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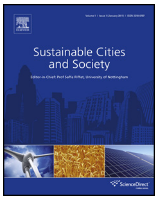

Do smart grids offer a new incentive for SME carbon reduction?

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ABSTRACT

Collectively small and medium sized enterprises (SMEs) are significant energy users although many are unregulated by existing policies due to their low carbon emissions. Carbon reduction is often not a priority but smart grids may create a new opportunity. A smart grid will give electricity suppliers a picture of real-time energy flows and the opportunity for consumers to receive financial incentives for engaging in demand side management. In addition to creating incentives for local carbon reduction, engaging SMEs with smart grids has potential for contributing to wider grid decarbonisation.

Modelling of buildings, business activities and technology solutions is needed to identify opportunities for carbon reduction. The diversity of the SME sector complicates strategy development. SMEs are active in almost every business area and occupy the full range of property types. This paper reviews previous modelling work, exposing valuable data on floor space and energy consumption associated with different business activities. Limitations are seen with the age of this data and an inability to distinguish SME energy use.

By modelling SME energy use, electrical loads are identified which could be shifted on demand, in a smart network. Initial analysis of consumption, not constrained by existing policies, identifies heating and cooling in retail and commercial offices as having potential for demand response. Hot water in hotel and catering and retail sectors may also be significant because of the energy storage potential. Areas to consider for energy efficiency schemes are also indicated.

1. Introduction

Local authorities are keen to reduce carbon emissions in their areas. For example, Reading Borough Council's Climate Change Strategy calls for the Borough's carbon footprint to be reduced by 80% from 1990 levels (Reading Borough Council, 2008). Almost half (48%) of Reading Borough's carbon emissions came from the commercial and industrial sectors in 2010 and 69% of this was due to electricity (DECC, 2012a). Nationally, the vast majority (over 99%) of private sector businesses are SMEs[1] and they employ 59% of the private sector workforce (White, 2011).

Business activity, built form and carbon reduction measures are diverse and inter-related typologies. SMEs are active in almost every business sector. They occupy a property portfolio, diverse in purpose, in age, in the building services supplied, in the state of maintenance and complicated by differing objectives of landlords and tenants. This obscures the applicable carbon reduction measures. Many SMEs consume little energy (sometimes 1–2% of costs) (Carbon Trust, 2009), which puts them below the threshold of existing carbon reduction policies and offers a trivial financial return.

Smart grids may introduce new incentives for demand side management (DSM) by SMEs. This includes demand reduction and demand response (principally shifting electricity demand to periods when the carbon intensity is lower) (Owen et al., 2011). The smart grid concept proposes an electricity network that integrates generation and consumption with real-time two-way communication. One definition is that the electricity network can *intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies* (European Commission, 2012).

This provides an opportunity for the energy supplier to offer financial incentives for reducing demand at peak times. Options include critical peak pricing (CPP) and real time pricing (RTP) (Dolman, Walker, Wright, & Stuart, 2012). With CPP a significantly higher price is imposed for brief periods or for a small number of days each year when demand is expected to be high. With RTP, the

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[1] An SME has fewer than 250 employees, a turnover up to €50 M or a balance sheet up to €43 M. http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/sme-definition/index_en.htm (30.03.13).

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tariffs vary during the day, to reflect the wholesale market price. There is very little experience of using these tariffs in the UK but technologies that enable stricter compliance through automatic switching may increase the energy reduction. Some companies currently offer incentives for on-site generating capacity to be maintained ready to operate in response to a request from an energy supplier (Flexitricity, 2012).

Matching electricity supply and demand will become a greater challenge this decade but smart grids could support this transition. The proportion of renewable (and non-controllable) generation is planned to quadruple between 2010 and 2020 to around 30% (DECC, 2009, 2011a). Around one fifth of conventional generating capacity will close by 2020 and the expenditure on new plant must be minimised in tough economic conditions (DECC & Ofgem, 2011). This will impose greater demand response requirements on generating plant. If consumption is reduced when the renewable supply is low or the demand is high, this eases the burden on system balancing, allowing electricity to be generated with lower carbon emissions. Currently the distribution network is largely a passive carrier. Focused investment is only possible with a more detailed picture of electricity flow.

In order to understand where smart grids may be relevant, energy use in buildings and businesses must be analysed. This paper identifies some of the challenges related to building and business classification and reviews some of the previous work. Initial analysis of electricity consumption by end use for different activity types is carried out, using publicly accessible data. The intention is to identify loads that could be switched off for short periods at peak times.

2. Classifications

2.1. Factors affecting classification

When classifying non-domestic property, some clarifications are needed. These could be expressed as: *What constitutes one non-domestic building?* and *How is business activity related to building type?* (Bruhns, Steadman, Herring, Moss, & Rickaby, 2000). Non-domestic property is more diverse than residential. There are many types of physical structures (such as sheds and halls) and the activities these buildings encompass are hugely varied. Understanding existing building types is a pre-requisite for characterising their energy consumption and the opportunities for carbon reduction.

A building encloses space which is accessible and useable for some human activity (Bruhns et al., 2000). In this context, this is limited to structures that require energy input (such as heating), are *reasonably permanent* (to include ‘Portakabins’ but not tents) and are above a certain size (ruling out telephone boxes). *Non-domestic* refers to buildings that are not private residential accommodation. Bruhns et al. (2000) included residential homes, homeless hostels and guest houses but not holiday letting. This includes premises that provide accommodation as part of a business but not private dwellings. Buildings occupied by businesses that operate from home are excluded.

There is a loose relationship between building structure and the activities enclosed (Bruhns et al., 2000). Many building types can contain office activities. A physical shed can contain a warehouse, factory units or offices. Frequently a building provides space for more than one business or a mixture of businesses and dwellings, such as a block of shops with offices or residential apartments above.

Each premise could contain a different business activity, with a different energy use profile. A *premise* is the accommodation that one business occupies exclusively and consists of part of a building, the whole building or many adjacent buildings (Bruhns et al., 2000). This relates it to *hereditament*, the property unit used by the Valuation Office Agency (VOA) to reference data for taxation.

2.2. Non-domestic building Stock Database (NDBS)

During the 1990s the Government sponsored the development of the NDBS. Its purpose was to better understand the non-domestic building stock in order to inform policy relating to CO_2 reduction (Steadman, Bruhns, & Rickaby, 2000). The NDBS classified property and gathered statistics on numbers, types and floor areas and on how energy was consumed.

Four main data sources were used:

- Surveys of 3350 properties from the outside in four English towns carried out between 1989 and 1992 (Brown, Rickaby, Bruhns, & Steadman, 2000). The construction, fabric, envelope and activities were recorded. The floor areas, flat roof areas and other dimensions were calculated.
- Internal surveys of 700 properties mainly in the same four towns, from the 1990s (Mortimer, Ashley, & Rix, 2000). This aimed to build a comprehensive picture of energy consumption by fuel and end use for different building types, by recording equipment loads and usage profiles.
- Records from the Valuation Office Agency (VOA) were used to scale up this data to represent the national stock (Steadman, Bruhns, & Rickaby, 2000). The VOA hold records of all non-domestic property in England and Wales that is subject to rates listed by hereditament (a premise with a single occupier). Properties such as agricultural buildings and places of worship are exempt (“Local Government Finance Act 1988,” 1988). This consists of the Rating List (RL) and the Summary Valuation (SMV), previously called the Valuation Support Application (VSA). The RL covers all 1.7 million hereditaments (with address, valuation and a brief description). The SMV database holds detailed data on the most prolific premises types (shops, offices, factories and warehouses) and now covers 1.5 million hereditaments following revaluation in 2005 (VOA, 2005).

Classification of buildings was simplified by separating each structure into its components, consisting of primary parts and *parasitic* structures (Steadman, Bruhns, Holtier, & Gakovic, 2000). Since this breaks the building down into shapes, it is possible to account for each component of a building, which enables the relationship between built form and energy consumption to be better understood. To classify business activities, a five level hierarchical classification, based largely on the VOA system was created (Bruhns et al., 2000). Statistics of floor areas and numbers for most building types, classified by activity in England and Wales were generated for 1994. Data on the extent of air-conditioning and analysis on a regional basis were identified.

The numbers of premises were compared with some other sources. A comparison with data from British Telecom produced group totals of premises (for related categories) that matched well (Bruhns et al., 2000). Individual totals differed widely, probably due to inconsistencies in definition. The NDBS work is of particular interest because it collated data on non-domestic property (types and floor areas) and combined it with energy consumption, broken down by fuel and end use. There are few other large scale, accessible sources of energy by end use. These bottom up data were used in the Carbon Reduction in Buildings Project (CaRB) to compare with top down data published in the Digest of UK Energy Statistics (DUKES) for 2004 (Bruhns, Steadman, & Marjanovic, 2006). The estimates for energy used by the public and commercial sectors in CaRB are about 15% lower than stated by DUKES. This is broadly consistent with the geographical limits of the two models: CaRB is restricted to England and Wales; DUKES covers the UK. For

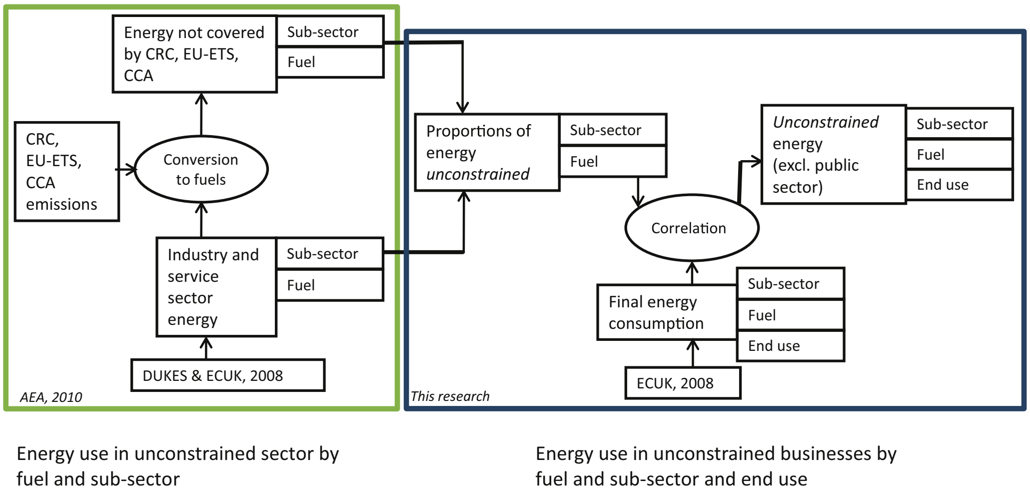

Fig. 1. Determination of *unconstrained* energy by sub-sector.

industry, the DUKES estimate is about 2½ times higher than CaRB. A large difference is expected because DUKES includes industrial process energy but CaRB only considers building related energy.

2.3. Non-domestic buildings Energy and Emissions Model (N-DEEM)

N-DEEM was developed by the Building Research Establishment (BRE) using data from NDBS to model energy use in non-domestic property and create scenarios for carbon reduction (Pout, 2000). It aimed to disaggregate the data according to six parameters: activity of the building user, construction (materials and structures), age of premises, size band, end use of energy and fuel. The activity of the occupant is key since it determines the purpose of the energy consumption. Evaluation by business sector allows the potential impact of new policies to be tested. The building age and size may infer physical features and construction methods and are used as *proxies* for construction data, which was not generally available. Analysis by BRE of DUKES, creates the disaggregation by end uses seen in Energy Consumption in the UK (ECUK), published annually by the Department of Energy and Climate Change (DECC).

2.4. The National Energy Efficiency Data framework (NEED)

NEED aims to create a central framework for recording information on the entire building stock in Great Britain (Neffendorf, Bruhns, & Harrison, 2009). It aims to monitor changes in energy use and energy efficiency, to target specific sectors for energy reduction and to create bespoke programmes for those sectors. Both domestic and non-domestic parts of NEED rely on matching property related data from several sources. A pilot study for non-domestic NEED in Bristol highlighted the wealth of property data available but the severe difficulty of accessing useful information due to the disparate nature of the sources (Bruhns & Wyatt, 2011). An example of this was the difficulty of matching premises and energy data. Initial analysis reported by DECC mentions the problems of address matching, made more difficult by multiple occupancy (DECC, 2012b). 1.8 million hereditaments make up 1.1 million non-domestic buildings. 95% of buildings have one occupier. The other 5% account for 46% of hereditaments. NEED will consider questions such as the effect of more accurate demand side data (including from smart meters) on managing supply side problems (Neffendorf et al., 2009).

3. Method of analysis

This previous research offers benchmarks for energy use and shows the challenge of identifying potential end uses of energy to time-shift. Electricity grid de-carbonisation offers new opportunities for consumers to contribute to supply management and carbon reduction. Smart grids can provide pricing incentives to encourage customers to reduce their consumption at peak times. This section attempts to identify blocks of electrical demand, which could contribute to demand side management.

SMEs are not distinguished from other consumers in publicly accessible electricity consumption data. The unconstrained sector (Forster et al., 2010) was considered to be the best available approximation to SMEs. This consists of organisations not regulated by the following carbon reduction policies: the Carbon Reduction Commitment (CRC), EU-Emissions Trading Scheme (EU-ETS) and Climate Change Agreements (CCA). This removes large users of energy (for example, the CRC applies to organisations using at least 6000 MWh/yr of electricity, recorded on half-hourly meters (Environment Agency, 2012)). The energy associated with each of these policies was allocated to the relevant business sector and disaggregated by fuel (Fig. 1, left box). This was subtracted from the industry and service sector energy consumption (DUKES data for 2008). This is regarded as a proxy for energy use by SMEs and small public sector organisations.

In this study, SME electricity was disaggregated by end use for each business sector. This represents a first estimate using publicly available data. For each sector, the ratio of unconstrained to total electricity was calculated from AEA's data. The SME electricity for each end use was calculated by multiplying these ratios by the end use data reported in ECUK for 2008. The public sector categories were removed leaving seven groups for the commercial sector and ten for industry, listed in Table 1. Matching the industrial sub-sectors between ECUK and DUKES required some approximation since the categories are based on different versions of the Standard Industrial Classification (SIC) system.

4. Results

Table 2 is an extract of service sector electricity consumption data published in ECUK. Categories relating to non-business buildings (the public sector and church the other buildings category) have been removed as these are not considered in the SME analysis. This gives a total of 69,543 GWh. Table 3 shows the calculated

Table 1
Business activity groups used in energy modelling.

Commercial sector	Industrial sector
Commercial offices Retail Warehouses (excluding industrial) Hotels and catering Transport and communication (building related energy use only)	Metals (ferrous and non-ferrous) Mineral products Chemicals Mechanical engineering Electrical engineering Vehicles
Sport and leisure	Food, beverages Textiles, leather Paper, printing
Other (includes churches and community centres)	Other industries (manufacturing of wood products, furniture, rubber and plastics; recycling and water treatment)

Source: Pout et al. (2002) and DTI (2002).
Public sector activities (education, government and health), excluded from analysis in this paper.

electricity attributed to unconstrained businesses (mainly SMEs). This is 25,257 GWh or 36.3% of the total in Table 2.

This is illustrated in Figs. 2 and 3. Four sub-sectors are not shown because of a lack of data (sport and leisure, agriculture, miscellaneous commercial and construction). In the end use categories, *other* relates to lifts, pumps, laboratory, photographic and other specialised equipment (Pout, Mackenzie, & Bettle, 2002, p. 60).

Figs. 2 and 3 illustrate electricity consumption in the *unconstrained* commercial and industrial sectors respectively, broken down by end use. Four sub-sectors are not shown because of a lack of data (sport and leisure, agriculture, miscellaneous commercial and construction). In the end use categories, *other* relates to lifts, pumps, laboratory, photographic and other specialised equipment (Pout et al., 2002, p. 60).

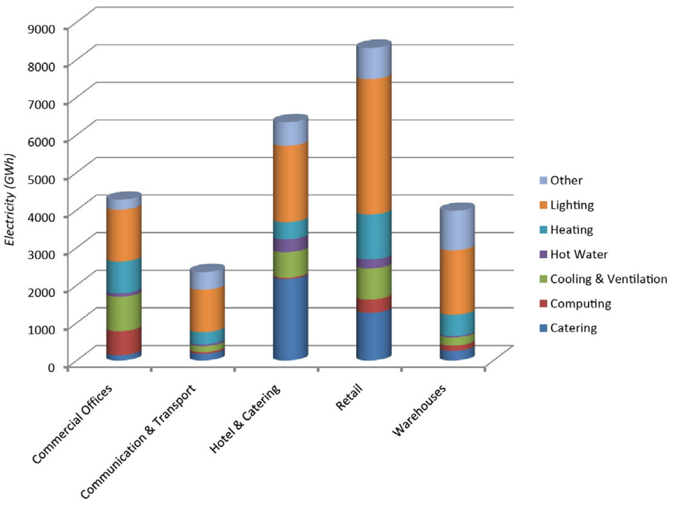

Fig. 2. Commercial sector: *unconstrained* electricity consumption by end use.
Source: DUKES, ECUK, AEA.

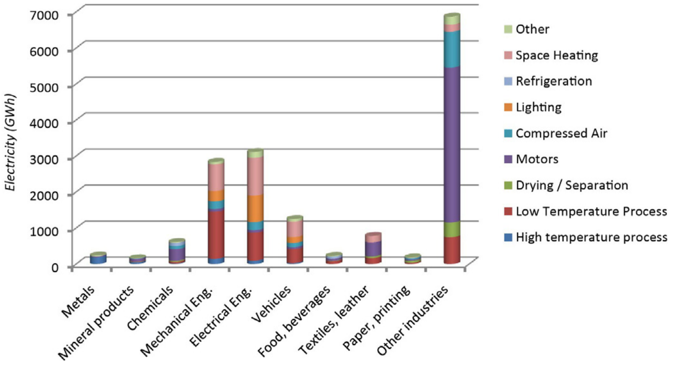

Fig. 3. Industrial sector: *unconstrained* electricity consumption by end use.
Source: DUKES, ECUK, AEA

5. Discussion

The active management of electricity consumption will become more important as the proportion from non-dispatchable sources increases. Analysis of the end uses of electricity as well as the business types and locations is necessary to highlight where DSM may be possible, with smart grid technology. Smart grids may lead to carbon reduction through demand reduction or demand response. The main form of demand response considered here is time-shifting of electrical loads away from peak periods. Owen, Ward, and Pooley (2011) state two further demand response types. These are cutting back on consumption (for example, by dimming lighting) and

Table 2
Service sector electricity, in GWh, 2008.

	Catering	Computing	Cooling and ventilation	Hot water	Heating	Lighting	Other
Commercial offices	141	637	917	92	844	1381	262
Communication and transport	178	45	160	50	324	1126	470
Hotel and catering	2166	37	677	344	454	2033	626
Retail	1264	357	825	242	1193	3606	827
Warehouses	254	141	218	36	565	1717	1048
Electricity, GWh	4004	1218	2796	764	3380	9862	3233

Source: ECUK Table 5.6: service sector final energy consumption by sub-sector and end use by fuel 2008, London: DECC.

Table 3
Unconstrained service sector electricity, in GWh, 2008.

	Catering	Computing	Cooling and ventilation	Hot water	Heating	Lighting	Other
Commercial offices	283	1275	1834	185	1689	2762	523
Communication and transport	355	90	319	99	647	2251	940
Hotel and catering	3610	62	1128	573	757	3388	1043
Retail	4577	1294	2986	878	4320	13,057	2996
Sport and Leisure	412	124	496	44	1052	1623	1092
Warehouses	689	382	591	98	1529	4650	2837
Electricity, GWh	9927	3226	7355	1877	9995	27,731	9433

Source: ECUK, AEA.

Table 4
Sectors with electrical loads considered most likely for time-shifting (*unconstrained* sector).

	Commercial sector (kt CO_2)	
Heating	Retail 645	Commercial offices 457
Cooling	Commercial offices 496	Retail 446
Hot water	Hotel and catering 186	Retail 131
	Industrial sector (kt CO_2)	
Heating	Electrical eng. 567	Mechanical eng. 402

Source: AEA (2010) and ECUK (2010).

generating electricity on site. Demand reduction arises from awareness raising which may be prompted by consumption data from a smart grid. Electrical loads which are candidates for time-shifting are likely to be peripheral to the main business activity and are most likely to be heating, cooling and hot water. It has been suggested that cooling may be switched off for up to 30 min, heating for up to 15 and hot water for a period determined by the demand pattern and storage (Dolman et al., 2012). Process loads may be suitable for time-shifting with sufficient notice or payment but this needs case by case evaluation.

Confidence in the data is good at the aggregate level but this is reduced at lower levels. Electricity suppliers provide DECC with consumption data (DECC, 2011b), from which business electricity use in DUKES is calculated. Allocation of energy to sub-sectors relies on data from the Government's Purchases Inquiry (PI) which asked around 6000 companies how much they spend on different types of fuel. These data are scaled in relation to the number of businesses in each SIC sector to match the totals in DUKES (DECC, 2010). The most recent PI data are for 2006 since this survey has been suspended. The allocation of energy to specific end uses relies largely on surveys carried out in the 1990s (for the NDBS Project). Electrical cooling and IT are now more widespread. This introduces some uncertainty in the allocations to end uses. The UK Green Building Council (2007) report that *electricity use in non-domestic buildings has risen very closely in line with floor space* [between 1992 and 2007]. More small electrical equipment (including computers) is now in use and this also increases the cooling loads. Display Energy Certificates were introduced in 2008 for larger public buildings in England and Wales (HM Government, 2007) which show the annual electricity and fossil fuel consumption. Analysis of the certificates from the first 29,000 buildings showed that the carbon emissions of some building types were close to the benchmarks but for some they were higher than expected (Bruhns, Jones, & Bordass, 2011). Many building types had higher electricity consumption than expected and lower heating energy. This is consistent with ECUK data for 2000–2011 which shows retail and office electricity consumption rising approximately in line with increases in floor space but natural gas consumption falling by 35–40% (DECC, 2012c). This suggests that the carbon emissions had risen during this period due to the greater CO_2 intensity of electricity than gas (the predominant fossil fuel).

Acceptable loads for time-shifting may be switched off for a short period without detriment to the business. Referring to Figs. 2 and 3, the largest blocks of discretionary demand emit the CO_2 stated in Table 4.[2] Collectively, this represents 6.8% of the estimated 49 Mt CO_2 emissions due to the *unconstrained* sector (Forster et al., 2010). The high demand for lighting (3606 GWh in retail) and motors (4303 GWh in other industry) (Fig. 3) suggests opportunities for energy saving. For example, T5 fluorescent lamps consume less energy for comparable light output than T8 or T12 lamps.

The actual load-shifting potential for a particular business type depends on several factors, including the HVAC system type and the building fabric. There is little publicly accessible data regarding the types and quantities of HVAC systems currently installed in non-domestic property. Rickaby and Gorgolewski (2000) classified HVAC systems during the NDBS Project, based on surveys of 419 properties in the 1990s. Additional surveys would be needed to update this work in order to apply it here.

Dolman et al. (2012) develop load profiles for the commercial sector disaggregated by end use, using data from half-hourly meters and a limited quantity of sub-meter data. Considering 5 pm on a winter weekday to be peak time, they estimate shiftable loads in each of three scenarios (conservative, moderate and stretch). The moderate scenario makes *reasonably ambitious flexibility assumptions*.[3] For the commercial sector only, they estimate the shiftable load as 1.2 GW (or 2.5 GW including lighting). It is assumed that the contribution that SMEs make to peak loads is in proportion to the contribution made by the unconstrained sector to the annual electricity consumption. The proportion of unconstrained service sector electricity calculated from Tables 2 and 3 (36.3%) is applied to this estimate of shiftable load, for all thermal end uses excluding lighting, as 0.4 GW (36.3% of 1.2 GW).

Time-shifting of electrical loads does not automatically reduce carbon emissions. Hawkes (2010) noted that the CO_2 intensity of the generators that respond to a specific *demand change* determine the CO_2 increase or decrease. Marginal emissions factors (MEFs) were evaluated which represent the CO_2 intensity of a change in demand. Based on data from 2002 to 2008, Hawkes calculated that the MEF peaked (at 0.7 $kgCO_2/kWh$) when the system load reached around 35 GW_e. Further increases in load (equivalent to a winter peak of 55 GW_e) resulted in the MEF reducing to 0.55 $kgCO_2/kWh$. This is likely to be due to hydro (natural flow and pumped storage) supplying energy. The MEF fluctuates during the day (mainly within a band of 0.6–0.7 $kg\,CO_2/kWh$), even when demand is relatively stable. This is due to operational constraints on generators.

The state of the building fabric (extent of insulation, thermal mass, ventilation and solar gain) will affect the acceptability of turning off the heating or cooling for a short period. Modelling of energy demand in individual premises, based on knowledge of the fabric is required. If electricity consumption in *all* businesses is analysed, the emissions are similar to Table 2 (although the values are higher). For cooling, retail emissions are higher than commercial offices. Hot water use in the retail sector is larger than hotel and catering.

6. Conclusions

Smart grids are expected to bring new incentives for SMEs to contribute to carbon reduction, through incentives for demand reduction and demand response. A lack of clarity and definition in energy use data presents a barrier to immediate, on-site carbon reduction initiatives. SMEs, the buildings they occupy and the end uses of energy are diverse and not well documented. The challenges of electricity grid de-carbonisation introduce a different opportunity, whereby consumers could receive incentives to support off-site initiatives through responsive energy management.

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[2] The CO_2 emission factor for electricity used is 0.541 $kgCO_2/kWh$, to maintain consistency with the previous work by AEA (Forster et al., 2010, p. 72).

[3] 50% flexibility for hot water, 20% for heating, cooling, lighting and refrigeration and zero for catering and IT (Dolman et al., 2012, p. 31).

Existing energy models of businesses and non-domestic property are valuable but they require updating to identify opportunities for SME carbon reduction. Energy consumption data collected in the 1990s are useful but the division into end uses is less reliable since electricity consumption has increased due to IT equipment and cooling.

This research has identified discretionary electrical loads, a proportion of which should be suitable for load-shifting. This consists of space heating, cooling and hot water in the commercial sector and heating in industry. The two largest blocks of demand in each end use category amount to 6156 GWh/yr (equivalent to 3.3 Mt CO_2/yr). The large electricity use by motors in industry and lighting in the commercial sector suggests scope for energy saving.

SMEs reducing their electrical loads at peak times may have a very minor impact on carbon emissions. There is not a straight forward correlation between time of day and carbon intensity of electricity (MEF) due to operational constraints on generators.

Detailed modelling of premises and energy consuming equipment is necessary in order to predict the scope for load-shifting. The equipment type and the profile of its use will affect the potential saving. Factors that affect heat generation and loss need to be modelled for complete buildings to understand the acceptability of load-shifting.

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