaged with 3 facilities management contractors to provide telephone survey data for BEES. In each case, telesurvey responses were handled by 1 individual. They would cover responses for all premises they were responsible for. Only 2 facilities management contractors were willing to support the site surveys.	The reliance on a single point of contact has meant that the quality of responses is expected to be of a lower quality than anticipated. In order to efficiently populate the survey, respondents appeared to auto populate data with the same response for many premises. Respondents may also only have had limited direct or recent knowledge of the premises they were responding on. Finally, where a respondent tended to provide a poor quality of responses, the issue would be magnified as they would typically be responsible for a third of overall submissions.
Data processing	Premises on Military sites are rarely directly metered.	The hypothesis model was calibrated based on site survey data on plant used on site, on the few data points where calibrated data was available, and against benchmark data for Military premises.	The calibration process could not be fully completed for this sector due to the incomplete energy data records.
Data aggregation	NEED did not contain an aggregation source for Military estate.	The team used the Property Gazetteer data, a Military estate inventory, for grossing.	There is no significant impact of using the Property Gazetteer.

Telephone survey and site survey data collection

Table B.2 shows that 64 telephone survey or equivalent records and 9 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[34]	Average Interview length (mins.)	Target sample size	Site surveys completed
Military accommodation	30	0	30	30	24	n/a	3	3
Military offices	29	0	29	29	24	n/a	3	3
Military storage	19	0	19	19	16	n/a	3	3
Military sector	**78**	**0**	**78**	**78**	**64**	n/a	**9**	**9**

Source: Telephone survey or equivalent records, England and Wales

[34] 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 Military sector. This is split out between electrical energy and non-electrical energy use.

Energy end use definitions

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

Table C.1: Definitions for energy end uses

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

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

End use category		Description
	equipment	
22	**Pool/leisure**	All energy use associated with pool and sport leisure facilities within the premises. This should include heating, lighting, pumps, ventilation, humidification, and dedicated controls, alarms etc.
23	**Other**	Any other energy uses which fall outside categories 1 to 21, which are "normal" - i.e. are typical for the specific building type.

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

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

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

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

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

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

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

Simplified end use category	BEES end use category	Electrical energy consumption (GWh per year)			
		Military accommodation	Military offices	Military storage	**Military (overall)**
Heating	Space heating	-	1	3	4
Hot water	Hot water	0	6	3	9
Cooling & humidification	Space cooling	4	80	0	80
Fans	Fans	10	90	2	100
Lighting	Lighting - internal	10	220	60	290
Small power	Small power	1	80	4	80
Other	Medical equipment	-	-	-	-
	ICT equipment	-	4	0	4
	Cooled storage	4	-	-	4
	Pumps	1	9	8	20
	Controls	1	8	1	9
	Humidification	-	-	-	-
	Laundry	4	-	-	4
	Lighting - display	1	-	-	1
	Lighting - external	0	4	2	6
	Entertainment lighting	-	-	-	-
	Vertical transport	0	1	-	1
	Distributed catering	1	9	4	20
	Central catering	10	10	-	30
	Entertainment equipment	4	4	1	10
	Lab equipment	-	-	-	-
	Pool/leisure	-	-	-	-
	Other - normal	0	-	20	20
Total		**50**	**530**	**110**	**690**
Unweighted base		*24*	*24*	*16*	*64*

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

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

Simplified end use category	BEES energy end use category	Non-electrical energy consumption (GWh per year)			
		Military accommodation	Military offices	Military storage	**Military (overall)**
Heating	Space heating	60	460	530	1,050
Hot water	Hot water	20	30	20	70
Catering	Catering	4	20	-	30
Other	Medical equipment	-	-	-	-
	Pool/leisure	-	-	-	-
	Humidification	-	-	-	-
Total		**80**	**520**	**550**	**1,150**
Unweighted base		*24*	*24*	*16*	*64*

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

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

Simplified end use category	BEES end use category	Electrical energy intensity (kWh/m^2 per year)			
		Military accommodation	Military offices	Military storage	**Military (overall)**
Heating	Space heating	-	0	1	0
Hot water	Hot water	0	1	0	1
Cooling & humidification	Space cooling	7	13	0	7
Fans	Fans	18	15	0	9
Lighting	Lighting - internal	18	37	12	25
Small power	Small power	2	14	1	8
Other	Medical equipment	-	-	-	-
	ICT equipment	-	1	0	0
	Cooled storage	8	-	-	0
	Pumps	2	2	2	2
	Controls	1	1	0	1
	Humidification	-	-	-	-
	Laundry	6	-	-	0
	Lighting - display	2	-	-	0
	Lighting - external	0	1	0	0
	Entertainment lighting	-	-	-	-
	Vertical transport	0	0	-	0
	Distributed catering	2	2	1	1
	Central catering	21	2	-	2
	Entertainment equipment	8	1	0	1
	Lab equipment	-	-	-	-
	Pool/leisure	-	-	-	-
	Other	0	-	4	2
Total		**94**	**89**	**22**	**60**
Unweighted base		*24*	*24*	*16*	*64*

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

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

Simplified end use category	BEES energy end use category	Non-electrical energy intensity (kWh/m^2 per year)			
		Military accommodation	Military offices	Military storage	**Military (overall)**
Heating	Space heating	103	79	104	91
Hot water	Hot water	30	5	4	6
Catering	Catering	7	4	-	2
Other	Medical equipment	-		-	-
	Pool/leisure	-	-	-	-
	Humidification	-	-	-	-
Total		**140**	**88**	**108**	**100**
Unweighted base		*24*	*24*	*16*	*64*

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

Appendix D: Abatement potential

The definitions for each measure type are included in this appendix as well as the abatement potential for each Military 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.

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).

Military accommodation

In Military accommodation there was an annual abatement potential of 20 GWh of electrical energy and 50 GWh of non-electrical energy (equivalent to 10 $ktCO_2e$ combined). This equates to a 39 per cent and 56 per cent reduction on energy consumption respectively. The capital cost to achieve this is £20m. The annual savings delivered would be £3m[35]. These figures are grouped according to measure type in Table D.2. The total abatement potential of the socially cost effective measure groups was 40 GWh, of which 10 GWh was electrical energy consumption and 30 GWh was non-electrical energy consumption. This represents the energy savings that could be achieved through measures where the benefits outweigh the costs to society. The total abatement potential relating to measure groups with a private payback of 3 years or less was 30 GWh, of which 10 GWh was electrical energy consumption and 20 GWh non-electrical energy consumption. Within each group of measures there will be some measures that are more cost-effective than others for each sub-sector. Some cost effective measures will therefore be hidden within groups that are not considered cost effective as a whole (Figure D.1).

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

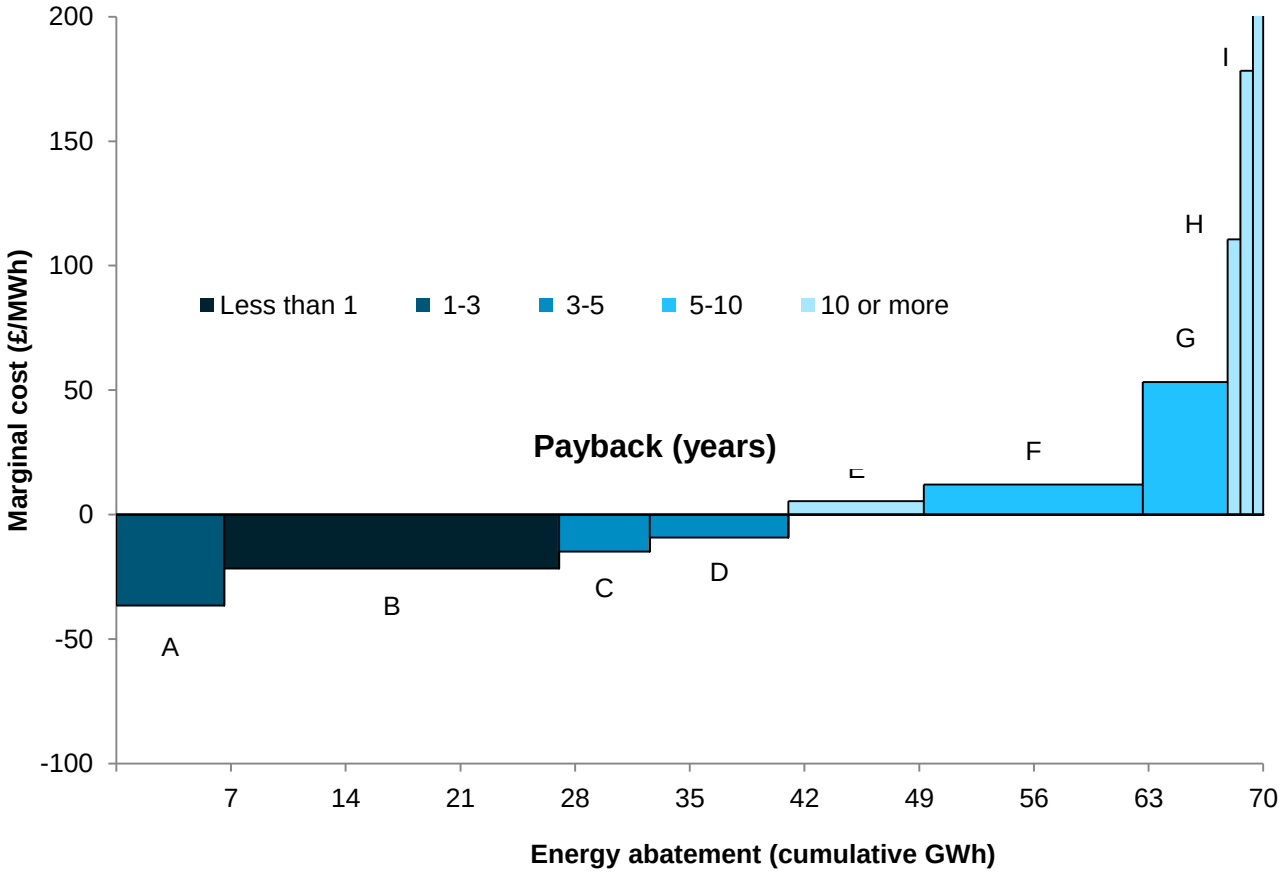
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	**Payback period (years)** [36]
Air conditioning and cooling	100	0	1	-	1	1,200	27
Building fabric	200	1	0	8	8	4,100	10
Building instrumentation and control	300	2	1	7	8	1,200	3
Building services distribution systems	100	0	1	-	1	800	6
Carbon and energy management	1,000	5	7	10	20	600	1
Hot water	100	1	0	5	5	600	4
Humidification	-	-	-	-	-	-	-
Lighting	600	2	6	-	6	1,800	2
Cooled storage	-	-	-	-	-	-	-
Small appliances	0	0	0	0	1	2,600	37
Space heating	300	2	0	10	10	3,000	8
Swimming pools	-	-	-	-	-	-	-
Ventilation	500	1	5	-	5	4,200	4
Total	**3,200**	**10**	**20**	**50**	**70**	**19,900**	‘’

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

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

[36] 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 Military accommodation, 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: £-37 per MWh. GWh: 6]
B Carbon and Energy Management [MAC: £-22 per MWh. GWh: 20]
C Hot water [MAC: £-15 per MWh. GWh: 5]
D Building instrumentation and control [MAC: £-9 per MWh. GWh: 8]
E Building fabric [MAC: £5 per MWh. GWh: 8]
F Space heating [MAC: £12 per MWh. GWh: 10]
G Ventilation [MAC: £53 per MWh. GWh: 5]
H Air conditioning and cooling [MAC: £111 per MWh. GWh: 1]
I Building services distribution systems [MAC: £179 per MWh. GWh: 1]
J Small appliances [MAC: £708 per MWh. GWh: 1]

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

Military offices

In Military offices there was an annual abatement potential of 310 GWh of electrical energy and 290 GWh of non-electrical energy (equivalent to 140 $ktCO_2e$ combined). This equates to a 58 per cent and 55 per cent reduction on energy consumption respectively. The capital cost to achieve this is £203m. The annual savings delivered would be £38m[37]. These figures are grouped according to measure type in Table D.3. The total abatement potential of the socially cost effective measure groups was 370 GWh, of which 210 GWh was electrical energy consumption and 160 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 360 GWh, of which 210 GWh was electrical energy consumption and 150 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 Military offices, 2014–15

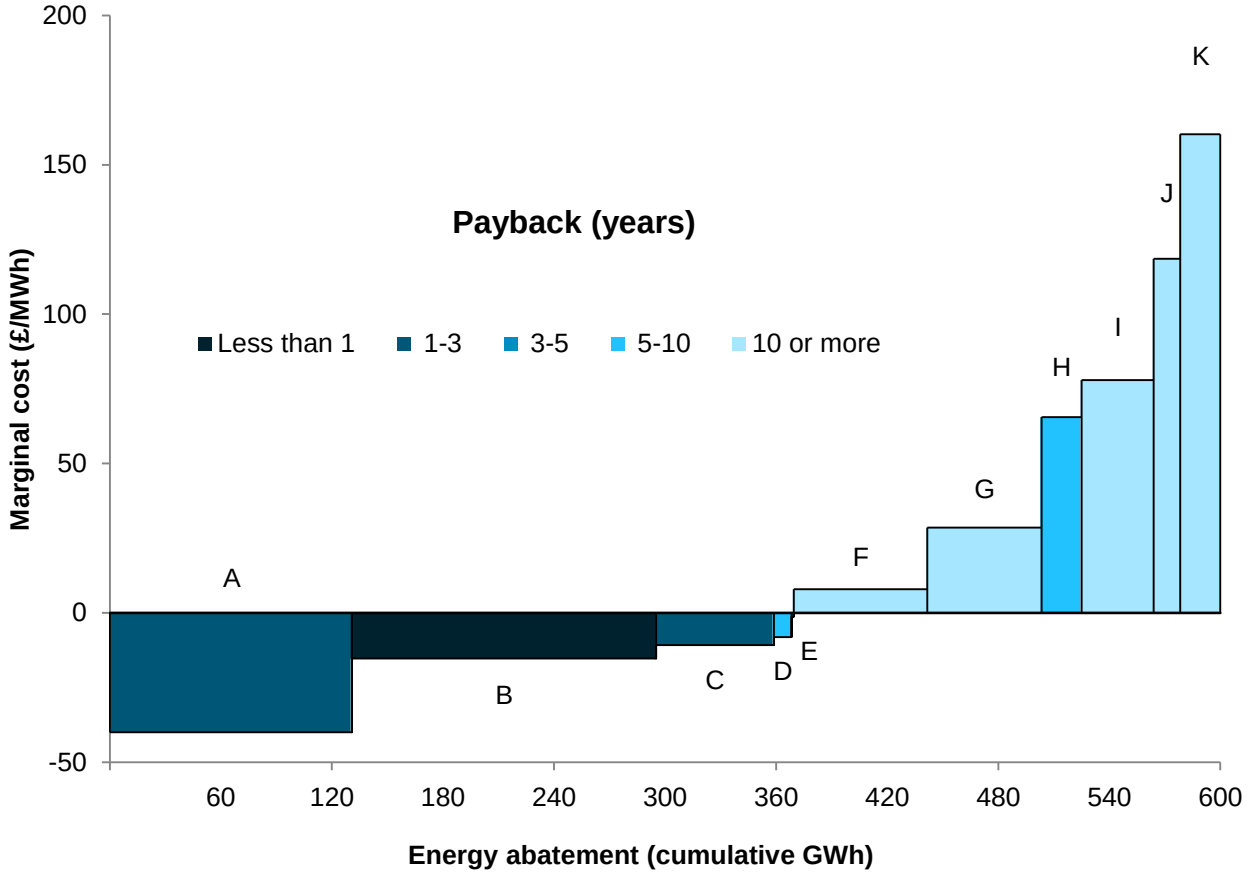
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	Payback period (years)[38]
Air conditioning and cooling	1,400	4	20	-	20	14,700	10
Building fabric	1,900	10	2	70	70	41,800	12
Building instrumentation and control	2,400	10	10	50	60	6,600	2
Building services distribution systems	2,100	6	20	-	20	10,800	3
Carbon and energy management	9,200	40	70	90	160	8,000	1
Hot water	300	2	0	9	10	1,700	5
Humidification	-	-	-	-	-	-	-
Lighting	12,900	40	130	-	130	32,300	2
Cooled storage	100	0	1	-	1	400	3
Small appliances	2,100	7	20	1	20	24,100	9
Space heating	1,600	10	0	60	60	21,800	11
Swimming pools	-	-	-	-	-	-	-
Ventilation	3,800	10	40	-	40	40,800	6
Total	**37,800**	**140**	**310**	**290**	**600**	**203,000**	‘’

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

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

[38] 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 Military offices, 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: £-40 per MWh. GWh: 130]
B Carbon and Energy Management [MAC: £-15 per MWh. GWh: 160]
C Building instrumentation and control [MAC: £-11 per MWh. GWh: 60]
D Hot water [MAC: £-8 per MWh. GWh: 10]
E Refrigeration [MAC: £-1 per MWh. GWh: 1]
F Building fabric [MAC: £8 per MWh. GWh: 70]
G Space heating [MAC: £29 per MWh. GWh: 60]
H Building services distribution systems [MAC: £66 per MWh. GWh: 20]
I Ventilation [MAC: £78 per MWh. GWh: 40]
J Air conditioning and cooling [MAC: £119 per MWh. GWh: 20]
K Small appliances [MAC: £160 per MWh. GWh: 20]

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

Military storage

In Military storage there was an annual abatement potential of 50 GWh of electrical energy and 280 GWh of non-electrical energy (equivalent to 30 $ktCO_2e$ combined). This equates to a 47 per cent and 52 per cent reduction on energy consumption respectively. The capital cost to achieve this is £87m. The annual savings delivered would be £12m[39]. These figures are grouped according to measure type in Table D.4. The total abatement potential of the socially cost effective measure groups was 40 GWh, 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 160 GWh, of which 10 GWh was electrical energy consumption and 150 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 Military storage, 2014–15

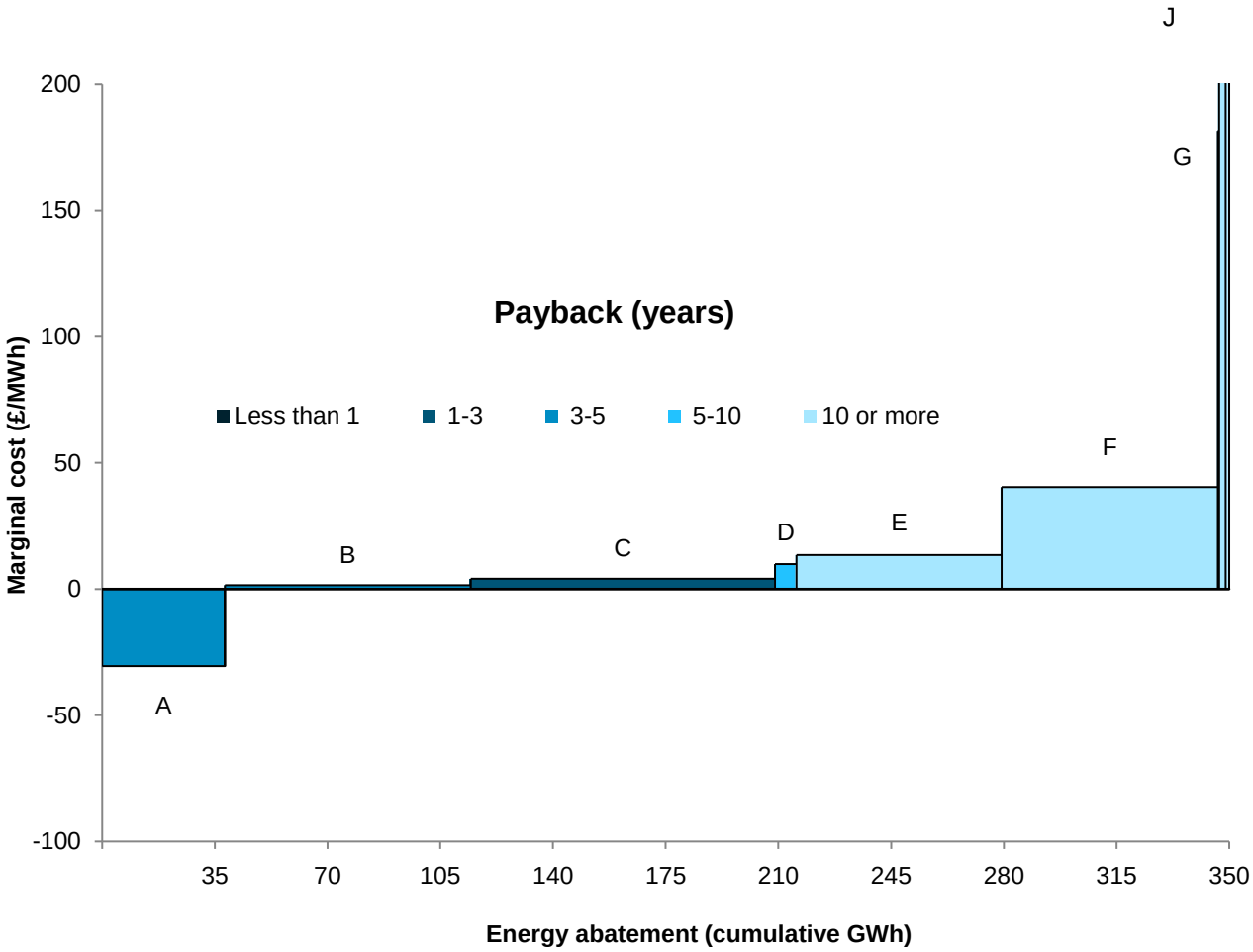
	Savings						
Measure type	Total annual energy bill saving (£ thousands)	Total annual greenhouse gas saving ($ktCO_2e$)	Total annual electrical energy savings (GWh)	Total annual non-electrical energy savings (GWh)	Total annual energy savings (GWh)	**Total capital cost of measure (£ thousands)**	Payback period (years)[40]
Air conditioning and cooling	0	0	0	-	0	400	99
Building fabric	1,600	0	0	60	60	25,700	9
Building instrumentation and control	1,900	1	1	70	70	7,400	3
Building services distribution systems	200	1	2	-	2	2,600	4
Carbon and energy management	3,100	6	10	80	90	5,200	1
Hot water	200	0	0	6	6	1,700	8
Humidification	-	-	-	-	-	-	-
Lighting	3,600	20	40	-	40	16,200	4
Cooled storage	-	-	-	-	-	-	-
Small appliances	0	0	0	0	0	400	15
Space heating	1,700	0	0	60	60	24,800	12
Swimming pools	-	-	-	-	-	-	-
Ventilation	100	0	1	-	1	2,400	13
Total	**12,400**	**30**	**50**	**280**	**330**	**86,800**	‘’

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

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

[40] 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 Military storage, 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. Note also that series 'I' is not visible as the y-axis has been capped for presentation purposes .

A Lighting [MAC: £-31 per MWh. GWh: 40]
B Building instrumentation and control [MAC: £2 per MWh. GWh: 70]
C Carbon and Energy Management [MAC: £4 per MWh. GWh: 90]
D Hot water [MAC: £10 per MWh. GWh: 6]
E Building fabric [MAC: £10 per MWh. GWh: 60]
F Space heating [MAC: £40 per MWh. GWh: 60]
G Small appliances [MAC: £186 per MWh. GWh: 0]
H Ventilation [MAC: £331 per MWh. GWh: 1]
I Air conditioning and cooling [MAC: £972 per MWh. GWh: 0]

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