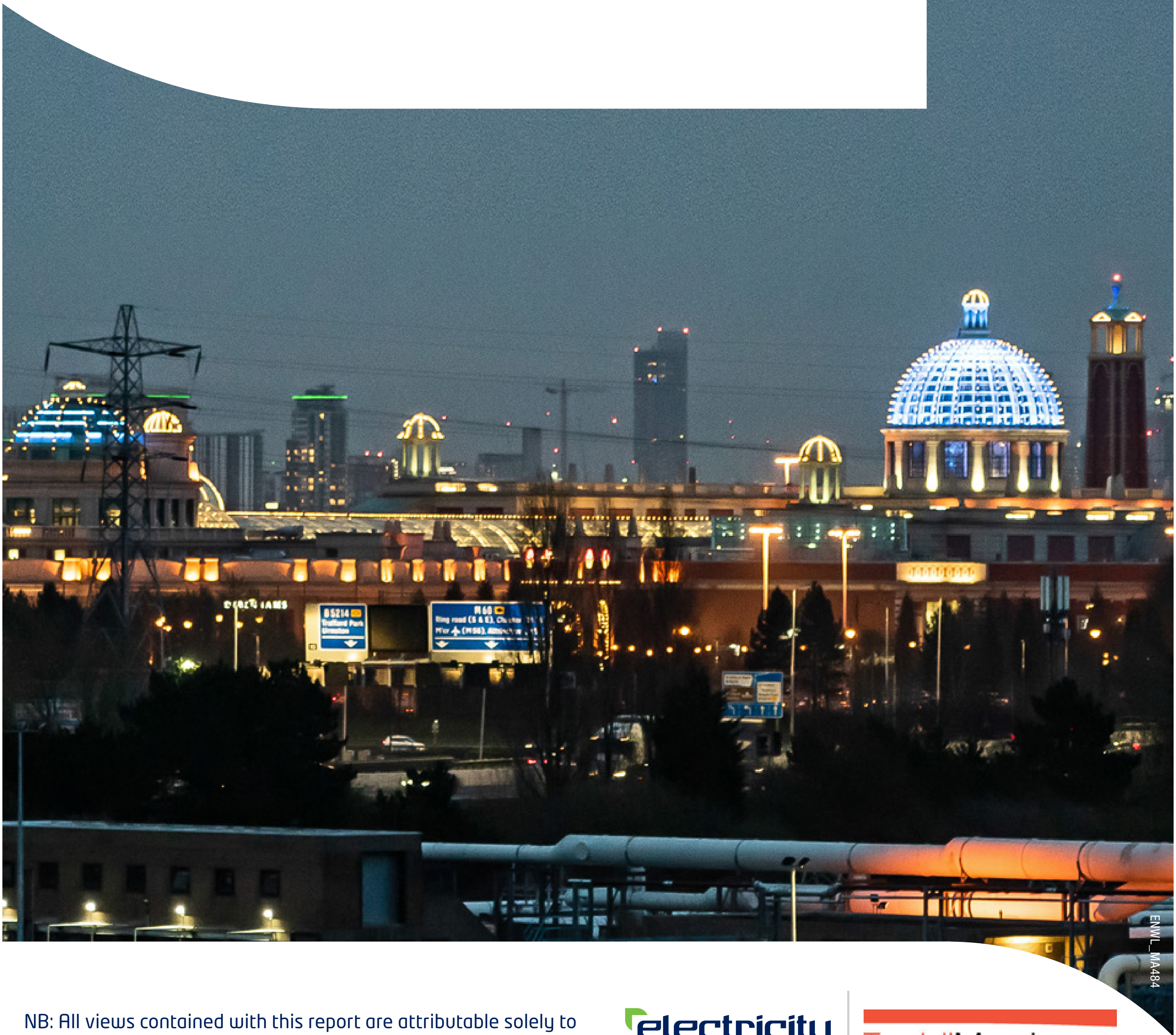
Review of Measures to Reduce Carbon Dioxide Emissions for Electricity North West Business Users



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Introduction

This report offers guidance on how businesses in the Electricity North West area can help to tackle climate change through their energy use. Given the need for urgent and widespread action to reduce carbon dioxide (CO_2) emissions from fossil fuel use, the guide provides examples of immediate steps that could be taken to reduce emissions within the next two years.

This report is in response to the urgent and rapid decarbonisation of energy required to meet Greater Manchester Combined Authority's 2038 carbon budget [1, 2], but the actions apply across the Electricity North West area. This review explores how businesses can apply interventions to reduce carbon emissions in existing buildings to support meeting rapid decarbonisation targets. It covers:

- direct energy use associated with buildings (Scope 1 – from direct combustion of fuel onsite);
- indirect energy use in buildings (Scope 2 from the emissions associated with electricity used onsite);
- emissions associated with commuting, business and customer travel (freight logistics are not covered in this report).

The review provides information on the immediate and near-term steps businesses can make to reduce energy demand and associated carbon emissions to support climate change targets. The structure of the report offers information as stand-alone guides to the short-term (in the next two years) options for emissions savings for five business types– retail, supermarkets, hotels, offices and warehousing/manufacturing. It also provides a review of measures to reduce emissions from travel - applicable across all of the business types.

Businesses are likely to be at different stages of their low carbon journey and there are a variety of constraints, e.g. building ownership, that mean a one-size fits all recommendation would not be suitable. However, the guide provides a range of potential carbon saving actions that can be applied differently depending upon individual circumstances and offers an assessment of the potential carbon savings that these steps might achieve if implemented.

Context

The Earth's climate is changing. An average increase in global mean temperatures of around 1°C since the pre-industrial period has been observed, and this is impacting natural and human systems [3]. The primary driver of this change in the world's climate is an increasing concentration of CO_2 in the Earth's atmosphere caused by a sustained increase in CO_2 emissions from human activities since the Industrial Revolution [3].

Increasing global temperatures have profound implications for every part of the world [4, 5]. Significant losses of ecosystems and bio-diversity as well as increased risks to human societies are expected as temperatures increase. Based on current trends global temperatures are projected to increase by more than 1.5°C above the pre-industrial average in the coming decades if there is not a rapid reduction in CO_2 and other greenhouse gases [3]. Globally, through the United Nations Framework Convention on Climate Change, countries have signed a common agreement (the Paris Agreement, signed in 2016) to keep global temperatures well below 2°C and to pursue efforts to limit temperature rise to 1.5C [6]. In 2019 however, global emissions continued their year on year increase, meaning that a major shift in energy use and decarbonisation of supply is urgently needed to meet the goals of the Paris Agreement [7].

Limiting climate change requires a rapid and sustained reduction in the CO_2 emissions from fossil fuel use. This means reducing energy demand and moving electricity, heating and transport onto low carbon energy sources. The UK Government recently announced a statutory net zero target for greenhouse gas emissions within the UK by 2050 – stopping most CO_2 from fossil fuel use and balancing out 'hard to decarbonise' sectors such as aviation and non-CO_2 greenhouse gases with carbon removals [8]. The UK has made good progress on reducing CO_2 emissions from electricity generation through phasing out coal-fired electricity generation while using more renewable and gas-fired generation, but it is not making progress on reducing emissions from heating and transport [9] (see Figure 1).

At a regional level, Greater Manchester Combined Authority (GMCA) have an ambition to reduce CO_2 emissions from energy in the GMCA area by around 15% per year and be carbon neutral by 2038 to support meeting the goals of the Paris Agreement [2]. This unprecedented rate of change in fossil fuel use in the UK requires new ways of tackling climate change and reflects the limited amount of time left to avoid some of the worst impacts of rising temperatures.

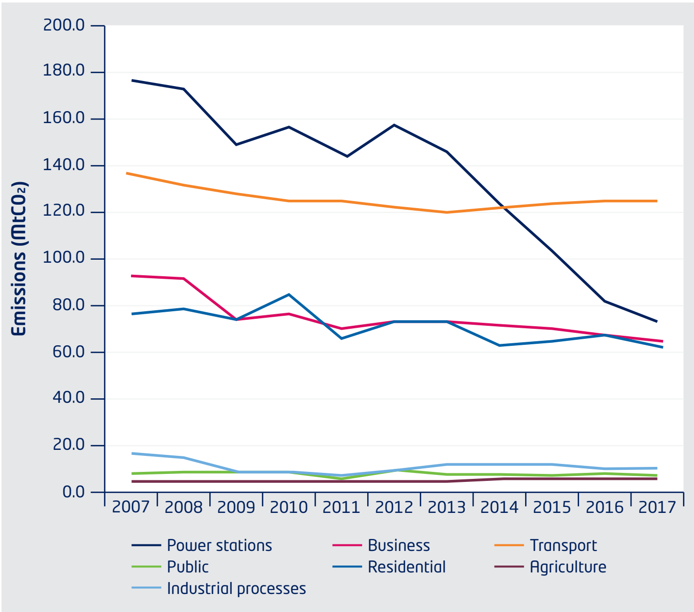

Figure 1: Carbon Dioxide Emissions (sources) for Key UK Sectors. Emissions for the sectors are for non-electricity emissions [10]

Figure 2 shows an example of how quickly CO_2 emissions from energy use in the Electricity North West area would need to reduce to make a 'fair contribution' to the UN Paris Agreement climate change goals based on a carbon budget method developed by Tyndall Manchester [11].[1] The available remaining carbon budget shown in Figure 2 highlights the need for urgent action within the next few years and for making significant progress by 2030.

Achieving this, or any climate change target to limit global warming, now requires action at all levels. All users of fossil fuel energy contribute to this issue and can contribute to the solutions. This includes national Government and local authorities but also large and SME businesses and individuals. Increasingly as climate change becomes a more apparent and near term risk for companies there is an increasing demand for businesses to act from investors.[2] The

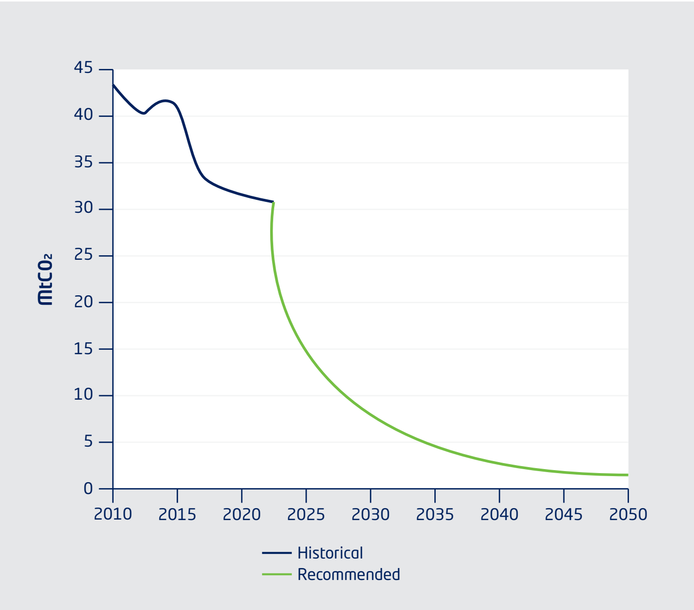

Figure 2: Maximum carbon emissions ($MtCO_2$) for the Electricity North West area compatible with the UN Paris Agreement

non-domestic building sector however has made limited progress in reducing its CO_2 emissions in the last decade [12]. Even when, as it often the case, there is a positive financial case for energy saving measures these have not always been adopted by businesses [13].

Meeting local and national climate change targets however requires a major shift in business as usual energy practices, with a wide range of organisations playing a leading role in decarbonisation through reducing and shifting energy demand and supporting renewable energy generation to meet targets [2].

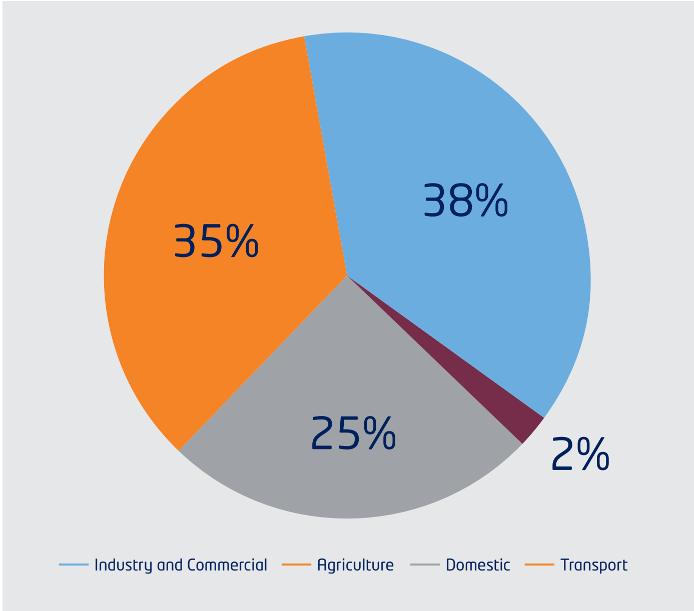

Figure 3: Carbon Dioxide Emissions for energy use in Electricity North West Region by Sector. Total emissions = 50.6 $MtCO_2$/year in 2017 from BEIS [14] Emissions from land use, land use change and forestry not included.

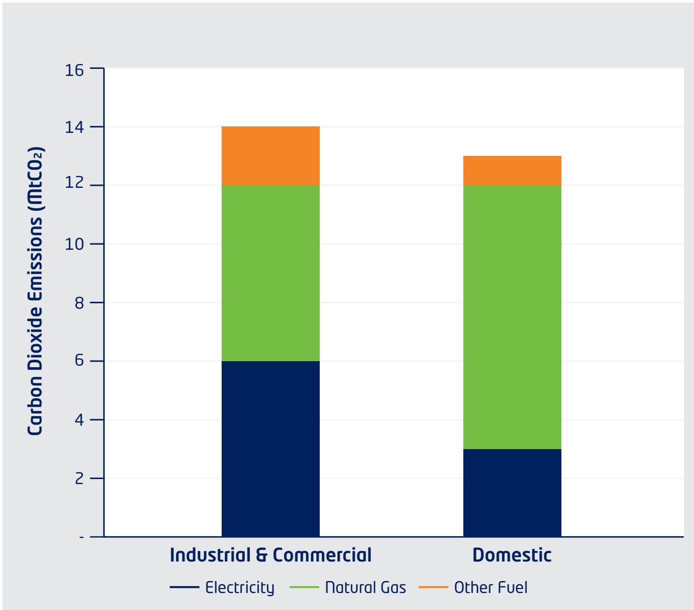

Figure 4: Sources of Onsite (i.e. non-transport) Carbon Dioxide Emissions for Industrial & Commercial and Domestic Users 2017 (excludes large industrial installations) BEIS [14]

1. See www.carbonbudget.manchester.ac.uk for the tool and methodology.

2. For example see statements by the Bank of England (https://www.bankofengland.co.uk/knowledgebank/climate-change-why-it-matters-to-the-bank-of-england) and Black Rock https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter

Across the UK, CO_2 emissions associated with electricity generation have been falling through increases in renewable and gas-fired generation. There is still however a long way to go to achieve a very low carbon electricity grid over the next decade [9] and ongoing support from energy users through reducing energy demand and onsite electricity generation, such as solar photovoltaics (PV), is needed.

Energy for heating services (hot water and space heating) is a major source of energy demand that remains largely fossil fuel based. Options to decarbonise this sector include switching to electricity based heating (such as heat pumps), replacing natural gas with hydrogen and biomethane in the gas network [15] and biomass boilers (with fuel from a sustainable source). Whichever route is chosen, a reduction in overall heating demand is needed to make this possible; something which can be achieved through better insulation and energy use practices.

The transport sector is falling behind on decarbonisation and, through transport emissions remaining almost static and emissions from power and industry falling, has become the highest contributor to UK emissions. Increasing modal shift from cars to active travel (walking and cycling), public transport and switching to electric vehicles are some of the solutions needed to make this happen. Organisations can play a role in supporting this, for example, by facilitating low carbon transport for employees and customers.

This report provides examples of carbon savings primarily based on secondary sources in published academic literature, consultancy reports, UK Government and international institutional publications. For some aspects of the different business types recent UK specific data was not found. The information provided relates to annual energy and carbon emissions intensity per square metre of a building and therefore can be scaled to buildings of various sizes for each business type. In some cases there are limitations due to the availability of recent UK data for the business types. For example the Chartered Institution of Building Services Engineers (CIBSE) provide rigorous and robust dataset that applies the same methodology to all sectors, making it a useful preliminary benchmark, however much of the datasets were last updated in 2012 and much of the underlying data it relies upon is older than this. In some cases where recent data from the UK is not available examples from similar businesses in Northern Europe is used to investigate the potential for carbon saving action or best practice example. The examples provided however offer the best understanding available from current sources and provide a clear indication to inform carbon reduction measures.

The report does not cover financial appraisals of the interventions reviewed, however energy efficiency measures, through long term cost savings, typically repay investment over time [16]. Many of the energy saving measures covered in this report are also eligible for Enhanced Capital Allowance[3], allowing these a write off of these costs against taxable profits. Low carbon heating measures discussed here, including heat pumps and biomass, can receive support through the Renewable Heating Incentive. Increasingly, barriers to energy efficiency and onsite renewables due to building ownership and operation arrangements are being removed through initiates such as green leases to help building occupants reduce their emissions [17]. Recently 23 of the UK's largest commercial property owners joined a new climate change commitment through the Better Buildings Partnership to make their portfolio's net zero carbon by 2050 through working with building occupiers [18]. It is therefore possible that the interventions reviewed may be undertaken by businesses within the next two years.

3. Eligible technologies listed online at https://www.gov.uk/government/collections/energy-technology-criteria-list-etcl-information-by-categories

Non-Food Retail

Energy Use in Non-Food Retail

The non-food retail sector comprises a wide range of business and building types. The energy intensity of a retail premises – the energy it uses annually per square metre (kWh/m²/yr) – varies depending on the characteristics of the business and the building. The main sources of energy demand for non-food retailers tend to be heating, ventilation and cooling (HVAC) and lighting. Lighting can make up more than 50% of energy demand (and even up to 80% in some stores) [19]. The Chartered Institution of Building Services Engineers (CIBSE) [20] suggest that lighting and HVAC may account for around 80% of carbon emissions in retail sector buildings.

Table 1 is a review of reported data on energy use in the non-food retail sector. Although this points to variability in energy intensity, compared to other sectors, the findings are quite consistent – between 146 kWh/m²/yr and 321 kWh/m²/yr where all aspects of building energy demand are considered.

Within these average values there is a variation in energy intensities for retail stores attributable to energy efficiency practices. For example, Ferreira et al [22] looked at the 250 highest revenue retailers in the world and found that for the non-food sector there was a difference of 6 to 1 between best and worst performers. Variability between stores is greater is some sub-sectors than for others. For example, there was a 5 to 1 variation between best and worst in electronics and household appliances but only 2 to 1 for auto shops and pharmacies. It is proposed that this is likely the result of luxury goods retailers having the highest energy intensities [22]. Overall these benchmark data points suggest that there can be significant improvements in energy use and therefore reduced carbon emissions through adopting best practice.

Table 1: Energy intensity benchmarks from academic literature

Store type	Energy use covered	Energy use of Average / Conventional practice (kWh/m²/yr)	Energy use of best practice (kWh/m²/yr)	Notes and source
All	Heating	105-190	40-55	Average based on study of German buildings. Best practice from IKEA stores in Switzerland certified to Minergie Standard [21]
All	Total	146-293	Around 80	The figure for best practice is estimated from Figures 4 (p.880). [22]
DIY	Total	150		
Furniture / decoration	Total	165		
Auto Shops	Total	169		
Electronics / household appliances	Total	212		
Pharmacy	Total	220		
Department store	Total	283		
Footwear / clothing	Total	321		
General retail	Electricity	165		[23]

Carbon Emissions

Work by Ferreira et al. [22] on carbon intensity ($kgCO_2/m^2/yr$) for retail suggests potential variation depending on the type of retail activity. DIY stores for example appear to have the lowest energy intensity but only the fourth lowest carbon intensity. This may reflect the difference in relative share of electricity and fuel for the energy services across retail store types. The apparent diversity within retail sub-sets – i.e. pharmacy, DIY, fashion etc - between best and worst performers – particularly for electronics / household appliances and for department stores, likely to reflect a wider variability in the way those store types operate and the building fabric [22].

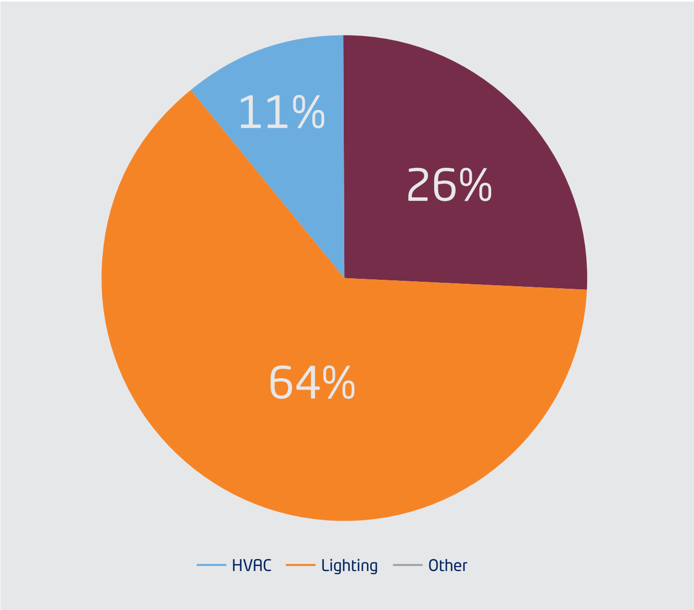

Figure 5: Carbon intensity ($CO_2/m^2/yr$) for reference Department store non-food retail

Taking a department store as an example, with typical benchmark energy intensity of 280 $kWh/m^2/yr$ applying an assumed 60% of energy demand is for lighting, 30% for HVAC (natural gas) and 10% other electricity appliances from the above literature, the annual carbon emissions intensity is estimated to be 67 $kgCO_2/m^2/yr$ (based on Defra CO_2 emissions factors for 2019).

Best Practice Interventions

For retail business to act on tackling climate change and go low carbon as quickly as possible means a step beyond business-as-usual and a renewed prioritisation of reducing energy use and supporting renewable energy use. Many new approaches are already coming from the retail sector itself and sharing these ideas and best practice across the sector is important for decarbonising all retail. Initiatives like the British Retail Consortium's 'Better Retail Better World'[4] is an example of such a role. Where retailers are located closely together there may be opportunities to pool resources and develop technologies that can supply multiple sites with renewable energy. This may be challenging in that collaboration and timing of actions across multiple organisations may be difficult to achieve at present, however where these opportunities exist they should be identified and acted upon to maximize decarbonisation potential.

Typically across the sector there are common approaches to minimise energy use and produce low carbon energy to use onsite to reduce imported energy from the electricity or gas network [24].

Organisations can benchmark their own building's carbon emissions and compare these with the generic benchmarks for initial feedback as to where they are starting from. The benchmarks can suggest the kind of energy reductions that should be expected as a first step. For example, if we take a mid-range energy intensity for general retail of 219 $kWh/m^2/yr$ – reducing that value to best practice levels of 80 $kWh/m^2/yr$ would entail a reduction of 63%. It is however necessary to better understand what the 'best practice' store is doing differently to the 'average practice' store and the role operational and building fabric features may play in overall energy use. Best practice itself is not a fixed target, particularly as the challenge of reaching 'zero carbon' on a very rapid timescale means new approaches and standards may be developed. This suggests that sharing information to help all retailers know what might be possible, is an important step.

An example of a longer-term strategy to progress retail emissions to zero carbon can be found in the Dutch Green Building Council's energy benchmarks based on a zero carbon 2050 target. For a non-food retail shop this leads to an energy benchmark of 80 $kWh/m^2/yr$ – which matches the proposed best practice in Ferreira et al. [22] refered to in Table 1. In order to achieve low carbon performance in onsite energy use in retail the UK Green Building Council recommends that reducing overall energy is prioritised [25].

As the two main areas of energy use in non-food retail are lighting and HVAC, they are the main focus for action to reduce energy use and GHG emissions, particularly as different levels of energy use can result in the same provision of end-goal services – such as good lighting, temperature and air quality [24]. Staff and customer expectations therefore can be met with significantly lower energy use than the evidence of current practice suggests are used currently.

1. Energy Management and Monitoring

Monitoring and understanding energy use is a vital first step to improvement. In terms of what should be measured, Schönberger et al [21] highlight what they see as best practice for energy monitoring of key areas key areas (e.g. heating, lighting and refrigeration):

- Specific energy consumption measured – $kWh/m^2/yr$ – this should be done per store and per main energy consuming process. As seen in the energy benchmarks above, this can be done for sales floor area or total floor area. Schönberger et al [21] suggest using sales floor area but whichever is used it should be done consistently.
- Lighting power density (W/m^2) – This should be looked at per store and per store zone where applicable. For specialist stores Schönberger et al [21] suggest a benchmark of less than 30 W/m^2.

For many retail stores issues with energy management can arise due to the ownership arrangement of the space in buildings – e.g. if the retail business rents rather than owns the building. The Better

4. https://brc.org.uk/making-a-difference/priorities/better-retail-better-world.

Building Partnership highlight the relationship between owners and occupiers in terms of the responsibilities and benefits for procurement and control of energy as a key barrier to improving the environmental performance of buildings [17]. One approach to overcoming this is through the use of a 'Green Lease'. This is a standard lease with additional clauses that address the environmental management and improvement of a building, making clear the responsibilities for both the owner and the occupier, and is legally binding. Alternatively, a non-legally binding Memorandum of Understanding can be agreed between owner and occupier. Investment to reduce energy demand has wider benefits beyond tackling climate change. For example the Carbon Trust, estimate that "with an investment of between 1-2% of energy spend in an effective employee engagement campaign, many organisations can save up to 10% on energy costs" [26]. This is likely to include education on reducing energy demand and incentives/ responsibility for energy reduction through staff roles.

2. Heating, Ventilation and Air Conditioning (HVAC)

Irrespective of the sector, the primary way of addressing energy demand for HVAC is through improvements in the building fabric. Within retail, Schöhberger, Martes and Styles [21] identify two Swiss retailers Migros and Coop, along with Ikea in Switzerland as examples of best practice. All of these have retrofitted existing stores to the Swiss Minergie standard which specifies that primary energy demand for heating, cooling, warm water and basic electricity use should not exceed 55kWh/m^2/yr for existing buildings and 40kWh/m^2/yr for new buildings.

Achieving significant reductions in energy use from heating and cooling requires improvements in the building fabric. The elements of this include [21]:

- Wall / roof / façade / floor
  - – Insulation materials can be changed
  - – Insulation thickness can be increased.
- Widows and glazing
  - – Change to more efficient windows
  - – Change to more efficient sashes and frames.
- Internal and external solar shading
- Air tightness
  - – Improvement of doors
  - – Fast acting doors
  - – Sealing
  - – Using buffer sections.

In addition to the use of technology, changes in practice can also result in energy savings. For example, in winter, when customers are dressed in warmer clothing, some stores may still have the heating set to enable staff to wear short sleeved uniforms. By ensuring that staff have adequate uniforms, the internal temperature can be reduced, reducing energy demand [27].

3. Ensure Best Practice Lighting

Although the challenges around lighting may differ between different sectors the main approaches to reducing energy demand are a well-controlled system that optimises the use of lights, which could reduce lighting load by 17% [19], and the replacement of older technologies with LEDs. Schöhberger, Martes and Styles [21] identify three retailers where electricity use for lighting has been reduced by 50% through these measures.

4. Increase Direct Use of Renewables

There are various options for on-site renewables in the non -food retail sector. Rooftop solar panels has been a popular option with retailers – for example, by 2016 Sainsbury's had installed solar PV panels on more than 200 sites with a cumulative capacity of 41MW [28]. Ground source heat pumps is another technology that has been utilised widely (see Example 4).

After heating demand has been reduced, remaining CO_2 emissions from natural gas or electricity use can be reduced further through switching to lower emission heating solutions. One option is electrification of heat, through the use of renewable heat in the form of air, or ground source, heat pumps, powered by electricity. An electric heat pump with a Seasonal Performance Factor (SPF) of at least 2.5 with reduce the carbon emissions for building heating energy use by 50% compared to a typical gas boiler system, based on current electricity grid CO_2 emissions. A more efficient system would reduce these emissions further, e.g. a system with a SPF of 4 would reduce space heating CO_2 emissions by 69%. Heat pump systems with an SPF above 2.5 qualify for the Renewable Heat Incentive[5] (RHI) which provides financial support to adopt low carbon heating. Such low temperature heating systems are more effective when the demand is low [24]. Biomass boilers may be another suitable option [29] in some settings (depending on local air quality controls) and can also qualify for RHI support.

Where it is not possible to install building integrated renewables at the store, there are examples of retailers in the sector deploying renewables at a different site for the benefit of the store. Best practice for buying in renewable energy is that it should be to add additional low carbon power generation that wouldn't otherwise of been installed [25], for example with direct purchase through a renewables developed delivered through a Power Purchase Agreement (PPA). Where retailers are closely located there may be opportunities to pool resources and develop technologies that can supply multiple sites with renewable energy.

5. See https://www.gov.uk/non-domestic-renewable-heat-incentive for details on edibility, tariff rates and how to apply.

Carbon Emissions Reduction Potential

The overall CO_2 emissions savings of the 4 Best Practice interventions depend on a number of factors, including the current baseline energy characteristics of the building and the potential for onsite renewables and building fabric change. In the example below for a Department store with a current energy intensity of 280 kWh/m^2/yr, conservative interpretations of the potential savings for building energy emission have been characterised to show the potential near term savings. Implementing efficient, automated lighting reduces electricity demand, by 35%, while interventions to better control temperatures in the building reduces energy for heating by 15%. Table 2 outlines the potential emissions reductions. This would equate to a 27% reduction in building energy emissions.

Table 2: Summary of possible energy efficiency interventions over the next 2 years

Timescale	Area	Intervention	Assumed % reduction against baseline
Next 2 years	HVAC	Improvements in controls and staff awareness	15
	Lighting	Improved lighting controls	10
		LEDs in 50% of store	25
	Other	Replacement of technology	10
		Staff awareness	10

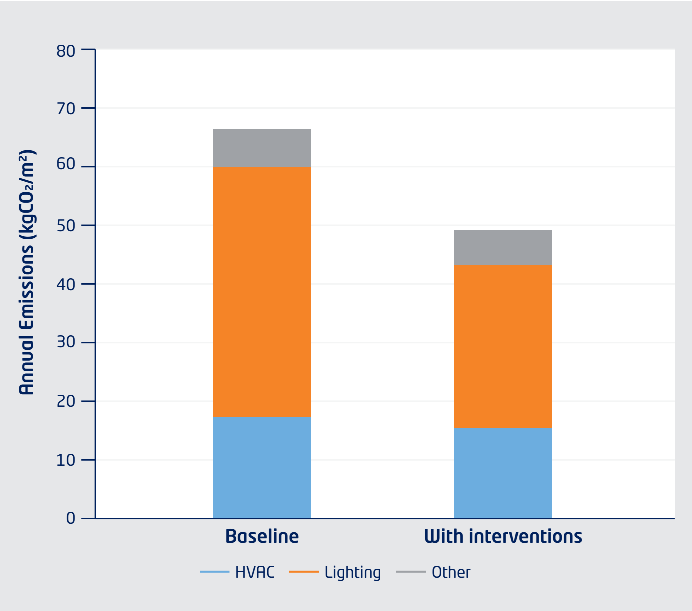

Figure 6: Indicative building CO_2 emissions saving from the best practice Interventions

Examples

The best practice interventions discussed are all based on existing and commercially available offers that have been successfully implemented in the sector. The following examples highlight how they have been applied in different contexts to-date.

Example 1

The B&Q trade counter in Peterborough generates more energy than it consumes. Using solar panels coupled to a battery system there is more than enough energy to power the energy efficient store that is fitted with an air source heat pump and LED lighting. The design is being rolled out to four more trade counters. Across its estate, Kingfisher (B&Q's parent company) has installed solar panels at 20 sites, biomass boilers supplying two distribution centres and air source heat pumps at 63 sites [30].

Example 2

Adopting a challengingly high standard like the Swiss Minergie standard could ensure significant energy reductions for retail buildings. Based on an average store, where heating accounts for 20% of energy use, and energy intensity is 500kWh/m^2/yr. Heating would account for 100 kWh/m^2/yr. This means that if the Minergie standard for retrofit was adopted, heating energy demand intensity would be reduced by 45%.

Example 3

At the White Rose Shopping Centre in Leeds, owners Landsec installed UK retails largest solar array. There are 2,902 solar panels and it generates 720,000 kWh of electricity per year. On one day in July 2016, the solar array generated nearly as much electricity as the Centre used. Electricity consumption at the centre has also reduced by 22% as a result of energy use interventions [31].

Example 4

In 2017 Sainsbury's pledged to adopt LED lighting across all of its stores through a partnership with Current, the smart buildings division of General Electric. The full LED conversion was expected to be done by 2020 and to reduce lighting energy use by 58% [32].

Example 5

Tesco has set out a set of targets based on a trajectory for its own operations in line with limiting warming to 1.5 C. Renewable energy is a key part of this and, as of 2018, all electricity in the UK and Republic of Ireland was purchased from renewable sources through Renewable Certificates. However, as this is a low credibility source of renewables, and Tesco have set out a plan for 2030 that will see 50% of electricity coming through Power Purchase Agreements (PPA), 40% through Renewable Certificates, and 10% from on-site renewables [33]. Since announcing the plan, Tesco have entered into a number of agreements to make this happen, including:

- A PPA with SDCL Energy Efficiency Income Trust (SEEIT) to install, operate and maintain 5MW of rooftop solar [34].
- An agreement with Macquarie's Green Investment Group (GIG) to own and operate solar panels on 20 sites
- Three PPAs with EDF Energy:
  - To install 5MWp of solar panels
  - To build a 10.8MW extension to Burnfoot East windfarm project
  - To build a new windfarm with a capacity of 43MW.

Two further PPAs have been signed with BayWa r.e. and Scottish Power [35].

Food Retail

Energy Use in Food Retail

Food retailers of various sizes are likely to have higher energy intensity in their buildings compared to other business users because of the need to provide and store goods at low temperatures. The average energy intensity (energy used per m^2 per year) of food retailers is around double that of non-food retailers and around five times larger than for offices [22]. It is estimated that on average 50% of energy use in supermarkets relates to refrigeration; 25% to lighting; 20% to heating, ventilation and air conditioning (HVAC); and 5% to electrical appliances and other processes [21]. This varies depending on the size of the retail store as, for larger stores, the density of refrigeration in the store is lower. For a hypermarket (>5750m^2) refrigeration might account for only 23% [36]. There is significant variation in energy usage across the sector. Table 3 below sets out some energy benchmarks from the literature for the food retail sector.

The available data on food retail energy use suggests significant variability in energy intensity benchmarks. Some of this may be explained by the different times at which these studies were undertaken, with later studies seeing improvements due to e.g. use of LED lighting. However, Foster, Evans and Maidment [39] suggest that while energy efficiency improvements can account for some of the difference, it cannot account for it all. One trend that is seen in all the studies is that smaller stores have higher energy intensity. This is due to the greater proportion of refrigeration in smaller stores and the high energy demand this brings.

Table 3: Energy intensity benchmarks from the literature

Energy use covered	Store Size	Average / Conventional Practice (kWh/m^2/yr)	Best Practice (kWh/m^2/yr)	Notes and Source
Total	<750m^2	524	209	Based on sample of 593 stores in UK best practice relates to the minimum values found [37]
Total	>750m^2	444	83	
Electricity	<280m^2	1480		Values are for Sales Area [38]
Electricity	1400 m^2	850		
Electricity	5000 m^2	600		
Electricity	10000 m^2	220		
Electricity	<280m^2	1200		Values are per Sales Floor Area rather than total m^2. From a survey of one national food retail organisation. Vales estimated from Figure 1 of [36]
Electricity	280-1400 m^2	800		
Gas	280-1400 m^2	450		
Electricity	1400-5750 m^2	750		
Gas	1400-5750 m^2	350		
Electricity	>5750 m^2	550		
Gas	>5750 m^2	200		
Electricity	280-1400 m^2	554		Values as for Sales Floor Area for electricity and gross floor area for total energy [39]
Electricity	5000-10000 m^2	523		
Total	All stores	450		
Total	All stores	346-700	~150	'Best practice' here relates to the lowest value from Figures 3. Values are for Sales Floor Area. 'best practice' here relates to the lowest values found from Figures 3 in [22]

Carbon Emissions

The relatively high energy onsite energy use of food retail means CO_2 emissions per m^2 per year are significant. Based on the benchmark energy use data in [36], and the current characteristics of the UK energy system, annual CO_2 emissions in this example range from 182 $kgCO_2/m^2$ to 307 $kgCO_2/m^2$, with smaller stores having greater emissions intensity per square metre due to the relative share of space for refrigeration.

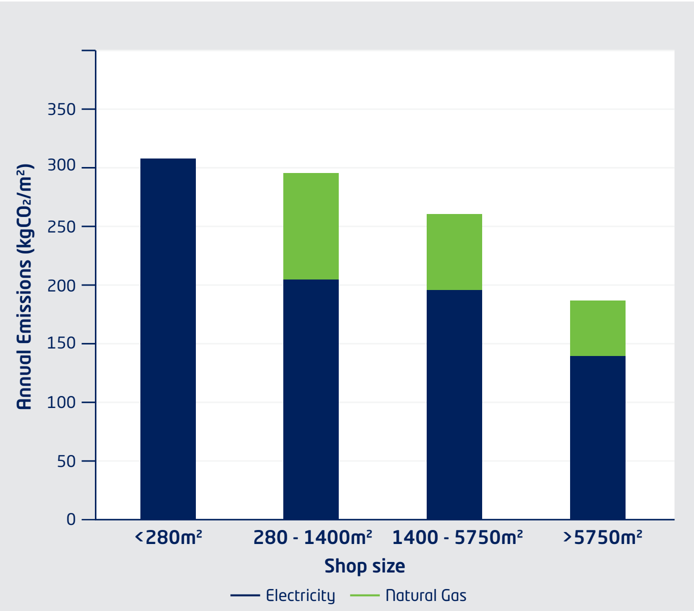

Figure 7: $CO_2/m^2/yr$ based on energy intensity values from Spyrou et al. [36]

In a more international study of food retail building emissions, Ferreira et al. [22] found an average carbon intensity for a Convenience store (smaller sized store) to average 568 $kgCO_2/m^2/yr$, a supermarket (medium sized store) to average 273 $kgCO_2/m^2/yr$, and a hypermarket (large store) to average 258 $kgCO_2/m^2/yr$ – although with varied CO_2 emissions for electricity in these countries.

When considering the overall climate change impact of in food retail buildings additional impacts due to the high global warming potential[6] of many refrigerants are often considered. The complexity of large refrigeration systems means that there is the potential for leakage of refrigerant and this can make a considerable contribution to greenhouse gas emissions. This can make a significant difference to the overall environmental impact of food retail stores. For example, in 2009, in the French retailer Carrefour's carbon footprint of operations, refrigerant leakage accounted for 42% of its reported global warming potential. For two other companies, Metro (Germany) and Migros (Switzerland) the figures were 12% and 21% respectively [21]. This report is focused on CO_2 emissions, but this is an important ongoing consideration for the food retail sector's response to climate change. The best option to significantly reduce the direct emissions is therefore through the replacement with different refrigerants. Carbon dioxide (CO_2), is seen as a promising refrigerant that offers a number of benefits and may result in more energy efficient refrigeration [37]. Switching from HFC refrigerant to carbon dioxide refrigerants is increasingly being adopted [21] and there is little difference in energy performance after switching [40].

Best Practice for Reducing Carbon Emissions

While the potential for energy saving and carbon emissions reduction will vary depending upon the baseline energy use and specific features of a food retail shop, there are common best practice measures that can potentially make a major contribution to reducing emissions.

Understanding current energy use in the building through more detailed monitoring of energy demand has been shown to be a common first step for companies successful in reducing their environmental impact [19]. Once energy use is understood, it can be useful to compare that energy use with energy benchmarks – that is industry wide figures in a format that enables comparison, usually energy use ($kWh/m^2/yr$)[7] – shown above. Benchmarks can suggest the kind of energy reductions that should be expected. For example, Kolokotroni et al [37] state that average energy intensity in a small food retail store is 524 $kWh/m^2/yr$, while best practice is 209 $kWh/m^2/yr$. If a store at the high end was to aim for best practice that would entail a 60% reduction. The key is to understand what the 'best practice' store is doing differently to the 'average practice' store. Best practice itself is not a fixed target, particularly as the challenge of reaching 'zero carbon' on a very rapid timescale means new approaches and standards may be developed. This suggests that sharing information to help all retailers know what might be possible, is an important step.

In order to achieve decarbonisation goals energy demand reduction needs to be prioritised [25]. This will necessitate a shift in perception and strategy for most business, as well as investment in new approaches, upgrades in technologies, and innovation. Meeting more of a building's energy needs onsite through renewable generation of power and heat is another way to reduce the carbon impact of food retail. Similarly retailers can make an important contribution to reducing CO_2 emissions from transport and improve local area quality by supporting low carbon travel for staff and customers (see Transport and Travel section).

1. Implement/Improve Energy Management and Monitoring

The three main areas of energy use and onsite CO_2 in food retail stores are refrigeration, lighting and HVAC. As noted in Ruud and Lindberg [24] ultimately the requirements of customers and staff, in terms of comfort, lighting, air quality and appliances can be met just as well with lower energy use.

6. The global warming potential (GWP) is a figure that shows how strong a contribution to global warming a particular gas may make when compared to carbon dioxide. While carbon dioxide has a GWP of 1, R-404A, a common refrigerant has a GWP of 3700.

7. In some energy benchmarks the area used is gross floor area, while in others it is sales floor area – this is an important distinction when comparing benchmarks and actual building energy use.

Monitoring and understanding energy use is a vital first step to improvement. In terms of what should be measured, Schönberger et al [21] highlight what they see as best practice:

- Implement specific energy consumption (kWh/m^2/yr) monitoring per each main energy consuming process.
- Monitor the energy consumption for refrigeration per metre of display case in kWh/m/yr. This can be compared to a benchmark of excellence of 3,000kWh/m/yr.
- Assess lighting power density – W/m^2 – This should be looked at per store and per store zone where applicable. For supermarkets a benchmark of 12 W/m^2 is recommended.
- Calculate the percentage of refrigerant leakage in store using annual refrigerant purchases for each store and per refrigerant type. Switch to natural refrigerants with a lower global warming impact.

Monitoring and control is not just about additional devices and metrics. The Carbon Trust, estimate that "with an investment of between 1-2% of energy spend in an effective employee engagement campaign, many organisations can save up to 10% on energy costs" [26]. Making monitoring and intervention in energy use within the store a priority for staff and providing relevant training can meet these aims.

2. Implement Best Practice Refrigeration

As in most food retail stores refrigeration is a key component of energy demand, this is a significant area for potential emissions savings. Adding glass cabinet doors to vertical chilled food display cabinets should in principle save significant amounts of energy. Tassou [38], Evans et al [41]and Schöhberger, Martes and Styles [21] show that adding cabinet doors can make a significant difference - 40% to 50% in some cases. Food retailer Aldi [42] however has stated that air curtains (a barrier of blown air acting to stop cool air leaving the chiller cabinet) and night shutters are more effective overall than glass doors, which in some cases may increase energy use because of opening and closing practices. While putting a physical barrier between customers and products has been perceived as detrimental to sales that does not appear to be the case. Studies for closed chest freezers show that after a short adaptation period sales figures are the same as for open freezers [21].

Supermarket refrigeration systems have many components and there is the potential to make energy savings at various points. For example, compressors account for much of the electricity use and savings of 20-30% are possible [38] . Heat gain from lighting can also be a significant factor impacting energy demand in refrigeration and should be avoided if at all possible within cabinets. If it cannot be avoided then LEDs should be used [21]. Adding regulated speed compressors and LED lighting to freezers could save up to 35% of freezer energy demand [43]. Schönberger et al. [21] discuss the finding of a German study that looked at a range of potential measures to save refrigeration energy use. The top 5 approaches identified in Schönberger et al. [21] are:

- Glass doors / lids – 40% saving
- Flooded evaporator – 30% saving
- Air humidity in shop area – 18% saving
- Speed control of compressor – 15% saving
- Fan motor outside cabinets – 10% saving.

There are also innovative ideas for food retailers to play a key role to play in the wider renewable energy system through the use of refrigeration as a form of battery storage. An example of this is a field trial by Tesco with the University of Lincolnshire. In this example algorithms, control the electricity supply refrigerators, switching them off – mimicking a defrost cycle – helping to balance grid electricity demand [44]. The researchers estimate that if all Tesco stores across the country were harnessed it would be the equivalent to a 25-50MW virtual battery [44].

3. Ensure Best Practice Lighting

Lighting is a relatively high proportion of energy demand onsite for food retailers. Although the challenges around lighting may differ depending on store type, the main approaches to reducing energy demand, as in other sectors, is reviewing how much lighting is required and upgrading to the most efficient lighting appliances. It has been demonstrated that through implementing a well-controlled system that optimises the use of lights overall lighting load for a building could be reduced by 17% [19]. Depending upon the current standard of lighting technology within the store, the replacement of older technologies with LEDs may offer significant saving in electricity. For example Schöhberger, Martes and Styles [21] identify three retailers where lighting load has been reduced by 50%.

4. Heating, Ventilation and Air Conditioning (HVAC)

Irrespective of the sector, the primary way of addressing energy demand for HVAC is through improvements in the building fabric. Within retail, Schöhberger, Martes and Styles [21] identify two Swiss retailers Migros and Coop, along with Ikea in Switzerland as examples of best practice. All of these have retrofitted existing stores to the Swiss 'Minergie' standard which specifies that primary energy demand for heating, cooling, warm water and basic electricity use, should not exceed 55kWh/m^2/yr for existing buildings and 40kWh/m^2/yr for new buildings.

Achieving significant reductions in energy use from heating and cooling requires improvements in the building fabric. The elements of this include [21]:

- Wall / roof / façade / floor
  - Insulation materials can be changed
  - Insulation thickness can be increased.
- Widows and glazing
  - Change to more efficient windows
  - Change to more efficient sashes and frames.

- Internal and external solar shading
- Air tightness
  - Improvement of doors
  - Fast acting doors
  - Sealing
  - Using buffer sections.

Specifically for food retailers the literature suggests that integration of refrigeration and HVAC systems, with heat recovery from refrigeration[8], offers the best opportunities for reducing energy demand. There are examples that this approach has proven successful where implemented in Europe. For one central European retailer, 40% of its stores employ heat recovery from refrigeration such that they are able to export excess heat to other companies locally – so in effect they have a negative specific energy consumption for heating. A further 10% of stores do not require any additional energy for heating [21].

In addition to the use of technology, changes in practice can also result in energy savings. For example, in winter, when customers are dressed in warmer clothing, some stores may still have the heating set to enable staff to wear short sleeved uniforms. By ensuring that staff have adequate uniforms, the internal temperature can be reduced, reducing energy demand [27].

5. Increase Direct use of Renewables

There are various options for on-site renewables in the food retail sector. Rooftop solar panels has been a popular option with retailers – for example, by 2016 Sainsbury's had installed solar PV panels on more than 200 sites with a cumulative capacity of 41MW [28]. More innovative approaches have also been trialed, such as Sainsbury's linking up with Biffa to use food waste from a store in Cannock to feed an anaerobic digester that produces biomethane, which is then used to produce electricity for the store (via a 1.5km electricity cable) [45].

After heating demand has been reduced, remaining CO_2 emissions from natural gas or electricity use can be reduced further through switching to renewable energy for heat. One option is the use of renewable heat in the form of air, or ground source, heat pumps, powered by electricity. An electric heat pump with a Seasonal Performance Factor (SPF) of at least 2.5 with reduce the carbon emissions for building heating energy use by 50% compared to a typical gas boiler system, based on current electricity grid CO_2 emissions. A more efficient system would reduce these emissions further, e.g. a system with a SPF of 4 would reduce space heating CO_2 emissions by 69%. Heat pump systems with an SPF above 2.5 qualify for the Renewable Heat Incentive[9] (RHI) which provides financial support to adopt low carbon heating. Such low temperature heating systems are more effective when the demand is low [24]. Biomass boilers may be another suitable option [29] and can also qualify for RHI support.

Where it is not possible to install building integrated renewables at the store, there are examples of retailers in the sector deploying renewables at a different site for the benefit of the store. Best practice for buying in renewable energy is that it should be to add additional low carbon power generation that wouldn't otherwise of been installed [25], for example through a renewables developed delivered through a Power Purchase Agreement (PPA). Where retailers are closely located there may be opportunities to pool resources and develop technologies that can supply multiple sites with renewable energy.

Carbon Emissions Reduction = Potential

The overall CO_2 emissions savings of the 5 Best Practice interventions depend on a number of factors, including the current baseline energy characteristics of the building and the potential for onsite renewables and building fabric change. In the example below for an example supermarket with current energy intensity of 1,250 kWh/m^2/yr, conservative interpretations of the potential emissions savings for building energy emission have been characterised to show the potential near term savings. In the example, implementing the best practice on refrigeration reduces electricity use by 32.5% efficient, automated lighting reduces electricity demand, by 35%, while interventions to better control temperatures in the building reduces energy for heating by 15%. Table 4 outlines the potential emissions reductions. This would equate to a 25% reduction in building energy emissions.

Table 4: Possible energy efficiency interventions over the next 2 years

Timescale	Area	Intervention	Assumed % reduction against baseline
Next 2 years	Refrigeration	Improvements in equipment (compressors etc)	30
		Doors on 25% of display cabinets	12.5
	HVAC	Improvements in controls and staff awareness	15
	Lighting	Improved lighting controls	10
		LEDs in 50% of store	25
	Other	Replacement of technology	10

8. Refrigeration cycles expel heat to the outside environment while they work to cool the air within the refrigeration space.
9. See https://www.gov.uk/non-domestic-renewable-heat-incentive for details on edibility, tariff rates and how to apply.

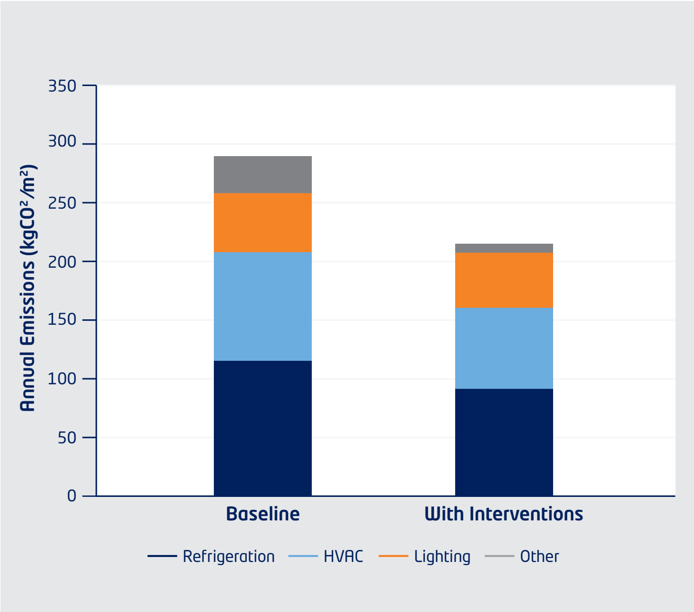

Figure 8: Indicative building CO_2 emissions saving from the 5 Interventions

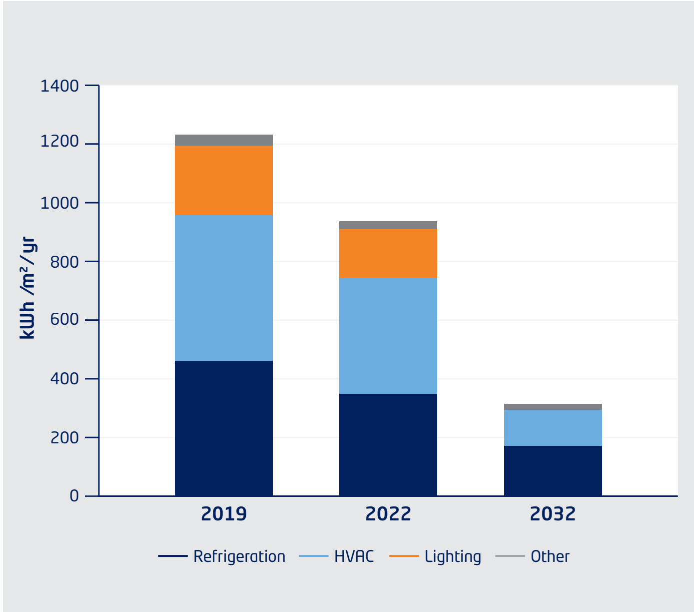

Figure 9: Impact on the energy intensity of a supermarket through various energy efficiency interventions

Further Emissions Reductions Potential

Food retail is a sector for which a lot of research into energy efficiency has been undertaken. In part, this may reflect the high energy density of the sector and the contribution that has to operating costs. In the example below for an example supermarket with current energy intensity of 1,250 kWh/m²/yr.

Table 5: Long term emissions reductions through energy efficiency

Timescale	Area	Intervention	Assumed % reduction against baseline
10 years	Refrigeration	Improvements in equipment (compressors etc)	35
		Doors on 100% of cooled displays	50
	HVAC	Substantial improvement in building fabric	60
		Heat recovery from refrigeration system	100
	Lighting	Improved controls	15
		LEDs in 100% of store	50
	Other	Replacement of technology	50
		Staff awareness	15

If we assume a supermarket with average energy intensities – e.g. 800 kWh/m^2/yr for electricity and 450 kWh/m^2/yr for gas [36], we can look at the impact these interventions have (Figure 9)[10]. This shows a short-term reduction in energy intensity of nearly 25% and a longer-term reduction of around 75%. Although this is a substantial reduction it should be noted that the under this example, the energy intensity in 2032 is still above the 150 kWh/m^2/yr potential outlined by the Dutch Green Building Council.

In terms of carbon emissions, based on 2019 emission factors, there would be a drop in carbon intensity of 25.4% by 2022 and by 74% by 2032, due to the increasing proportion of renewable energy in the UK energy mix leading to a reduced carbon intensity of grid electricity. However, current proposals for electricity decarbonisation are implemented, the carbon intensity of electricity generation will drop to 0.1 kgCO_2e/kWh [9]. This would result in a combined reduction of carbon intensity for our example store of nearly 90% if all interventions are also applied.

It is possible through aggressive improvements in energy efficiency to substantially reduce carbon emission over the next 10-20 years. However, to be 'zero carbon', it also requires the use of renewable energy to supply, in this case, the remaining 302 kWh/m^2/yr of electricity.

Examples

The best practice interventions discussed are all based on existing and commercially available offers that have been successfully implemented in the sector. The following examples highlight how they have been applied in different contexts to-date.

Example 1

Kolokotroni et al [37] identify a convenience store in the UK where energy efficiency measures including:

- Booster CO_2 system
- Intercooler (internal gas cooler)
- Heat recovery to water, utilized for domestic hot water production, heating of ventilation air and over door heater
- Destratification fans –to distribute warm or cool air evenly.

Total energy use was reduced by 56%, with an energy intensity reduced to 447 kWh/m^2 compared to an average for similar stores of 1,039 kWh/m^2.

Example 2

Sainsbury's has used heat recovery from refrigeration systems and ground source heat to supply 100% of heating requirements at 30 stores (as of 2015). Waste heat is collected from the back of the refrigerators and it is then stored in a heat chamber located under the car park. The heat can then be pumped back into the building as it is needed [46]. In 2017 they pledged to adopt LED lighting across all of its stores through a partnership with Current, the smart buildings division of General Electric. The full LED conversion was expected to be done by 2020 and to reduce lighting energy use by 58% [32]

Example 3

Adopting an exacting standard like the Swiss Minergie standard could ensure significant energy reductions. If we take an average store, where eating accounts for 20% of energy use, and energy intensity is 500kWh/m^2/yr. Heating would account for 100 kWh/m^2/yr. This means that is the Minergie standard for retrofit was adopted, heating energy demand intensity would be reduced by 45%

Example 4

Tesco has set out a set of targets based on a trajectory for its own operations in line with limiting warming to 1.5 C. Renewable energy is a key part of this and, as of 2018, all electricity in the UK and Republic of Ireland was purchased from renewable sources through Renewable Certificates. However, as argued earlier, this is seen as a low credibility source of renewables, and Tesco have set out a plan for 2030 that will see 50% of electricity coming through Power Purchase Agreements, 40% through Renewable Certificates, and 10% from on-site renewables [33]. Since announcing the plan, Tesco have entered into a number of agreements to make this happen, including:

- A PPA with SDCL Energy Efficiency Income Trust (SEEIT) to install, operate and maintain 5MW of rooftop solar [34].
- An agreement with Macquarie's Green Investment Group (GIG) to own and operate solar panels on 20 sites
- Three PPAs with EDF Energy:
  - To install 5MWp of solar panels
  - To build a 10.8MW extension to Burnfoot East windfarm project
  - To build a new windfarm with a capacity of 43MW.
- Two further PPAs have been signed with BayWa r.e. and Scottish Power [35].

10. It is assumed that Refrigeration accounts for 40% of total energy, HVAC for 36% of total energy (and 100% of gas use), Lighting for 20% and other for 4

Offices

Energy Use in Offices

Offices occupy a wide range of building types. While there may be commonalities in terms of appliance use within the workplace, overall energy intensity of office space per square metre (kWh/m^2/yr) may vary due to building context, responsibility for utility bills and building ownership and occupancy level.

Estimates of the different components of energy use in offices can vary. According to CIBSE [20] heating accounts for just under half of energy use in commercial offices, just over a fifth is from lighting, while office equipment is responsible for around 10%. The Carbon Trust [47] suggest that office equipment accounts for 15%, while other estimates suggest a figure of 20% for overall electricity usage [48].

Due to the potential variability in energy use for a specific office building, monitoring is an important first step and, and consistently a common features for companies that successfully improve their energy performance [19]. Given an understanding of how much energy is being used and through what processes, it can be useful to compare that energy use with energy benchmarks – that is industry wide figures in a format that enables comparison, usually energy use (kWh)/m^2/yr. Table 6 below sets out some energy benchmarks for offices.

Table 6: Energy intensity benchmarks from the literature

Energy use covered	Store Size	Average / Conventional Practice (kWh/m^2/yr)	Best Practice (kWh/m^2/yr)	Notes and Source
Electricity	General office	95		[23]
Gas (thermal)	General Office	120		
Total	Office (new build)	136		Values taken from American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) benchmarks [49]
Total	Office (post 1980)	205		
Total	Office (pre 1980)	236		
Electricity	Office (air conditioned)	219	159	This is calculated for Net Lettable Area (NLA) [50]
Other fuels	Office (air conditioned)	107	58	
Electricity	Office (non-air conditioned)	108	70	
Other fuels	Office (non-air conditioned)	85	54	

Carbon Emissions

Building CO_2 emissions ($kgCO_2/m^2/yr$) are linked to energy intensity. Figure 10 takes the data for air conditioned and non-air conditioned offices from the Better Building Partnership (featured in Table 6) with current UK energy system emissions factors to show the carbon intensity of a 'typical' (combining typical values for electricity and other fuels) and a 'best practice' (combining best practice values) office space.

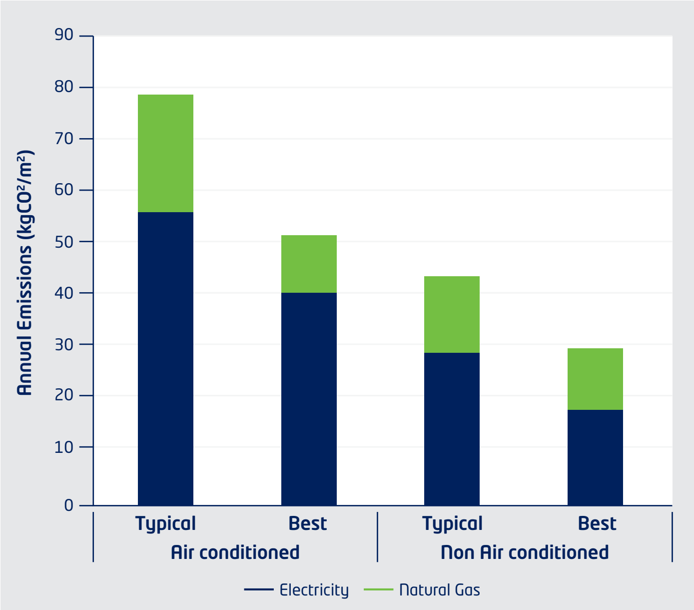

Figure 10: $CO_2/m^2/yr$ based on energy intensity values from Better Building Partnership [50]

Comparing these values there is a difference of 63% between 'typical' air-conditioned office and 'best practice' non-air-conditioned office. These values show the potential for office building use to have significant opportunity for CO_2 emissions savings where typical practice currently exists.

Best Practice Interventions

Achieving the rapid decarbonisation of building energy use needed for tackling climate change requires prioritising reducing energy use. There are a number of new approaches from within the office building sector itself and it is essential that these ideas, and best practice, are shared across the sector. This will necessitate a shift in perception and strategy for most business, as well as investment in new approaches, upgrades in technologies, and innovation. Meeting more of a building's energy needs onsite through renewable generation of power and heat is another way to reduce the carbon impact of offices. Similarly offices an make an important contribution to reducing CO_2 emissions from transport and improve local area quality by supporting low carbon travel for staff and customers (see Transport and Travel section).

Understanding current energy use in the building through more detailed monitoring of energy demand has been shown to be a common first step for companies successful in reducing their environmental impact [19]. Once energy use is understood, it can be useful to compare that energy use with energy benchmarks ($kWh/m^2/yr$). Benchmarks can suggest the kind of energy reductions that should be expected. For example, if we take a mid-range energy intensity for an air-conditioned office of 270 $kWh/m^2/yr$ – reducing that value to best practice levels of 217 $kgCO_2/m^2/yr$ would entail a reduction of 20%. The key is to understand what the 'best practice' office building is doing differently to the 'average practice' offices. Best practice itself is not a fixed target, particularly as the challenge of reaching 'zero carbon' on a very rapid timescale means new approaches and standards may be developed. This suggests that sharing information to help all office occupants know what might be possible, is an important step.

The three main areas of energy use in offices are HVAC, lighting and office equipment, and they are the main focus for action to reduce energy use and CO_2 emissions. Different levels of energy use can result in the same provision of end-goal services – such as good lighting, temperature and air quality [24] therefore staff and visitor expectations can be met with significantly lower energy use than the evidence of current practice suggests is used currently.

1. Energy Management and Monitoring

Best performance is usually achieved where companies have comprehensive energy monitoring systems in place [19]. Schönberger et al [21] highlight what they see as best practice for energy monitoring to examine total energy use and the energy usage from key areas (e.g. heating, lighting and refrigeration):

- Specific energy consumption measured ($kWh/m^2/yr$) - This should ideally be done for the office space used by an organisation (if they don't occupy an entire building) and per each main energy consuming process.
- Lighting power density – W/m^2 – This should be looked at for the office space and for zoned areas where applicable. In some instances lighting intensity can be reduced while improving overall illumination function.

For many office buildings, issues with energy management can arise due to the ownership arrangement of the space in buildings – e.g. if the organisation rents rather than owns the building the offices are in. The Better Building Partnership highlight the relationship between owners and occupiers in terms of the responsibilities and benefits for procurement and control of energy as a key barrier to improving the environmental performance of buildings [17]. One approach to overcoming this is through the use of a 'Green Lease'. This is a standard lease with additional clauses that address the environmental management and improvement of a building, making clear the responsibilities for both the owner and the occupier, and is legally binding. Alternatively, a non-legally binding Memorandum of Understanding can be agreed between owner and occupier. Investment to reduce energy demand has wider benefits beyond tackling climate change.

2. Heating, Ventilation and Air Conditioning (HVAC)

Irrespective of the sector, the primary way of achieving significant reductions in energy demand for HVAC is through improvements in the building fabric. For an existing office building, big improvements are likely to involve a major refurbishment. The elements of building fabric to consider are [21]:

- Wall / roof / façade / floor
  - Insulation materials can be changed
  - Insulation thickness can be increased.
- Widows and glazing
  - Change to more efficient windows
  - Change to more efficient sashes and frames.
- Internal and external solar shading
- Air tightness
  - Improvement of doors
  - Fast acting doors
  - Sealing
  - Using buffer sections.

In addition to these measures, CIBSE (2012) suggest a number of energy savings opportunities than can be realised through refurbishment:

- Increasing natural ventilation and daylight
- Increasing passive measures for air-conditioning
- Maximising the use of free cooling
- Removing air-conditioning completely
- Zoning buildings to enable more effective controls
- Installing an efficient and fully insulated hot water system.

These measures can significantly shift heating and cooling energy needs from typical practice towards best practice.

3. Low Energy Lighting

The main approaches to reducing energy demand from lighting are a well-controlled system that optimises the use of lights (which could reduce lighting load by 17% [19], and the replacement of older technologies with LEDs. As with other measures in the office building sector, ownership and control of lighting may be complicate implementation, however as shown in Example 1 landlords, building managers and occupants can collaborate to deliver low carbon interventions.

4. Office Equipment

Assessing the lifetime operational energy use cost of an appliance as well as the upfront cost, and prioritising energy saving, will support a reduction in office building carbon emissions.

While changes in technology for more efficient office equipment can be important, one of the main issues with office equipment if how it is used. The Carbon Trust [51] suggest that good practice involves:

- People taking responsibility for the equipment under their control (ensuring it is turned off)
- Any energy saving features are enabled
- Centrally monitor IT equipment where possible
- Only equipment with a high energy efficiency rating is purchased
- Any vending machines are controlled to minimise out of hours energy use.

5. Increase Direct Use of Renewables

There are various options for on-site renewables. Rooftop solar panels are a popular option for low carbon electricity. For office buildings in use during the day, an appropriately sized solar PV system may mean high levels (>80%) of the electricity generated onsite through rooftop renewables could be used by the building. The majority of electricity generated onsite therefore contributes to reducing imported electricity costs and the associated emissions – with surplus electricity bought by the electricity supplier and contributing to decarbonising the rest of the electricity network. The typical electricity production through solar PV for the North West of England is around 820 kWh per kW of installed rooftop capacity [52]. As an example – applying the methodology of [53] to a generic mid-size non-domestic building (8 kW peak electricity load) with 15 kW PV system installed in Northern England, 70% of PV generation could be used on-site, meeting around 40% of annual electricity demand.

If heating load is supplied through gas boilers then even if that load is reduced, there will be direct CO_2 emissions. One option is the use of renewable heat in the form of air, or ground source, heat pumps, powered by electricity. An electric heat pump with a Seasonal Performance Factor (SPF) of at least 2.5 with reduce the carbon emissions for building heating energy use by 50% compared to a typical gas boiler system, based on current electricity grid CO_2 emissions. A more efficient system would reduce these emissions further, e.g. a system with a SPF of 4 would reduce space heating CO_2 emissions by 69%. Heat pump systems with an SPF above 2.5 qualify for the Renewable Heat Incentive (RHI)[11] which provides financial support to adopt low carbon heating. Such low temperature systems are more effective when the demand is low [24]. Biomass boilers may be another suitable option [29] and can also qualify for RHI support.

Where it is not possible to install building integrated renewables at the store, there are examples of businesses in the sector deploying renewables at a different site for the benefit of the building. Best practice for buying in renewable energy is that it should be to add additional low carbon power generation that wouldn't otherwise of been installed [25], for example through a renewables developed delivered through a Power Purchase Agreement (PPA). Where businesses are closely located there may be opportunities to pool

11. See https://www.gov.uk/non-domestic-renewable-heat-incentive for details on edibility, tariff rates and how to apply.

resources and develop technologies that can supply multiple sites with renewable energy. As mentioned earlier, being in rented space complicates the ability to utilise on-site renewables but could be a factor in a green lease (see Example 1).

Emissions Reduction Potential

The overall CO_2 emissions savings of the 5 Best Practice interventions depend on a number of factors, including the current baseline energy characteristics of the building and the potential for onsite renewables and building fabric change. In the example below conservative interpretations of the potential emissions savings for building energy emission have been characterised to show the potential near term savings. Table 7 outlines some potential interventions that could be made over the next two years to reduce CO_2 emissions. The baseline reference case in the example is a mid-range performance, air conditioned office (190 kWh/m^2/yr).

Figure 11 shows the potential impacts of the above interventions for an air-conditioned office with a mid-range energy intensity of 190 kWh/m^2/yr. Through these near-term interventions CO_2 emissions associated with the office building are reduced by 30%.

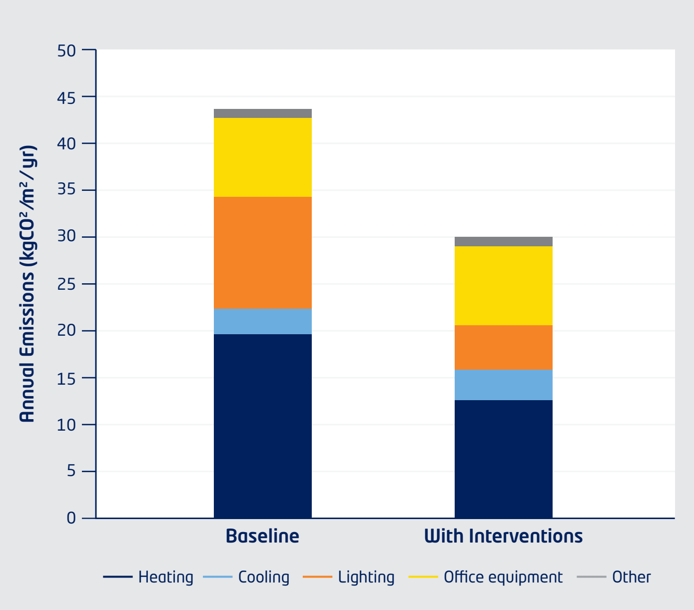

Figure 11: Indicative building CO_2 emissions saving from the 5 Interventions

Table 7: Possible energy efficiency interventions over the next 2 years

Timescale	Area	Intervention	Assumed % reduction against baseline
Next 2 years	Heating	Lower temperature	8
		Change switch-on switch-off times	20
		Ensure no overlap between heating and cooling	10
	Cooling	Ensure no overlap between heating and cooling	10
		Ensure cooling system serviced	10
	Lights	Switch off non-essential lights out of office hours	10
		Install sensors to switch off lights on brighter days	20
		Replace 50% of lights with LEDs	25
	Office Equipment	Ensure equipment switched off when not in use	5
		Replace some equipment with more efficient versions	10
	Other	Staff awareness	10

Examples

The best practice interventions discussed are all based on existing and commercially available offers that have been successfully implemented in the sector. The following examples highlight how they have been applied in different contexts to-date.

Example 1

Landsec, the commercial real estate company, has set targets for carbon reductions approved by the Science Based Targets Initiative[12]. Since 2014 it has reduced the carbon intensity in its portfolio by 39.8% and is pursuing an 80% reduction by 2050[13].

Example 2

The Low Carbon Buildings Partnership refurbished a 3800m² office space and reduced energy consumption in the building by 64%. Measures used included: enhancing insulation to walls and ceilings; improving air tightness; installing a new ventilation system that recovered 85% of energy from extracted air; the replacement of glazing, the installation of low energy lights; and the use daylight controls and occupancy detection on lights[14].

Example 3

For its refurbishment of Record Hall in Hatton Garden Conservation Area, Workspace has utilised low carbon energy, improved energy efficiency, and enhanced low carbon transport options. The building incorporates an 85m² soar array generating electricity, and reversible air source heat pumps have been installed. Importantly, extensive sub-metering has been installed so the energy performance can be monitored in detail by the building team and occupiers of the space. The building has 51 indoor cycle spaces, 54 lockers, and six showers and changing facilities. A Travel Plan has been developed to encourage more sustainable options[15].

12. https://sciencebasedtargets.org/
13. https://landsec.com/sustainability/efficient-use-natural-resources/climate-change-carbon
14. http://www.betterbuildingspartnership.co.uk/low-carbon-workplace%E2%80%99s-refurbishment-premier-house
15. http://www.betterbuildingspartnership.co.uk/workspace%E2%80%99s-sustainable-refurbishment-record-hall

Hotels

Energy Use in Hotels

Hotels are multi-functional spaces that offer catering, leisure and event services and parking as well as accommodation. Most hotels have kitchen facilities and restaurants in-house to be considered when assessing overall energy demand. Similarly, there is diversity in the building stock of hotel premises - with a significant proportion of old building stock in the northern European hotel sector [54]. The combination of these services and building stock will influence the overall energy demand of the building and its role in the wider carbon emissions impact of the business [55].[16] However despite the variability across the hotel sector there are common areas of energy demand consistently reported across the literature.

The Chartered Institution of Building Services Engineers (CIBSE) provide benchmarking data for building energy use by business activity type:

Table 8:CIBSE Benchmarks for Hotels (Table 20.1 from Guide F, 2016)

Type	Standard Practice (electricity kWh/m²/yr)	Standard Practice (fuel use kWh/m²/yr)	Typical Practice (combined energy kWh/m²/yr)	Good Practice (electricity kWh/m²/yr)	Good Practice (fuel use kWh/m²/yr)	Good Practice (combined energy kWh/m²/yr)
Holiday	140	400	540	80	260	340
Luxury	150	460	610	90	300	390
Small	120	360	480	80	240	320

CIBSE data also highlights the possible additional energy demand where leisure facilities (swimming pool) and air conditioning is included.

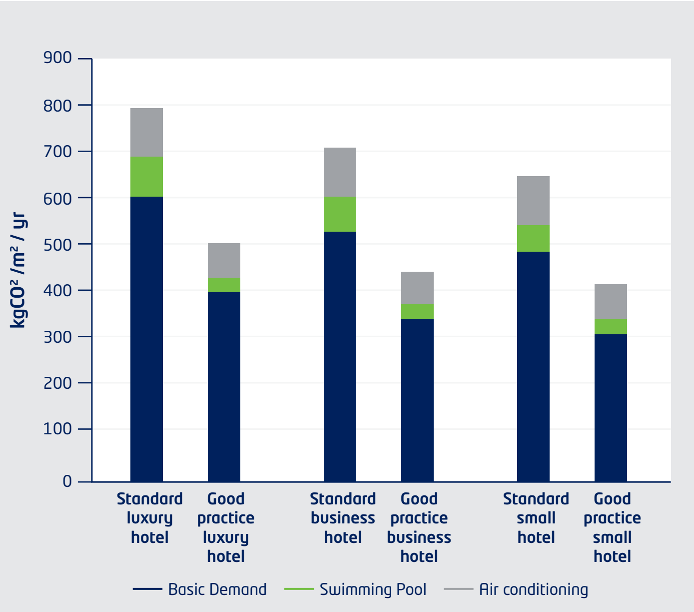

Figure 12: Energy demand benchmarks by hotel type (CIBSE, 2016)

A number of reviews into hotel energy use have found average energy use suggests significant variations in annual energy use in hotels. A Europe wide meta-analysis project of studies about the hotel sector- the Hotel Energy Solutions study – finds a range of 200 kWh/m²/yr to 400 kWh/m²/yr for European hotel energy use. A study by Filimonau, Dickinson [57] reports energy use for two hotels in Poole Dorset of 206 kWh/m²/yr and 220 kWh/m²/yr based on 2008 metered data for small hotel buildings constructed in 2000 and 1996 respectively with no air conditioning, on-site laundry or restaurant. A 2007 study of 184 Hilton and Sandic hotels in Europe [54] reports average annual energy consumption of 364 KWh/m²/yr and 285 kWh/m²/yr respectively for these hotels chains. These reports suggest that the CIBSE Good Practice benchmark is a more appropriate measure of typical hotel energy use. It also highlights that there may be significant opportunities to reduce average annual energy use in line with current best practice.

While there are indications of considerable variability in baseline energy demand for hotels, the proportional share of demand from energy services is consistent across the studies reviewed. Space and water heating are the main contributors to onsite hotel energy demand. The Hotel Energy Solutions review finds ~50% of hotel energy use is heating cooling and ventilation (HVAC), 15% hot water and 12-18% lighting. The CIBSE data shows ~75% of energy use is onsite fossil fuel use, which is likely to include heating, hot water and cooking provision. Similarly the Accor Hotels Environmental Footprint Report, while not providing a kWh/m²/yr figure for their hotels, do report their breakdown of energy use in their European hotels. Depending on whether a particular facility is on site they state 0-10% (electric systems in rooms), 40-45% (HVAC), 0-10% laundry, 3-5% lighting, 10-20% hot water, 2-5% computers and 10-20% kitchen equipment [58]. Carbon Trust also report ~45% for energy for heating, ~25% hot water, 15% catering, 10% lighting and 10% air conditioning [59].

16. The most detailed review on the impact of occupancy rates on energy use in hotels identified in the literature found only a weak relationship between occupancy rate and hotel energy demand. This study was however limited to 29 hotels in Singapore See - 56. Priyadarsini, R., W. Xuchao, and L.S. Eang, A study on energy performance of hotel buildings in Singapore. Energy and Buildings, 2009. 41(12): p. 1319-1324.

Carbon Emissions

Based on the above characterisation of hotel energy use, and within the context of the current UK energy system, most of the energy relate CO_2 emissions for a hotel from the building itself are from natural gas use for heating, hot water and kitchen services[17]. The chart below is an illustrative view of CO_2 emissions from hotel buildings (Scope 1&2) based on benchmark energy demand data. The significance of emissions from natural gas is due to the relatively high share of energy demand for space heating and hot water. Reflecting the difference in energy intensity (kWh/m²/yr) emissions of CO_2 are expected to vary by hotel type – with further variation likely due to inclusion of services such as leisure facilities. For the benchmark data used in this example annual CO_2 emissions intensity varies from 69 $kgCO_2/m^2$ to 84 $kgCO_2/m^2$ for basic hotel energy needs – increasing to between 92 $kgCO_2/m^2$ and 109 $kgCO_2/m^2$ with air conditioning and leisure services included.

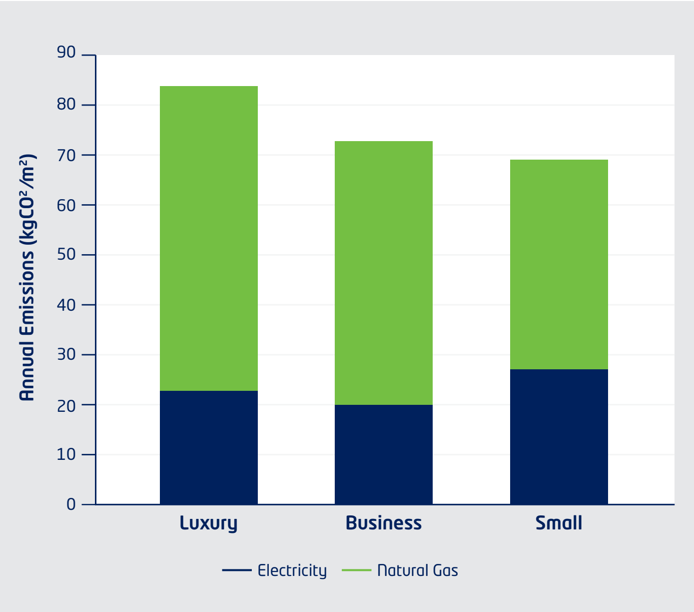

Figure 13: $CO_2/m^2/yr$ based on CIBSE Good Practice Benchmark data by Hotel type [20] and Defra CO_2 emissions factors for 2019

Reducing CO_2 emissions from a hotel requires steps to reduce onsite energy use and a transition to lower carbon energy provision (i.e. renewable heat and onsite solar PV). Implementing demand management and onsite renewables provides quicker, more direct reductions in hotel emissions than changes to the electricity network alone [12]. Although dependent on the building context, taking these steps can lead to reduced building operating costs and provide a return on investment. Not all of the best practice interventions require investment in new equipment or additions to the building – some relate to building management practices that can be implemented with most building ownership arrangements. Based on the relative contribution of space and water heating to hotel building CO_2 emissions, heating demand reduction and supplementing heating load with renewable heat provision are particularly significant for reducing carbon emissions from hotels.

Best Practice

A decoupling of energy demand from economic performance and an overall reduction in energy demand for service provision is consistently named as the first step towards decarbonisation of energy and an effective near term implementation option [60], [61], [62]. This is because;

- Demand reductions achieve near term emissions reductions ahead of decarbonisation of supply options – which remain largely fossil fuel based
- Lower peak and overall energy demand opens up further options for renewable technologies – e.g. heat pumps and solar thermal
- Reducing demand first then adding onsite electricity generation or renewable heat allows for more optimal sizing of these systems.

Demand reduction itself may come not only through equipment and building fabric change, but through new energy management processes and engagement with staff and customers. With the reduced technology costs and improved options for onsite renewable electricity generation and renewable heat technologies, meeting an increasing proportion of building energy demand without imports from gas and electricity networks can also be an option, depending upon building configuration. Hotels may also be able to play a role in supporting the move to low carbon transport through facilities and incentives that help staff, customers and suppliers to switch to lower emissions travel (see Travel and Transport Section.

1. Monitoring Current Energy Demand to Identify Wastage and Improved Control:

Levels of energy monitoring and control can vary significantly between buildings. While standard practice may include periodic monitoring of consumption at the meter point, implementing thermostatic controls on radiators and room sensors, a wide range of further interventions for monitoring and control of energy use are available. These measures can identify current avoidable wastage of energy for quick wins and also set a benchmark to identify high use areas and services within the building to tackle such as the measures below. For example better control of building temperature can reduce heating energy requirements without effecting comfort [63]. This may also identify where draughts and over-lighting elevate energy consumption in particular parts of the building [59]. Other examples include control measures to prevent countervailing actions such as having windows open or radiators on while air conditioning is operating [63].

Monitoring and control measures are the primary reported intervention by Accor Hotels [58] and Hilton Hotels. While these examples refer to integrated Building Management Systems, there are also intermediate interventions in control measures such as; lighting sensors, zonal

17. This is assuming that natural gas is used for heating and hot water. If standard electric heating (i.e. no heat pump) is used instead for heating and hot water, based on current electricity grid factors overall emissions would be 20% greater for a building of the same energy usage.

temperature setting, control hot water flow temperature, and control and improved thermostat location [59] that can be applied. As well as technical interventions, new protocols for staff to check and correct overheating in parts of the building can also reduce waste energy [59, 64]. Equipment check (clean parts) and avoiding overcooling in refrigeration can reduce the energy consumption of refrigeration equipment. For example setting increasing fridge/freezer temperatures by 1ºC can save 2-4% in refrigeration energy use [59].

2. Improving the Performance of the Building and Equipment

Refurbishment and maintenance cycles can be important opportunities to add more efficient equipment or improve the thermal efficiency of the building. If hotel property is refurbished on a 7-10 year cycle [59] this represents an important opportunity to merge maintenance and energy efficiency interventions to reduce the cost of both within an upcoming refurbishment cycle. There are examples of how improving the air tightness of a hotel, improving insulation levels for walls, windows and doors may lead to energy demand for heating of 18% to 40% [59, 64, 65] depending on the baseline performance of the building. It is suggested in Styles D., Schönberger H. [65] that adding complimentary ventilation and heat recover can reduce the energy needed to heat and cool hotels even further. Easy to implement measures to reduce hot water usage through spray taps and shower controls will also lead to reduced energy use and therefore carbon emissions [59].

3. Reduce Energy Used for Lighting

Although lighting may only be around 15% of a hotel's onsite energy use, if older lighting technologies and manual controls are currently in place there can be significant immediate reductions in electricity demand. The main approaches to reducing energy demand from lighting are a well-controlled system that optimises the use of lights (which could reduce lighting load by 17% [19]), so that – for example – lights do not remain on while there is sufficient natural light, or unused areas are not lit. Similarly, the replacement of older technologies with LEDs will not only provide energy and cost saving while in use, but also have longer rated service lives, meaning reduced spending on replacement bulbs. LED lighting can typically reduce power requirement for lighting by a third when replacing fluorescent bulb lighting.

4. Add Onsite Renewables to Reduce Imported Energy.

For buildings in use throughout the day, such as a hotel, an appropriately sized solar PV system may mean high levels (>80%) of the electricity they generate onsite through rooftop renewables can be used by the building. The majority of electricity generated onsite therefore contributes to reducing imported electricity costs and the associated emissions – with surplus electricity bought by the electricity supplier and contributing to decarbonising the rest of the electricity network. The typical electricity production through solar PV for the North West of England is around 820 kWh per kW of installed rooftop capacity [52]. Given the potential significant daytime electricity load, all electricity generated by an appropriately sized PV array could be used by a hotel onsite and contribute to reducing Scope 2 emissions by reducing electricity imports from the network. For example – applying the methodology of [53] to a generic mid-size non-domestic building (8kW peak load) with 15kW PV installed in Northern England 70% of PV generation could be used on-site, meeting 42% of annual electricity demand.

Solar thermal installed on rooftops can supplement hot water heating. The extent to which solar thermal can reduce natural gas use for hot water heating depends on available external space and overall demand. Some assessments suggest that 40% of hot water demand could be supplied by solar thermal [66]There are examples of solar PV and solar thermal installation on the same hotel rooftop such as in Example 3. As between 10% and 20% of hotel energy use is likely to be hot water supply from natural gas or direct electric heating, halving imported energy to the building by utilising solar irradiance on the building can provide an important emissions saving. In some reported applications – where steps are taken to reduce hot water energy demand overall, solar thermal can provide most hotel hot water needs [64]. These systems do however require hot water storage tanks.

Carbon Emissions Reduction Potential

The overall CO_2 emissions savings of the 4 Best Practice interventions depend on a number of factors, including the current baseline energy characteristics of the building and the potential for onsite renewables and building fabric change. In the example below, conservative interpretations of the potential emissions savings for building energy emission have been characterised to show the potential near term savings. In this example, energy monitoring and conservation measures (Steps 1 to 3) reduce electricity demand by 15% and heating demand by 20% assumed based on the above review of actions. The potential for 35% of onsite electricity demand to be met by solar PV and 30% of hot water provided by solar thermal is shown. If achieved this would equate to a 36% reduction in hotel building energy emissions.

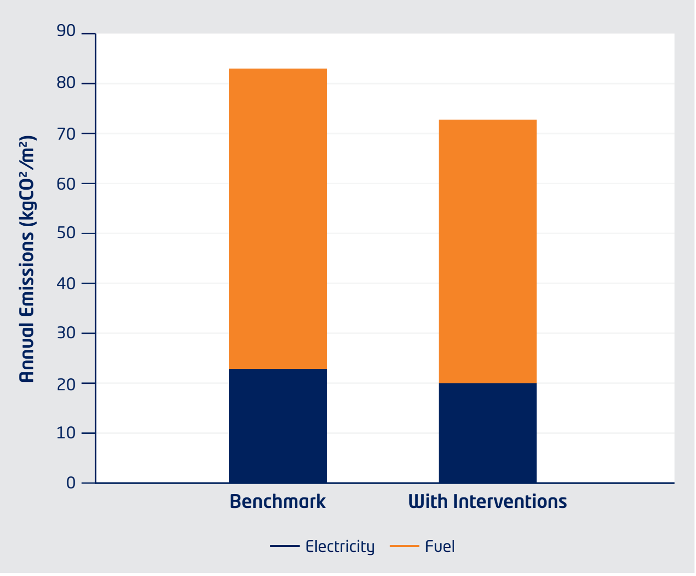

Figure 14: Indicative building CO_2 emissions saving from the 4 Interventions

Examples

The following examples are UK cases where best practice is being applied and CO_2 emissions are being reduced in the hotel sector.

Example 1

Hilton have proposed a strategy to reduce emissions across the hotel chain. The Hilton Travel with Purpose initiative aims to cut Scope 1 and Scope 2 emissions by 61% (of 2008 levels) by 2030. This includes a number of initiatives on energy monitoring and real time control[18]. The focus on monitoring and control as part of this highlights the role of energy conservation in having substantive impacts on hotel building related emissions.

Example 2

The Sandford Springs Hotel in Hampshire is an example of the emissions saving potential of investing in advanced HVAC measures. The developer of the scheme reports a 31% reduction in energy use through an HVAC 'Smart Cool' management system at the property[19].

Example 3

Available roof space is a potential constraint on the extent to which onsite renewables can be deployed. However, Tower Hotel in London is an example of adding significant PV and solar thermal capacity[20] where 49.4kWp of PV capacity and 140 solar thermal collectors producing 98,000kWh thermal output per year.

Example 4

Since 2005 the Accor Hotel group have implemented a wide-ranging Building Management System (OPEN). They have begun to implement heat recovery through ventilation systems (35% of properties in 2016) and nearly all hotels in the group are reported to have installed high efficiency lighting. As of 2015, 15% of their hotels had installed solar thermal and solar PV units to increase onsite energy provision.

Example 5

At Premier Inn, a combined 1.6MW of solar PV was installed at 88 hotels between 2013 and 2015 with a projected increase to 3MW installed capacity. The company have also complete their first fully battery operated hotel with a 100kW lithium ion battery at its Gyle at Edinburgh Park hotel. Onsite battery capacity is charged from the national grid when electricity prices are low and used to meet demand when electricity is higher cost or export to the grid for balancing and flexibility services. Providing this type of capacity provides important services to National Grid which support wider uptake of renewables [60].

18. https://newsroom.hilton.com/corporate/news/our-commitment-to-fighting-climate-change
19. https://anesco.co.uk/sandford_springs/
20. http://www.solaruk.com/case-study/commercial/towerhotelwaterheating.asp

Warehousing and Factories

Energy Use

Warehousing and factory units consist of wide range of business types with a mix of spaces including warehouse, workshop production and office areas. Within the warehouse sector there is likely to be diversity in energy use depending on the flow of goods (storage to rapid fulfilment centres) and whether there is refrigeration onsite [67]. Factories as a classification cover a wide range of activities including food products and manufacturing which have different process and energy needs and goods storage requirements.

The Chartered Institution of Building Services Engineers (CIBSE) provide benchmarking data for building energy use by business activity type. The CIBSE data was last updated in 2012 however it is highly detailed assessment of actual warehouse and factory buildings which provides a useful guide to energy use characteristics within the sector. As noted by the UK Committee on Climate Change [68] there has been limited change in CO_2 emissions from non-domestic buildings in recent years, therefore while these benchmarks may be conservative given possible improvements in some buildings, it is expected that they remain broadly representative of current typical practice.

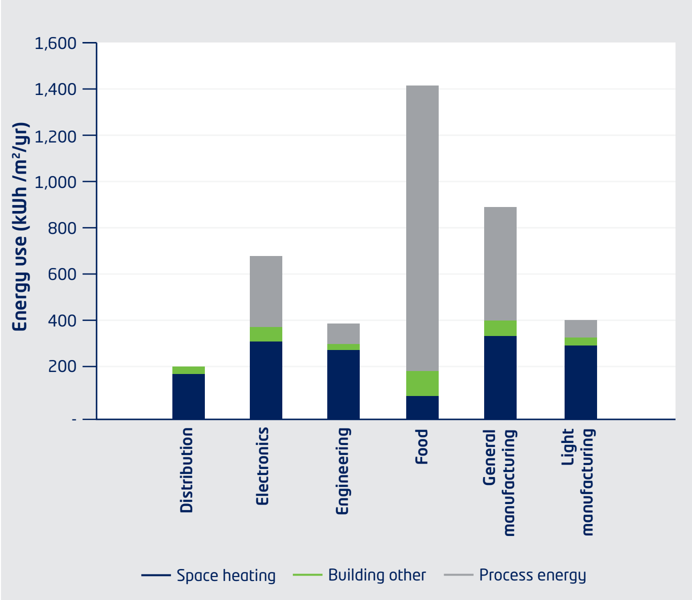

Figure 15: Annual Energy Use per Square Metre by Business Type. Based on [20].

Table 9: Energy Use Benchmarks for Warehouse (Distribution) and Factory Types [20]

Industry	kWh/m²/yr		
	Space heating	Building other	Process energy
Distribution	164	44	-
Electronics	298	65	341
Engineering	257	45	85
Food	80	93	1,247
General manufacturing	328	81	495
Light manufacturing	286	38	82

For some organisations, lighting is a major proportion of electricity used on site. The Carbon Trust estimate the share of electricity demand from lighting is as high as 80-90% for warehousing and logistics and 20-50% for light engineering and 10-30% for manufacturing. Space heating is another consistently large proportion of onsite energy use – with CIBSE data suggesting it may account for over 50% of energy use in distribution, engineering and light manufacturing classifications.

'Building Other' in this assessment is taken to mean electricity for non-process services, such as lighting and office equipment. The contribution to energy use of process energy is very site specific, depending the operation of the business and will also vary due to the number of shifts being run. The CIBSE benchmark, based on a sample of UK operations in each category, does however given an indication of the relative contribution of different activities to overall energy use.

Carbon Emissions

The CO_2 emissions ($kgCO_2/m^2/yr$) of a warehouse or factory building are linked to energy intensity. Figure 16 takes the data for air conditioned and non-air conditioned offices from CIBSE (in Table 9) with current UK energy system emissions factors to show the carbon intensity of a 'typical' (combining typical values for electricity and other fuels) and a 'best practice' (combining best practice values) warehouse or factory building.

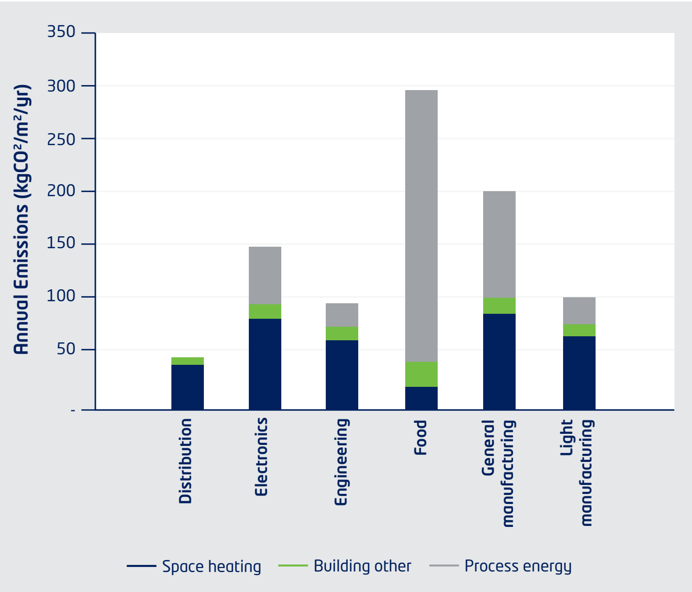

Figure 16: Carbon emission ($CO_2/m^2/yr$) for warehouse/factory building types

Best Practice Interventions

1. Implement Low Energy Lighting With Monitoring And Automation.

Lighting may be a significant contributor to onsite electricity consumption in large facilities with near continuous operation – as for multi-shift factory and warehouse settings. For a non-refrigerated warehousing it may be that 65% of energy demand is related to lighting [69]. Where older sodium or metal halide discharge lighting is replaced by LED lighting the same lighting (lumens) can be provided with around 50% less electricity. Similarly, replacing fluorescent tube lighting with LED will cut electricity use for lighting by around 30%. The specified operating lifetimes of LED lighting bulbs is also significantly longer than for discharge and fluorescent bulbs providing further cost savings over time. Coupling improved lighting sources with occupancy and ambient light sensors to avoid over-lighting can reduce the energy used for lighting even further (see Example 2) [69].

2. Improving Workplace Heating, Cooling and Ventilation

Large volume buildings with regular air flow due to ventilation and open entrances/exits, as is often typical for warehouse and factory settings are a particular challenge for efficient space heating and cooling.

Increasing the thickness of insulation materials on external walls and roofs may improve the U-value[21] of a building by 50% to 70% - meaning that improved thermal comfort in a building can be achieved with less energy for heating [70]. One study of a 8,060 m^2 distribution centre in Sheffield found the potential to reduce heating emissions by 11.6% by moving from low to high insulation through improved roof insulation [70]. A similar study in Germany found energy reductions of 12% to 14% when improved insulation is added to a reference building [71]. There is variation in the 'embodied carbon' of insulation materials – with the production of some insulation materials having CO_2 emissions associated with cancelling out some of the emissions savings from reduced energy use. In some warehouse and factory setting rooftop glazing (skylights) provides lighting to the building. Without high efficiency glazing, more heat is likely to be lost through glazed compared to the rest of the roof area – although this maybe counterbalanced by reduced energy needed for lighting [70].

In addition to improving the energy performance of the building fabric, alternative methods of heating and cooling warehouse and factory spaces can be implemented to offer thermal comfort with less energy use. Radiant (or infrared) heat panels are a particularly good option for buildings that have high ceilings and a lot of air flow [20]. Instead of increasing the overall air temperature of a building like a standard convection heater, the heat from a radiant heat panel is absorbed only by the bodies it interacts with, therefore achieving the same level of comfort for occupants at a lower temperature [20]. Radiant heat panels can be supplied by natural gas, electricity or a source of medium high temperature hot water or steam. It may be possible to reduce heating energy use by 10% to 25% depending upon the building fabric by replacing convention heating with radiant heat panels [72]. Similarly, passive and active chilled beams can provide direct cooling of building space with less energy requirement and background noise than ventilation air conditioning [20, 73].

3. Improve energy efficiency of electrical equipment

Where a warehouse/factory unit has a number of appliances with inductive loads such as motors, compressors, welding sets and induction heaters could save money on electricity and reduce carbon emissions through power factor correction. The power factor indicates the difference between how much energy is being used to provide power. A low power factor indicates that more energy is being used than is required to provide power to a machine and therefore energy is being wasted. Where the power factor is low (<0.9) investing in power factor correction equipment will improve the power factor – reducing energy costs and carbon. It is not uncommon for industrial sites to be operating equipment at below 0.8 power factor. Correcting this to 0.95 power factor would save around 10% of the electricity used for equipment – with greater savings achieved if the baseline power factor is lower [74]. Power factor correction may also prolong the life of machinery [74] and reduce electricity network charges.

Voltage optimisation is another strategy for improving the energy efficiency of electrical appliances in factories, with the potential to save around 13% in electricity bills and resultant carbon if implemented [75]. Electricity North West can provide advice on power factor correction and voltage optimisation options.

21. How much energy is transferred through a material over time.

4. Onsite Renewables:

Typically warehouse and manufacturing locations may have sufficient roof space to support significant solar PV for electricity generation. Depending upon the size of PV array, and the overall and pattern of demand (e.g. due to number of shift and process types), PV can meet some of a facilities onsite power demand. Where there is a routinely high electricity demand through the day it may be the case that all PV generation is used onsite to meet the building's needs and reducing electricity import costs accordingly. Where PV electricity generation exceeds what can be used onsite the surplus electricity is bought by the electricity grid and helps to decarbonise the rest of the network.

Vehicle charging equipment for use for onsite electric vehicles such as electric forklifts and running equipment such as compressors at times of peak solar PV output can help to maximise onsite self-consumption of renewable energy and provide wider benefits. Electric powered forklifts for internal transport within warehouses and factories reduce direct emissions of pollutants compared to diesel and LPG options, reducing CO_2 emissions onsite and also benefiting air quality and health [76]. Electric forklifts may not be able to transport the same maximum load as diesel options, however even on a full life cycle basis (including manufacturing the truck and battery) on a tonne moved per km basis they are shown to reduce CO_2 emissions [76].

Renewable heat can also be supplied onsite through heat pumps or biomass heaters. An electric heat pump upgrades low temperature heat from the air, ground or water outside of the building to use for heating the inside. An electric heat pump with a Seasonal Performance Factor (SPF) of at least 2.5 with reduce the carbon emissions for building heating energy use by 50% compared to a typical gas boiler system, based on current electricity grid CO_2 emissions. A more efficient system would reduce these emissions further, e.g. a system with a SPF of 4 would reduce space heating CO_2 emissions by 69%. Purely electric heat pumps operate best with high levels of insulation and limited ventilation [24], therefore a hybrid heat pumps maybe a more useful option in a building where there are constraints on achieving this. Hybrid heat pumps use some gas combustion to supplement the outflow temperature of the heat pump system. Depending on how they are operated hybrid heat pumps may meet 93% to 75% of heating demand via electricity inputs with natural gas meeting the rest of the demand [77], meaning that they still provide a large reduction in CO_2 emissions compared to gas boiler heating [77]. Heat pumps and biomass heaters qualify for the Renewable Heat Incentive[22] (RHI) which provides financial support to adopt low carbon heating, if they meet the scheme's efficiency criteria.

Carbon Emissions Reduction Potential

The overall CO_2 emissions savings of the 5 Best Practice interventions depend on a number of factors, including the current baseline energy characteristics of the building and the potential for onsite renewables and building fabric change. In the example shown in the figure below, conservative interpretations of the potential emissions savings for building energy emission have been characterised to show the potential near term savings. Implementing efficient, automated lighting reduces electricity demand, by 40%, while interventions to reduce draughts and heat loss through the building fabric reduces energy for heating by 10%. Switching from convection to radiant heat reduces energy for heating by a further 10%, while voltage optimisation and power factor correction devices lower process electricity demand by 10% [74]. The example case below also assumes that onsite PV electricity generation replaces 40% and 25% of grid imported electricity for warehousing and factories respectively. This would equate to between 24% and 34% reduction in building energy emissions depending on the type of business.

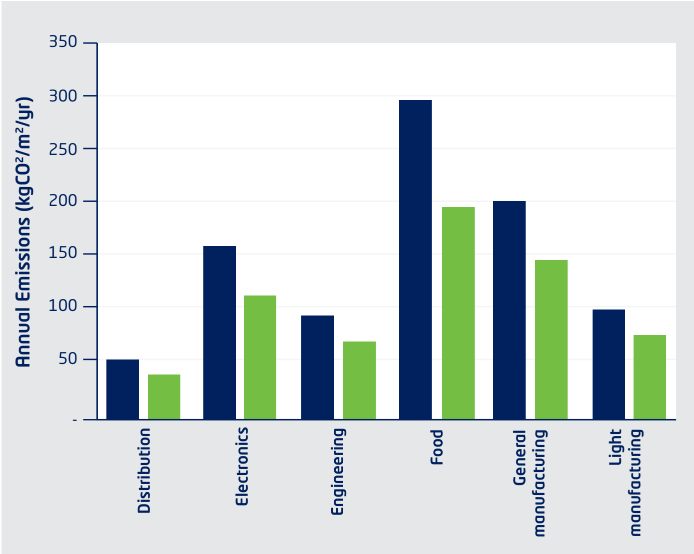

Figure 17: Example carbon reduction potential by building/business type

22. *See https://www.gov.uk/non-domestic-renewable-heat-incentive for details on edibility, tariff rates and how to apply.*

Examples

The best practice interventions discussed are all based on existing and commercially available offers that have been successfully implemented in the sector. The following examples highlight how they have been applied in different contexts to-date.

Example 1

Dixons Carphone state a 50% reduction in energy for lighting after installing high efficiency LED lighting at their distribution warehouse in Newark[23].

Example 2

Logistics firm DHL are rolling out a package of low carbon interventions to reduce overall demand and utilise onsite electricity generation. This includes a building energy management and control system for savings in heating and cooling demand in warehousing through optimisation. The business relationship between HVAC system optimiser BeeBryte and DHL means no upfront costs to DHL and a sharing of energy savings instead to pay for implementation and operation. At the pilot site in Singapore, the company reported a 29% reduction in energy costs although this was for a warehouse with significant heating control requirements[24].

Example 3

Marks & Spencer installed a 6.1 MW capacity solar PV array to their distribution centre at Castle Donnington. The array expects to produce 5,000 MWh of electricity per year and meet 25% of the total energy demand of the 83,613m^2 facility. The scheme is financed through a power purchasing agreement (PPA) with the installer[25].

Example 4

Bentley Motors installed a large 5MW rooftop solar PV system (20,000 panels) at their factory in Crewe in 2013[26]. This was followed in 2019 with a 2.7MW solar PV carport. These developments are part of a wider strategy to source all electricity used in factory from renewable sources, including contracting offsite renewables.

23. https://www.whitecroftlighting.com/pdf/casestudy/dixons-carphone-knowhow-retail-distribution-centre.pdf
24. https://logisticsofthings.dhl/next-on-the-green-agenda-for-logistics-energy-efficient-warehouses
25. https://corporate.marksandspencer.com/media/press-releases/2015/mands-starts-generating-renewable-energy-from-uk-s-largest-roof-mounted-solar-array
26. https://www.gov.uk/government/case-studies/bentley-motors-solar-pv-rooftop-array

Transport and Travel Emissions

Decarbonising surface transport (roads and rail) is a significant priority for meeting decarbonisation targets. As emissions in other sectors have reduced, the proportion of UK emissions from surface transport has increased to 28% of all UK greenhouse gas emissions in 2017 [9]. It is estimated that travel for work accounts for 37% of all passenger transport emissions, with 24% coming from commuting and 13% from travel for business [78].

In terms of carbon reporting, commuting and business travel fall into what are called Scope 3 emissions. Scope 1 relates to direct emissions from burning fuels (e.g. natural gas use and fuel used in company owned vehicles), and Scope 2 to electricity, heat and steam that is bought in. Scope 3 covers indirect emissions that occur throughout a company's value chain[27]. Mandatory reporting does not cover Scope 3 emissions (although it is recommended) and as a result they are often overlooked or poorly accounted for [79]. However, to meet ambitious carbon targets – such as the Greater Manchester 2038 target - it is essential that emissions from travel to and for work are decarbonised. Greater Manchester, for example has a goal to "To double and then double again cycling in Greater Manchester and make walking the natural choice for as many short trips as possible" [80, p.2]. Shifting more travel onto 'active modes' like walking and cycling provide reduced emissions and can contribute to improved health and reduced traffic congestion. Shifting from private cars to public transport for travel also reduce traffic congestion and improve local air quality, while a move to electric vehicles will reduce overall CO¬2 emissions compared to petrol and diesel cars. All three interventions can be supported through work place schemes, e.g. subsidised season tickets, and new onsite facilities such as secure bike storage and electric vehicle charging points, to reduce emissions from commuting to work, business travel and customer travel.

Commuting

One approach to addressing carbon emissions from commuting is 'workplace travel planning'. A workplace travel plan puts in place measures to encourage and enable staff to take more travel to work using low carbon transport [81]. A review of 21 travel plans by Cairns, Newson and Davis [81] found that they could have a significant impact but that this varied between companies. For example, in terms of reducing the number of cars per 100 staff, the best performing organisation reduced the figure by 68%, while the lowest reduction was 5%. The average reduction was 18%. Correspondingly, over the 21 travel plans, organisations had, on average, doubled the number of employees commuting on foot, or by bike, bus or train. Across the organisations, the highest levels of commuting by foot was 23% of employees, for cycling it was 21%, and for public transport 53%. This compares with national figures of 10.3%, 3.2% and 17.9% respectively for the different modes, showing that significant impacts can be made through effective travel plans.

Various factors are important in the success of workplace travel plans but across the 21 case studies parking management appears to be the most important factor in the level of success on a workplace travel plan [81]. Different organisations approached parking management in different ways – some limited parking spaces, some paid employees not to bring cars, some charged for parking. Whatever the approach, it is clear that while effective, parking management may also be contentious. Parking management is also typically linked to efforts to promote car-sharing, for example, exempting those who car shared from parking charges. For car-sharing schemes to be successful, Cairns et al [81] argue that a critical mass of users is needed as early as possible. In addition to aiming to reduce car use, another approach is to try and facilitate a shift to lower emission cars – specifically now electric cars. This is one approach that IKEA is taking by through wider use of electric vehicles and charging points at stores [82].

Workplace travel plans can also benefit from specific measures to promote alternatives to car travel. In the case studies reviewed, the most successful organisations at promoting bus travel had provided free dedicated shuttle buses to link up their site with other bus and rail routes [81]. Others had managed to increase the number of regular buses arriving at their site, while negotiating (or subsidising) ticket discounts for employees so that costs were kept down was also important.

For cycling, the most important factors for increasing usage were good (or improving) off-site routes, provision of on-site parking facilities, having a bicycle user's group and cycle repair services. Some organisations had provided facilities such as showers and changing rooms, or discounted cycle equipment. The attitude of the organisation to cycling – really promoting it and giving it high profile – was important and could overcome other barriers, like poor access [81]. Utilising the Cycle-to-Work scheme, which enables employees to save money on new bikes through reduced income tax and National Insurance, might be seem as important, particularly if aligned with approaches outlined previously. However, in itself, the evidence that the scheme has had much impact is unclear (see e.g. [83]). The use of electrically assisted bikes offers a new approach and there is some evidence of potential impacts. In a trial in Brighton, 80 commuters were loaned electric bikes and three-quarters of them used it at least once a week, with an average of 15-20 miles cycled per week. Across all participants there was a 20% drop in car miles. These results were consistent with other European studies showing sustained usage of e-bikes for active travelling more frequently and over greater distance [84]. Looking across other studies, the highest proportion of e-bike trips that replaced car trips is 76%, with four studies reporting figures of over 50%. Through a study of the Swiss Bike4Car programme[28], Moser et al [85] examined whether habitual associations that people had with cars could be weakened. This is seen as important as habit is a key part of travel behaviour. They found that after 1 year, people who had been involved in the scheme did have weaker habitual associations with cars, with those who had purchased an e-bike as a result of the scheme lower still.

Good access is important if employees are going to walk to work. Successful efforts through travel plans to promote walking include allocating funding to walking, such offering financial incentives, specifically promoting walking (often with a health message), and offering things like umbrellas and pedometers [81].

27. See, https://www.carbontrust.com/resources/faqs/services/scope-3-indirect-carbon-emissions/ for a simple overview.
28. A scheme where car owners are offered a two-week trial of an electric bike in exchange for their car keys. At the end of the 2 weeks participants were offered a discount voucher to purchase an electric bike (Moser et al., 2018).

Business Travel

Business travel may be an area that companies can take direct action to reduce their transport emissions by introducing new practices and expectations that take advantage of new technology and reduce spending on travel as well as reducing emissions. An example of measures to reduce emissions from business travel in Wreford, L. and J. Leston [86]. They set out four stages in decreasing order of priority:

1. Reduce the need to travel – while some travel is necessary, that is not always the case and all business travel should be justified. Technology can be used to keep people better connected and make travel less frequent.
2. Reduce travelling distances by optimising meeting locations
3. Reduce carbon emissions by travelling efficient modes of travel or low carbon fuels – Flights can account for significant levels of emissions and should be minimised. Meeting should be held in places easily accessible by public transport and rail or bus should be the default choice of transport.

Customer Travel

In addition to focusing on employee travel, travel plans can also cover the travel of customers. In some cases there may be obvious overlaps – for example, if more buses are coming to a site then they can also bring customers. However, there is very little evidence that many companies are looking at customer travel at present. As part of its initiative to be 'carbon positive', IKEA does appear to be considering this side of travel. In its Sustainability Report, they highlight the way that public transport links is always considered when planning a new store, and how they are changing approach from only having large out of town stores to opening more city centre stores and pick up points. They are also improving their home delivery offer and providing electric car charging points for customers at stores. In Germany, they have trialed a scheme of trailers that could be pulled by hand or by bike to take products home from 12 stores [82].

Within Greater Manchester, organisations should be looking to link in with the initiatives outlined in Made to Move [80] to provide improved access for customers to get to stores without cars, and can provide better facilities (e.g. secure bike parking) on-site.

Glossary

CIBSE	Chartered Institution of Building Services Engineers
ENWL	Electricity North West
CO_2	Carbon dioxide
SPF	Seasonal Performance Factor
PPA	Power Purchase Agreement
GHG	Greenhouse Gases
GWP	Global Warming Potential
$CO_2/m^2/yr$	Annual carbon emissions per square metre
$kWh/m^2/yr$	Annual energy use in kilowatt hours per square metre
HVAC	Heating ventilation and cooling

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