An investigation into the use of temporal factors for CO_2 emissions accounting in buildings

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Abstract

This paper is an investigation into the issues around how we calculate CO_2 emissions in the built environment. At present in Building Regulations and GHG protocol calculations used for buildings and corporate CO_2 emissions calculations it is standard to use a single number for the CO_2 emission factor of each source. This paper considers how energy demand, particularly electricity at different times of the day, season and even year can differ in terms of its CO_2 emissions. This paper models three different building types (retail, office, home) using standard software to estimate a profile of energy demand. It then considers how CO_2 emissions calculations differ between using the single standard emissions factor and using an hourly emissions factor based on real electrical grid generation over a year. The paper also examines the impact of considering lifetime emissions factors rather than one-year factors using UK government projections.

The results show there is a significant difference to the analysis of benefit in terms of CO_2 emissions from different measures – both intra- and inter-year – due to the varying CO_2 emissions intensity, even when they deliver the same amount of net energy saving.

Other factors not considered in this paper, such as impact on peak generation and air quality, are likely to be important when considering whole-system impacts.

In line with this, it is recommended that moves are made to incorporate intra- and inter-year emissions factor changes in methodologies for calculating CO_2 emissions. (This is particularly important as demand side response and energy storage, although generally accepted as important in the decarbonisation of the energy system at present will show as an increase in CO_2 emissions when using a single number.) Further work quantifying the impact on air quality and peak generation capacity should also be considered.

Keywords carbon accounting, CO_2, decarbonisation, electricity, emissions

1.0 Introduction

In 2008 the UK government set a legal requirement to reduce CO_2 emissions by at least 80% by 2050 against a 1990 baseline (1). To achieve this, the energy we use in our buildings will come under intense scrutiny and our buildings may actually have to reduce CO_2 emissions by more than this, in order to allow other sectors such as aviation (which are considered more challenging to decarbonise) to continue to operate and grow.

CO_2 emissions accounting is not like that for ball-bearings or money; it is very rare to actually measure the emissions, partly due to the impracticality of doing so. In lieu of this it is common to use CO_2 emissions factors for fuels or mains electricity and apply these values to the amount used (i.e. in litres or kWh) to give the total amount of CO_2 emissions

These are calculated in different ways by different organisations for different purposes. Some examples that will be familiar to many CIBSE members include those used in Part L (2) of the Building Regulations and under the GHG protocol (3). While the methodologies are different in each of the above cases, a static emissions factor is used for both – regardless of when a unit of energy is used it is assigned a single value of CO_2 or CO_2 equivalent.

Some of the emissions factors are based primarily on combustion, e.g. when mains gas (methane) is burnt it gives off CO_2 as part of the chemical reaction and this is the basis of the emission factor used, (with the addition of the CO_2 from obtaining and delivering the gas). With grid electricity however the calculation/estimation is much more complex and involves the aggregation of coal-, gas- and oil-fired power stations, nuclear, wind and solar farms, transmission losses, etc. For example, for Building Regulations Part L/Section 6 in the UK, the current emission factor for mains electricity is 0.519kgCO_2 per kWh. Similar tables are used in the GHG protocol, in particular from DEFRA.

Building Regulations Part L emissions factors are laid out in the SAP (Standard Assessment Procedure) document and have been updated periodically (2005, 2009 and 2012, and soon to be updated for 2016). Building Regulations require that new and existing buildings are assessed for their carbon emissions using these static factors for up to 10 years when generating energy performance certificates (EPCs), environmental impact ratings and for the life of the building; these are required when demonstrating compliance with the CO_2 emissions thresholds for new buildings which will apply for the life of the building. (The SAP methodology actually uses a retrospective three-year rolling factor for compliance but includes a 15-year projected CO_2 emissions factor that can be used for unofficial analysis.)

The emissions factors are a simplification and, to some degree a subjective calculation – the factors are determined using a set methodology that is agreed by committee. Whether the precise value is right or not it is in most cases fairly static for each fuel: mains gas combusted today will have the same CO_2 emissions as if it were combusted ten years from now and the same at 6am, midday or 6pm (excluding liquefaction, transport). Even this may change however if biomethane injection levels increase.

With electricity however this is not the case. The CO_2 emissions factor of mains electricity not only varies significantly over a time period of years, but also by a significant amount during a day. (13)

It is hypothesised that these differences between the static values which must be used in calculations and the actual grid factor is significant over short periods such as a day and over the longer period of years. It would therefore be beneficial for the decision-making process for factors used to take into account the intra-day and lifetime changes expected.

A simple example of this is generating electricity via solar panels against the retrofitting of LED lighting. While solar panels can work effectively to generate electricity, this is more often than not during the summer and during the middle of the day, when overall electricity demand is low. During these times many of the more carbon-intensive forms of electricity generation are offline or at reduced output, therefore displacing relatively cleaner forms of generation such as gas. Conversely, during a winter's evening, there is no solar generation, typically when more carbon-intensive systems such as coal will be retained in order to provide generation which meets peak demand. Therefore a kWh saved through LED lighting may deliver greater CO_2 emissions savings than a kWh generated by solar.

This issue has become more important and urgent due to the fact that time shifting of energy demand, often called demand side response (DSR) and energy storage (commonly in the form of batteries), are now being used much more extensively, even down to the domestic scale. (9) The driver for this has been primarily financial (see below) but there may also be significant CO_2 emissions benefits, as broadly the carbon intensity of mains electricity correlates with the level of demand, (see figure 3). At present static electrical emission factors actually mean that any energy storage device always appears to increase CO_2 emissions as the device will always be less than 100% efficient and therefore the energy supplied will be less than that required to charge it.

For most non-domestic buildings the varying demand is accounted for in the cost of electricity, with charges such as the Distribution Use of System (DUoS) charges and Triads, applied at peak demand times, to represent the greater cost of generation and distribution at peak times, but the same thing does not happen with carbon accounting.

Table 12: Fuel prices, emission factors and primary energy factors

Fuel	Standing charge, £ [a]	Unit price p/kWh	Emissions kg CO_2 per kWh [b]
Gas:			
mains gas	120	3.48	0.216
bulk LPG	70	7.60	0.241
bottled LPG		10.30	0.241
LPG subject to Special Condition 18 [c]	120	3.48	0.241
biogas (including anaerobic digestion)	70	7.60	0.098
Oil:			
heating oil		5.44	0.298
biodiesel from any biomass source [d]		7.64	0.123
biodiesel from vegetable oil only [e]		7.64	0.083
appliances able to use mineral oil or biodiesel		5.44	0.298
B30K [f]		6.10	0.245
bioethanol from any biomass source		47.0	0.140
Solid fuel: [g]			
house coal		3.67	0.394
anthracite		3.64	0.394
manufactured smokeless fuel		4.61	0.433
wood logs		4.23	0.019
wood pellets (in bags for secondary heating)		5.81	0.039
wood pellets (bulk supply for main heating)		5.26	0.039
wood chips		3.07	0.016
dual fuel appliance (mineral and wood)		3.99	0.226
Electricity: [a]			
standard tariff	54	13.19	0.519
7-hour tariff (high rate) [h]	24	15.29	0.519
7-hour tariff (low rate) [h]		5.50	0.519
10-hour tariff (high rate) [h]	23	14.68	0.519
10-hour tariff (low rate) [h]		7.50	0.519
18-hour tariff (high rate) [h]	40	13.67	0.519
18-hour tariff (low rate) [h]		7.41	0.519
24-hour heating tariff	70	6.61	0.519
electricity sold to grid		13.19 [i]	0.519
electricity displaced from grid			0.519 [i]
electricity, any tariff [j]			

Figure 1 SAP 2012 9.92, emission factors used in Part L and EPCs

The authors' hypothesis in this paper is that the static values used are no adequate; the benefit of simplicity which they bring is outweighed by the inaccuracy they enforce in analysis and the impact they have on decision making; variable factors may be more complex but the benefits they bring in reducing real levels of CO_2 emissions outweigh this additional complexity.

Improving the accuracy of the way by which CO_2 emissions are calculated could potentially lead to changes in policy, better informed investments and decision making. Decisions made now or in the next few years can lock in emissions and savings for the decades up to 2050.

As the generation make-up of the grid changes over the next few years and the proportion of renewable energy increases it is expected that the variability of carbon intensity on both an intra- and inter-basis will become more pronounced necessitating the need for more complex carbon accounting methods and a move away from the static values currently employed. This will be particularly true if the benefit of energy storage and demand side response is to be recognised.

There are further issues for energy generation and use that are not accounted for by the accounting of costs or CO_2 emissions, for example air quality issues, geographic location or the impact on peak demand or system balancing. While these are not considered here, it is felt that these are important and should form part of any new methodology.

This paper sets out to consider the impact of including a lifetime CO_2 impact, considering a reasonable lifetime over which to estimate CO_2 emissions, and how accounting for the actual intra-year and inter-year variation in CO_2 emission factors may affect the calculations and measures to reduce them. It does not aim to provide a replacement methodology for CO_2 accounting but to consider if one is required and if so, how it could broadly work.

2.0 Methodology

Historical electrical generation data for the period from October 2015 to September 2016 was obtained from the Elexon website (4). This data source is widely used and contains information about actual generation across this period, differentiated by its source. This website however does not account for generation from solar farms connected at a distribution level, which is seen on the network effectively as a reduction in demand, rather than generation in its own right. Therefore this information was supplemented with half-hourly data from the National Grid which provides estimates of the generation from solar over this period (5).

Once this data was combined, emissions factors associated with each kind of generation type were applied for every half-hourly time period. The factors used are shown in the table below, (hereafter ‘real time’). This was compared against the static CO_2 emission factors in SAP 2012 9.92 (used for Building Regulations).

Fuel Type	CO_2 (gCO_2/kWh)
Combined cycle gas turbine	360
Open cycle gas turbine	480
Coal	910
Nuclear	0
Wind	0
Pumped storage	0
Non-pumped storage hydro	0
Other	300
Oil	610
French Interconnector	90
Irish Interconnector	450
Dutch Interconnector	550
East-West Interconnector	450

Table 1 Emission factors by generation mode (6)

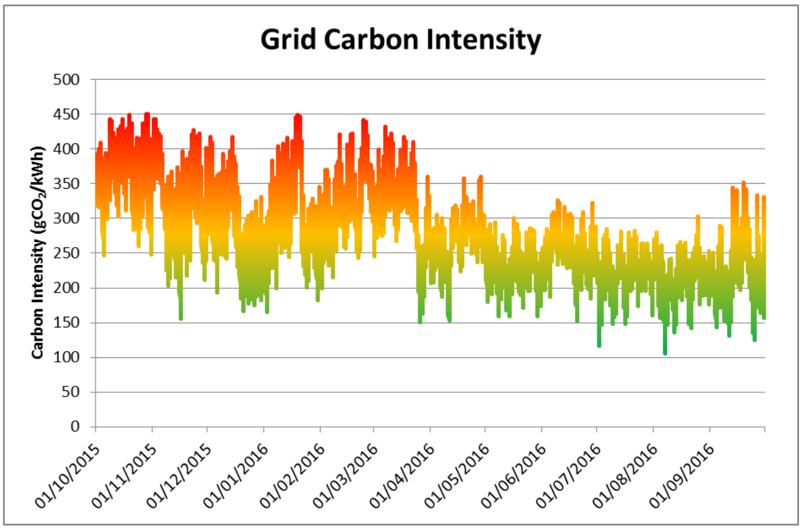

Figure 2 Grid carbon intensity variance (October 2015 to September 2016)

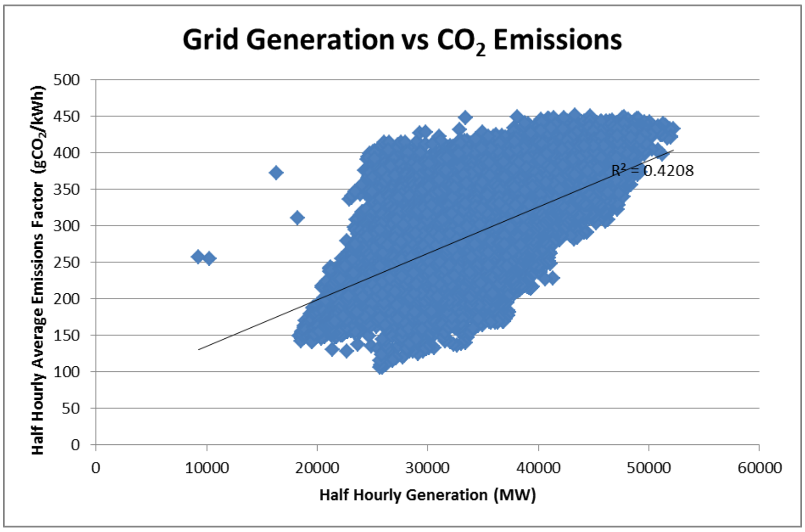

Figure 3 CO_2 intensity plotted against generation (Oct. 2015 to Sept. 2016)

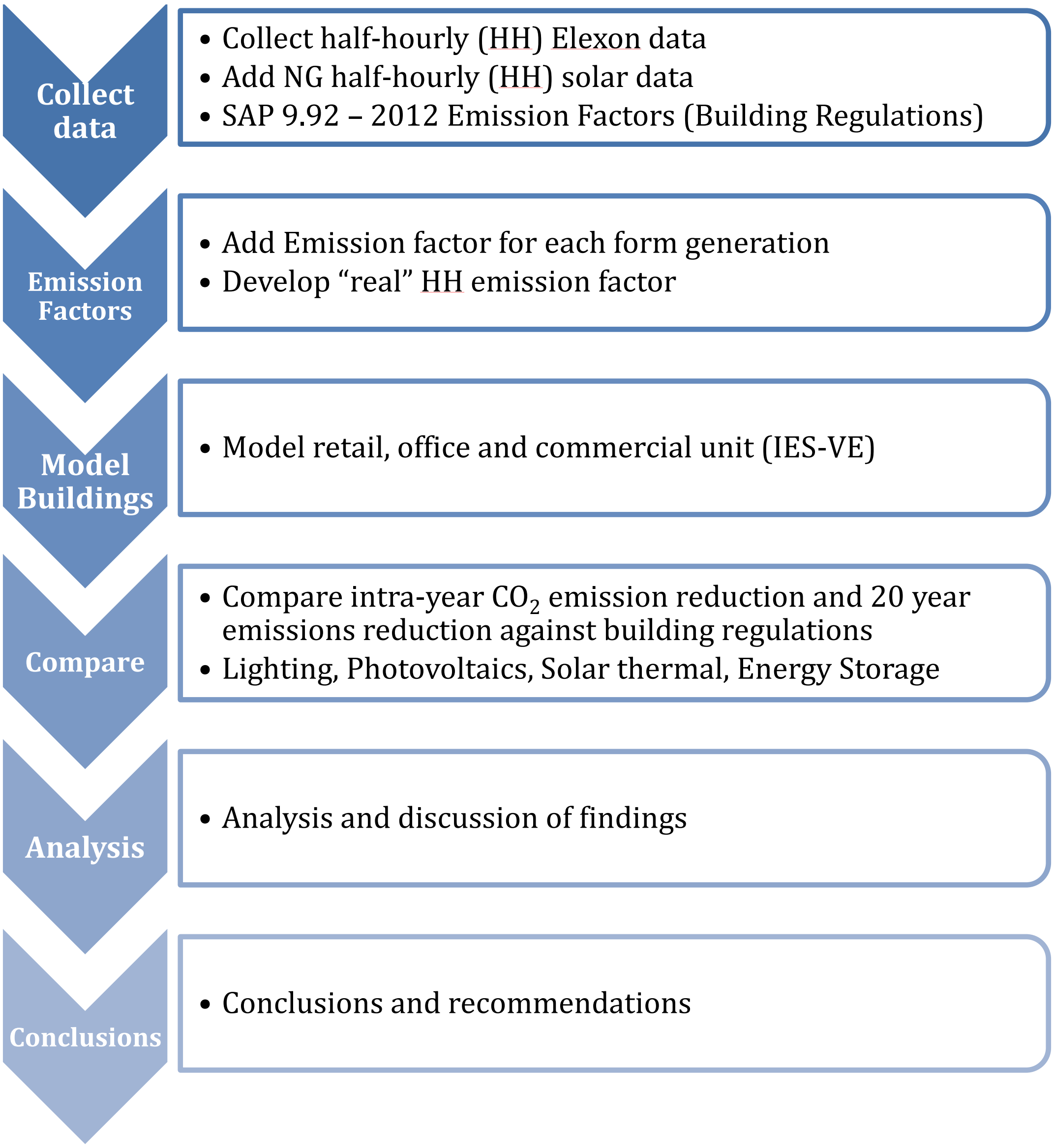

Figure 4 Research Methodology

3.0 Modelling

To analyse how the impact of accounting for variations in CO_2 emissions over a year and over the lifetime of a project comprising three buildings was modelled we used Integrated Environmental Solutions – Virtual Environment (IES-VE) dynamic simulation modelling (DSM). This software is used to model the energy/CO_2 emissions performance of new and existing buildings as part of demonstrating Building Regulations Part L compliance and generating energy performance certificates (EPCs). These models would form a baseline against which several measures to reduce CO_2 emissions could then be applied.

The buildings were modelled in Leicester, UK; the broad details are laid out below. The units' characteristics were chosen to be simple, representative of their type and to have characteristics that would make it possible to extrapolate the results reasonably, although they may vary depending on size and type, usage patterns.

Unit	Details
Retail	500m^2 GIA All in accordance with National Calculation Methodology (NCM) – single storey, side lit, gas boilers, electric chillers
Domestic	100m^2 GIA. All in accordance with NCM – double storey (detached), gas boiler, natural ventilation
Commercial	1,000m^2 GIA. All in accordance with NCM – 3 storey, side lit, heat pump heating/cooling, mechanically ventilated

Table 2 Units Modelled

The hourly energy demand data was then extracted and analysed in MS Excel to understand the baseline demand profile. A number of measures were then modelled in IES-VE and MS Excel to consider the impact and relative merits of each technology with regards to the carbon emissions/savings using the static method and using an hourly analysis. These included:

- The inclusion of roof-mounted photovoltaics
- The inclusion of roof-mounted solar hot water
- Energy storage (Li-ion battery) – charging at 03:30 (when carbon intensity is typically lowest) and discharging at 17:30 (when demand /carbon intensity of the grid is normally highest)
- Lighting efficiency improvements (high-efficiency LED lighting)

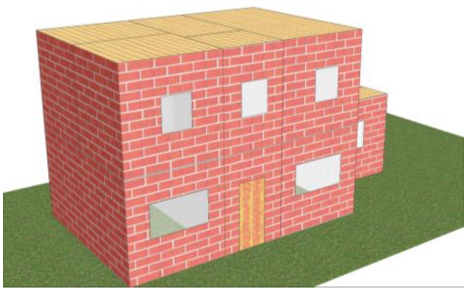

Figure 5 IES model domestic visualisation

4.0 Analysis

When considering the actual generation modes of the grid for every half-hour period between October 2015 and September 2016, the weighted average carbon intensity was found to be 290g CO_2/kWh, when distribution losses are accounted for (typically 7%), this rises to 312g CO_2/kWh. (Note: This is not directly comparable to the value of 519g CO_2/kWh used in Part L of the building regulations which uses a different, retrospective methodology).

During this period the lowest carbon intensity was found to be 107g CO_2/kWh (or 115 when accounting for distribution losses). These low periods generally occurred during the early morning, when demand was at its minimum. The greatest was 451g CO_2/kWh (or 485g CO_2/kWh when counting for distribution losses). The graphs below illustrate some of these points.

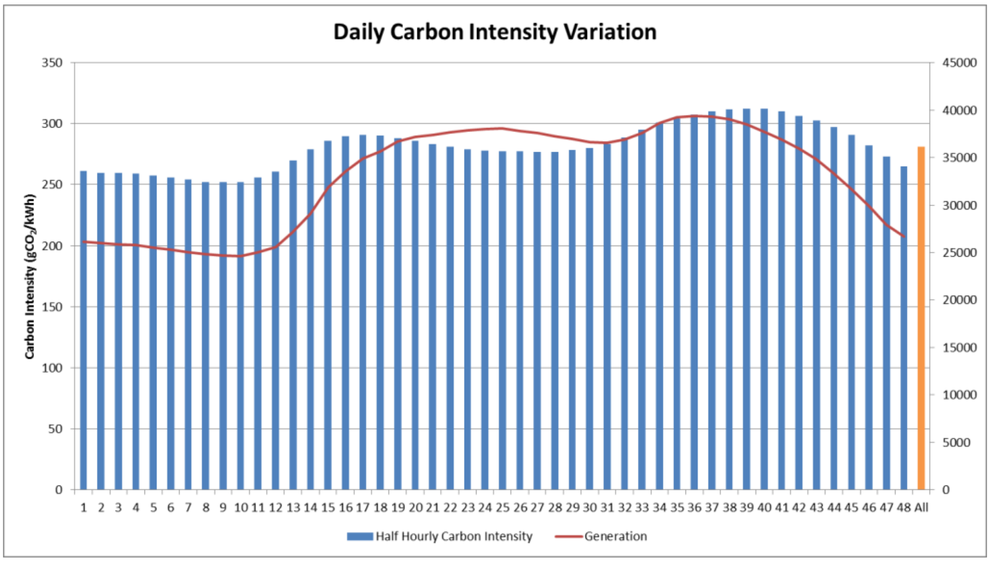

Figure 6 Average HH Daily carbon intensity and generation

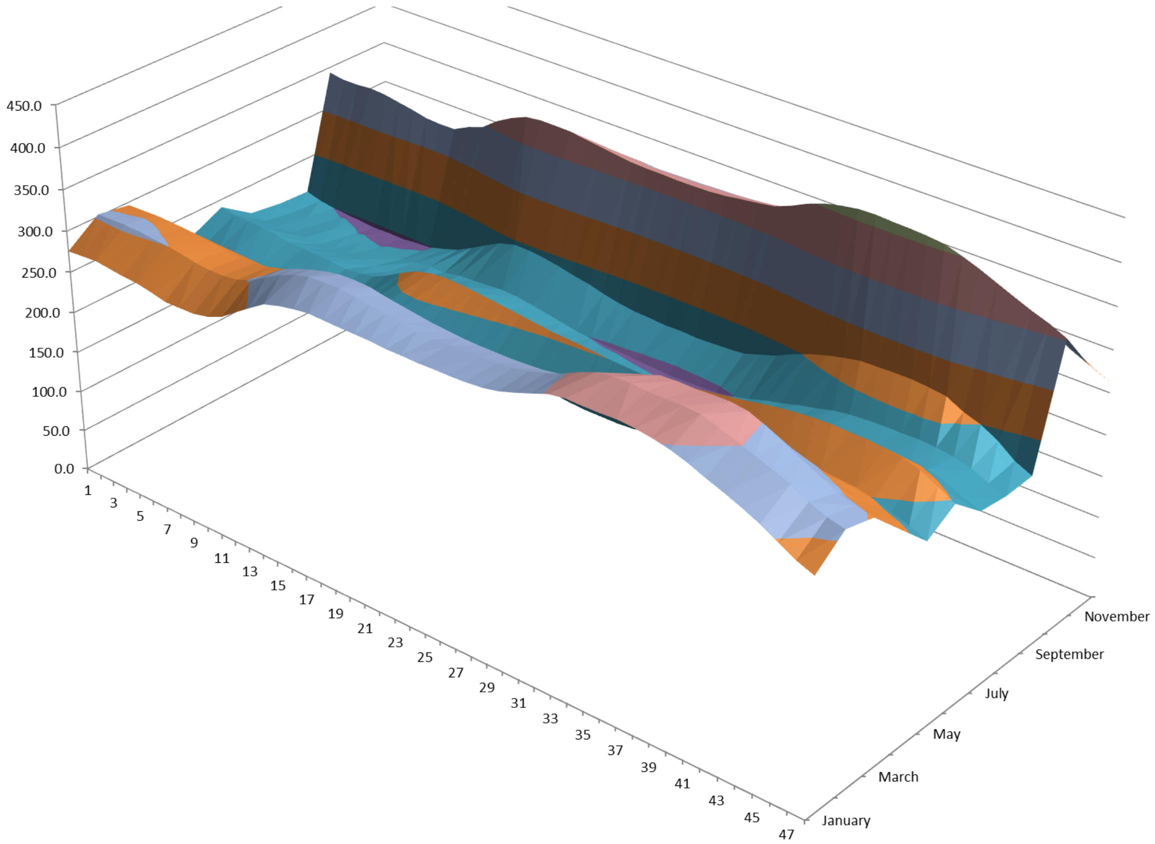

Figure 7 Daily carbon intensity fluctuations by month (3D)

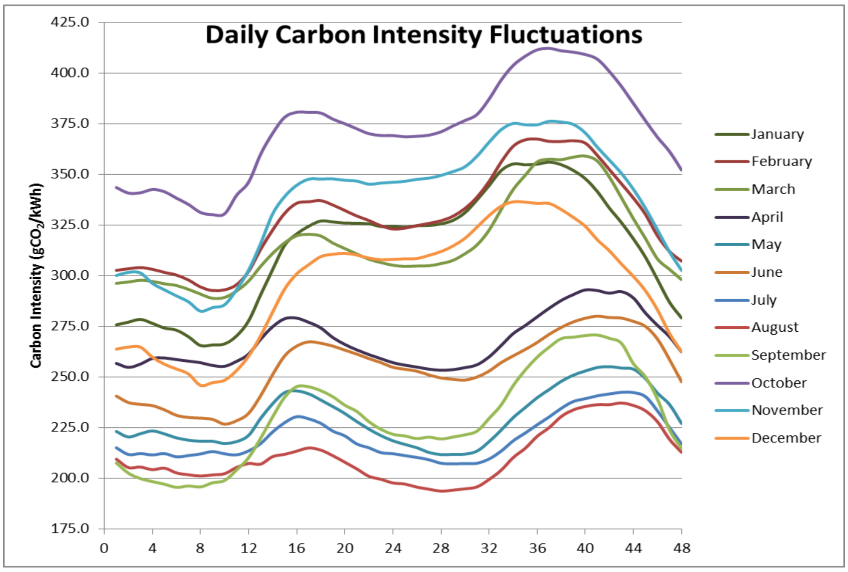

Figure 8 Daily carbon intensity fluctuations by month

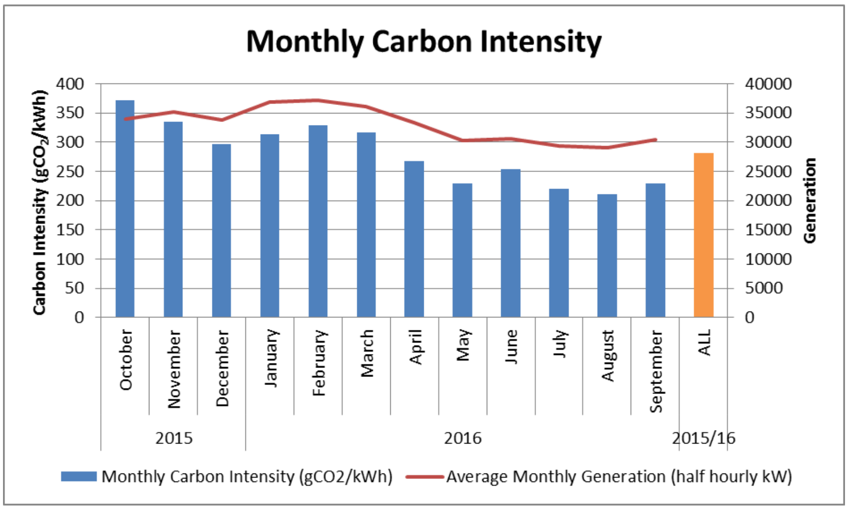

Figure 9 Comparison of monthly generation and average carbon intensity

The results from the IES-VE and MS Excel modelling are shown below showing how using a variable CO_2 emission factor based on the Elexon data would alter the results.

4.1 Retail Analysis

Measures	Real time CO_2 intensity of saving (gCO_2/kWh)	
	Electrical	Gas
Baseline (grid average from Elexon)	290	216
Lighting (1MWh electrical demand reduction)	280	N/A
Solar PV (1MWh electrical generation)	251	N/A
Solar Thermal (1MWh gas demand reduction)	N/A	216
Battery (85% effic. 1MWh demand shifting)	13	N/A

Table 3 Carbon savings comparison – Retail

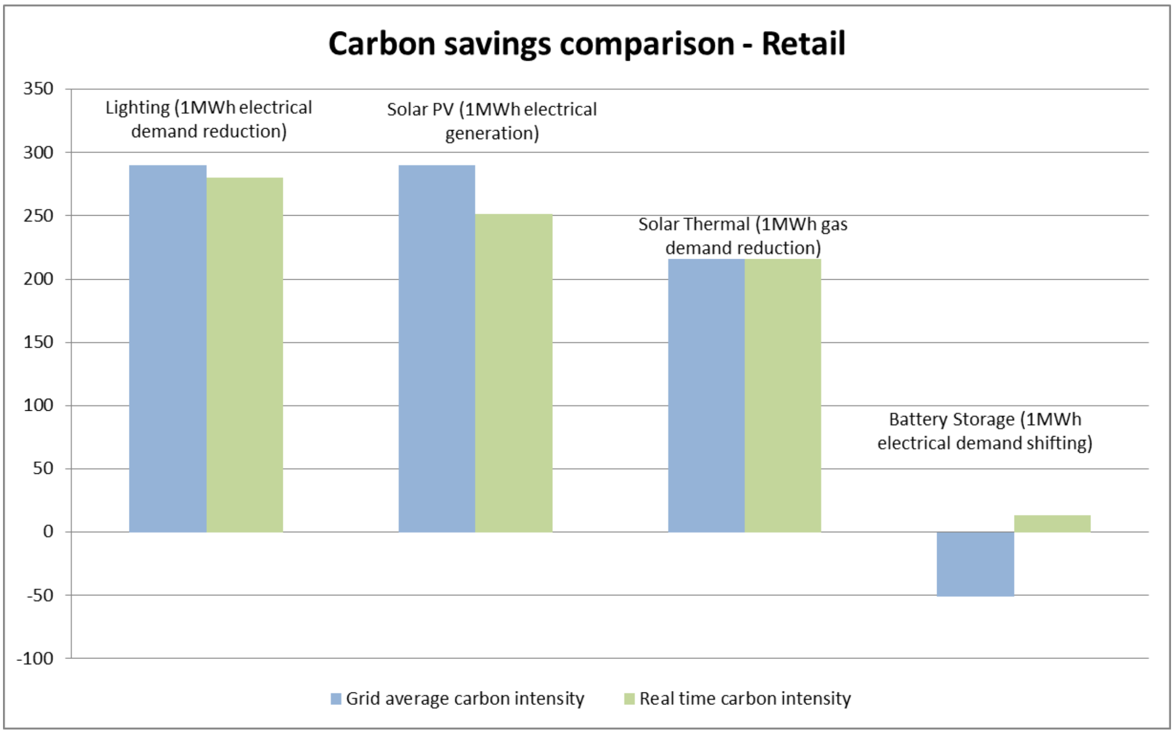

Figure 10 Carbon savings comparison – Retail

The results for the retail model show the variance in the CO_2 emissions savings depending on the method utilised. The traditional method would use a static factor for each of these technologies and would therefore not differentiate between them in terms of carbon savings, and would show a battery as an increase in CO_2 emissions.

The NCM (national calculation methodology) profile for this use type is for lighting use to occur mainly during the day and use at some time during the evening; due to its nature, lighting would be required more or less continually during a store's opening hours. As the store opens at 9am and closes at around 6pm, it misses much of the high carbon intensity period in the morning and evening. Similarly the rooftop solar displaces mainly low-carbon electricity in the middle of the day so its effectiveness is lower than the grid average value.

As no energy storage device is 100% efficient, using a static factor will mean its use will always show an increase in CO_2 emissions. Despite a roundtrip efficiency of 85% used in the modelling, the battery system is able to reduce CO_2 emissions. Being charged at night and being used during the peak carbon intensity period can provide effective savings.

4.2 Residential Analysis

Measures	**Real-time carbon intensity of saving (gCO_2/kWh)**	
	Electrical	Gas
Baseline (grid average from Elexon)	290	216
Lighting (500kWh demand reduction)	295	N/A
Solar PV (500kWh generation)	260	N/A
Solar Thermal (500kWh gas demand reduction)	N/A	216
Battery (85% effic. 0.5MWh demand shifting)	13	N/A

Table 4 CO_2 emissions savings comparison – Residential

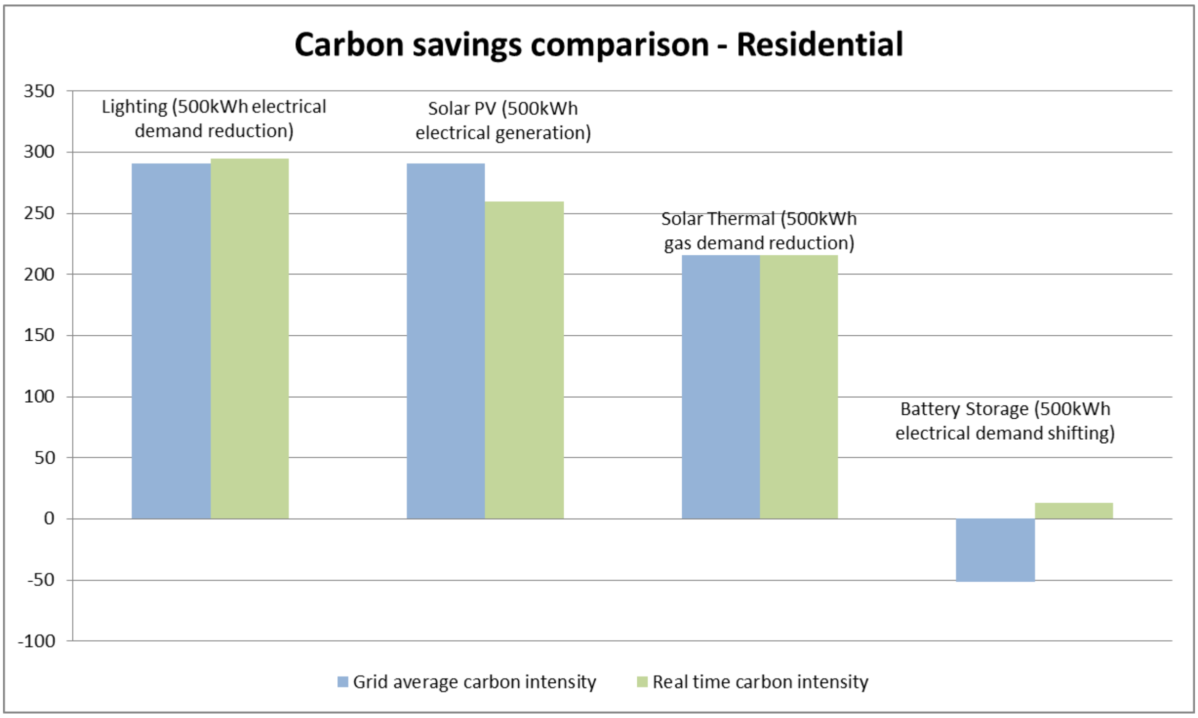

Figure 11 Carbon savings comparison – Residential

The results for the residential model broadly match the retail unit but the housing unit is assumed to be occupied in the evenings, therefore a reduction in the lighting load from LEDs has provided a higher CO_2 emissions saving than solar PV and even the grid average. The CO_2 emissions saving due to the Solar PV is also higher than the retail example.

As would be expected the effect of solar thermal technologies and demand shifting via battery storage is the same as in the retail example.

4.3 Office Analysis

Measures	**Real-time carbon intensity of saving (gCO_2/kWh)**	
	Electrical	Gas
Baseline (grid average from Elexon)	290	216
Lighting (1MWh demand reduction)	239	N/A
Solar PV (1MWh generation)	262	N/A
Battery (85% effic. 1MWh demand shifting)	13	N/A

Table 5 CO_2 emissions savings comparison – Office

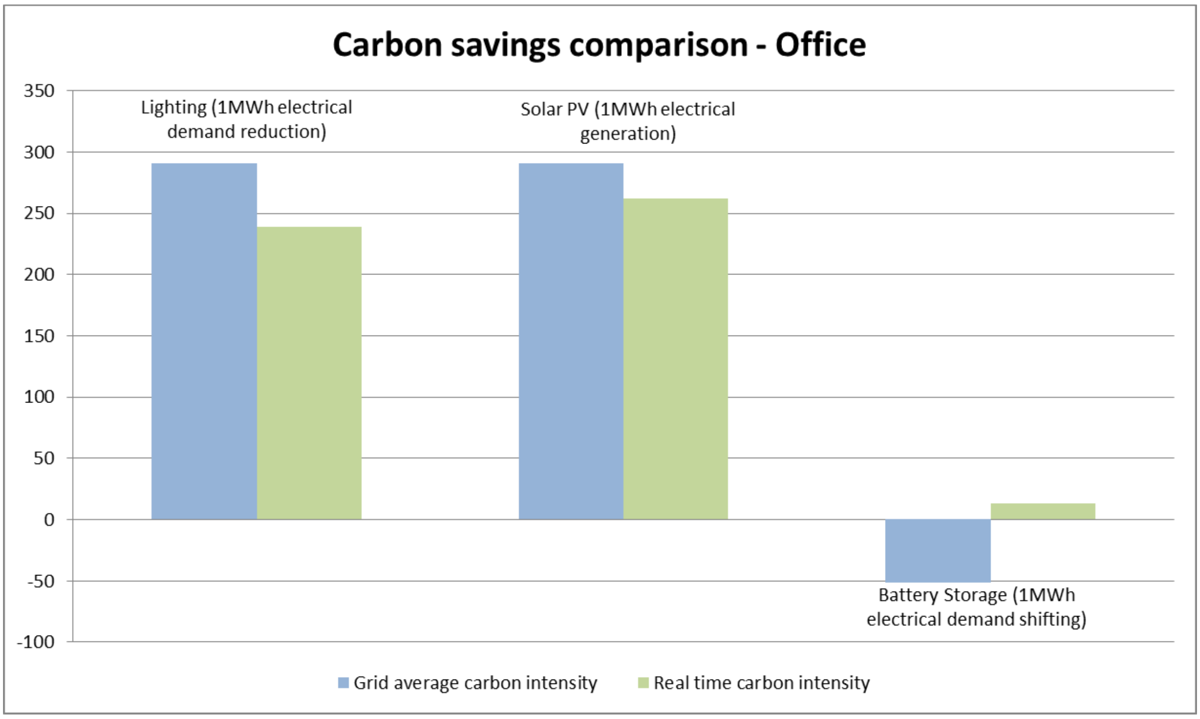

Figure 12 Carbon savings comparison – Office

The standard profiles used for say, offices assume occupancy mainly between the hours of 9am to 5pm (with reduced occupancy between 7am and 9am and between 5pm and 7pm and also during the middle of the day at lunch time).

This indicates that for lighting, this use type presents a worse option in terms of carbon saving than the previous two examples, as there is reduced lighting consumption during the hours of 5pm-7pm and none in the evening. Therefore there are smaller savings made during the time of day when we would expect more carbon intensive generation plant to be brought online (4pm-7pm).

4.4 Generation Merit Order

Although these figures look at the carbon intensity of the grid at the time of use, this may not be an accurate reflection of the benefit of the technology. This is because the reduction in energy use displaces energy generation from a particular technology than by the average emissions factor. Therefore it is worthwhile considering the alternative ‘Merit Order’ of electricity generation as another methodology when undertaking this analysis.

The Merit Order is a way of ranking electricity generation by order of preference. Generating plant which is typically cheapest in terms of short-run marginal costs is preferred to that with higher marginal costs. For example, natural gas has a lower marginal cost for generation compared to an oil-fired station (due to fuel costs), therefore simplistically a CCGT would be a preferred form of generation traditionally.

In addition, other considerations can be taken into account, such as plant which can be easily turned down or switched-off against that which cannot. For this reason nuclear and to a large extent coal-fired stations have been traditionally used to provide a base load, while oil and gas can have their output modulated far more easily and are therefore used as peaking plant.

The exact order of these can be debated (and is complicated by the use of interconnectors). For the purpose of this analysis the merit order is assumed as per the table below; interconnectors are not considered in this analysis but recent analysis from Ofgem suggests that the use of gas has reduced in recent years due to rising fuel costs, while the use of interconnectors has risen as these have become comparatively cheaper.

Oil (least preferred)
OCGT
CCGT
Coal
Nuclear
Renewables (most preferred)

Figure 13 UK assumed merit order (ignoring interconnectors) (10) (11)

In reality, oil and OCGT power stations are rarely used to generate electricity regularly in the UK. Therefore, the majority of electricity reduction methods serve only to reduce the use of CCGT power stations, which are in fact less carbon intensive than coal (360 gCO_2/kWh against 910 gCO_2/kWh). Therefore in the short term the reduction in electricity use displaces generation from CCGT power plant. As the grid average over this period (a weighted average of 290 gCO_2/kWh) was lower than the carbon intensity from CCGTs, this has a larger effect than simply considering the average or even the generation make-up during each half-hourly period.

Measures	CO_2 intensity saving (gCO_2/kWh) - real time	CO_2 intensity saving (gCO_2/kWh) - Merit Order
Lighting (1MWh electrical reduction)	280	365
Solar PV (1MWh electrical generation)	251	364
Battery Storage (1MWh electrical demand shifting)	13	-58

Table 6 Carbon savings comparison considering merit order - Retail

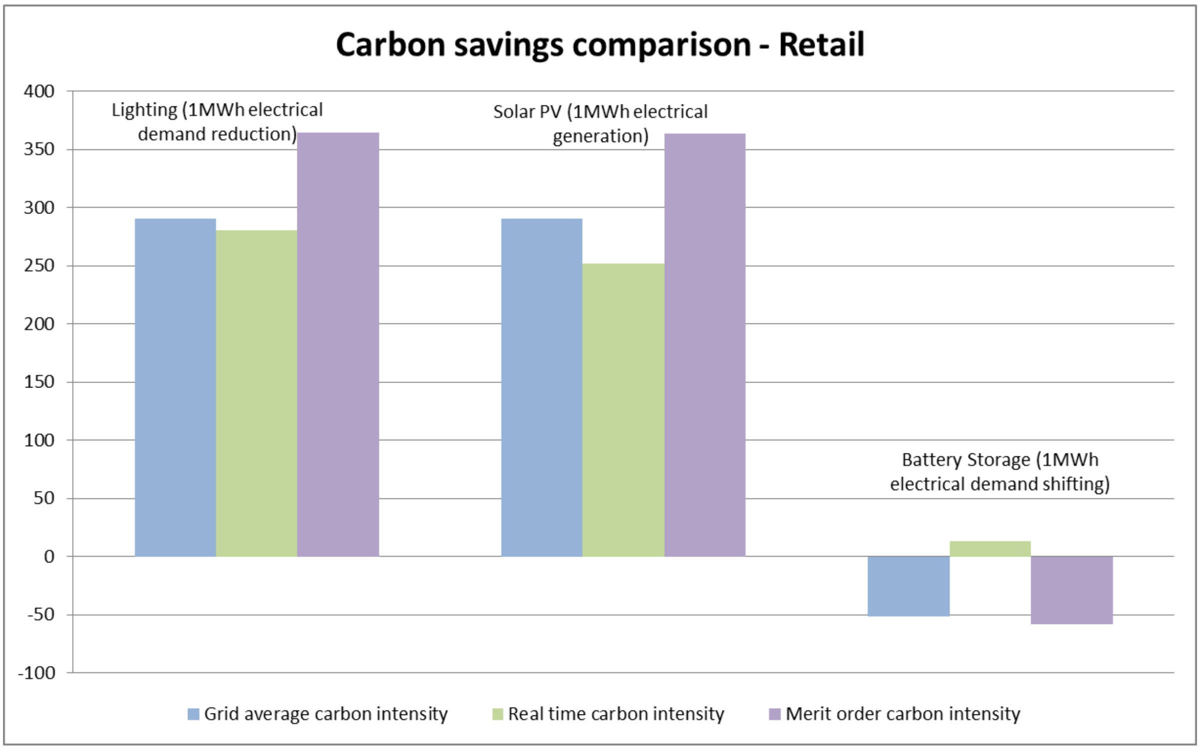

Figure 14 Carbon savings comparison considering merit order - Retail

The alternative methodology using the merit order shows an increase in the carbon savings due to Solar PV. This is because this displaced CCGT generation at 360 gCO_2/kWh has a higher carbon intensity than the previously-calculated grid average of 290 gCO_2/kWh. For similar reasons the savings from efficient lighting are also increased using this alternative methodology.

Battery storage now no longer shows a saving. There is still a saving made by charging the battery during periods of low demand and discharging during high demand, however the difference is reduced significantly. During both of these periods this methodology suggests that the battery is typically displacing CCGT power stations. Therefore the savings made are outweighed by additional energy use due to battery efficiency. This may be a limitation of the merit order methodology; energy storage is accepted and promoted by the National Grid as crucial in the decarbonisation of electricity as well as to balance the grid and reduce peak generation costs. This does not appear under the merit order methodology due to the fact that it is an instantaneous analysis rather than considering the long-term impact.

4.5 Lifetime Analysis (Long Run Marginal)

The GHG emission factors published by the UK government for the use of corporate reporting are updated each year (3). In addition, the UK Government Interdepartmental Analysts Group (IAG) has long run emission (LRM) factors that should be used for the impact of measures over years. The GHG emission factors DEFRA GHG and IAG LRM (7) projected for the next twenty years are shown below. (Again the methodologies for calculating these figures are different and therefore the absolute numbers are not directly comparable.)

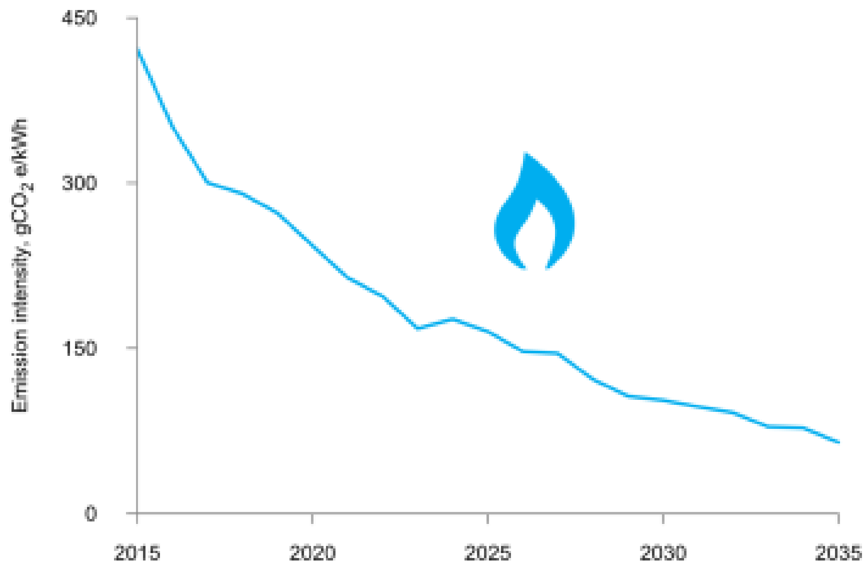

Figure 15 GHG Electrical CO_2 emissions intensity projections (8)

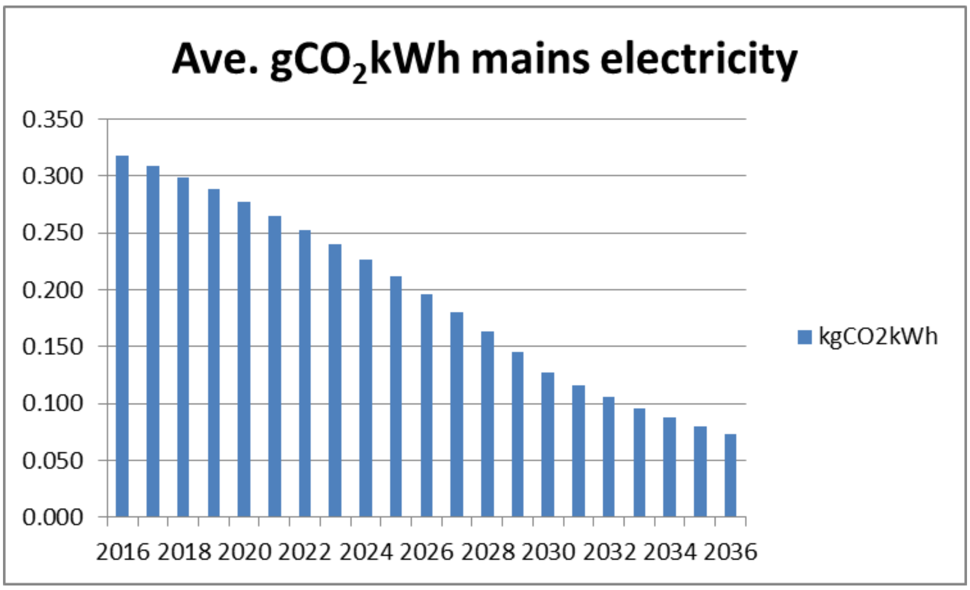

Figure 16 UK IAG Long Run Marginal Emission Factor (Commercial)

What the graphs indicate is that calculations on savings due to electricity conservation/generation will see diminishing benefits over the long term due to the reduced CO_2 intensity of grid electricity.

This method does not take into account the hourly fluctuations in CO_2 intensity and therefore all of the electrical forms of energy savings described earlier will display the same results. A 20-year period has been considered as this represents a reasonable average on the useful life of the equipment being considered. The results are shown in the table below.

Unit	Total 20-year emissions savings ($kgCO_2$) - 2016 static	Total 20-year emissions saving ($kgCO_2$) - Annual LRM figure
Retail (1MWh elec. saving)	6,173	3,740
Domestic (500kWh elec. saving)	3,087	1,870
Commercial (1MWh elec. saving)	6,173	3,740

Table 7 Comparing CO_2 emissions savings using LRM for electrical use

The table above shows that for any calculation of CO_2 emissions savings, extrapolating CO_2 emissions factors for a single year shows much greater savings than when using an average factor. When the savings are considered over 20 years (2017-2036), the total calculated emissions represent only 60.6% of the first year emissions multiplied by the 20-year period. The average CO_2 saving (LRM) over this period can be calculated as being only 187 gCO_2/kWh – less than that for gas which is 216 gCO_2/kWh (the switchover point being after year 16). Therefore, when considering savings over a 20-year period, the displacement of gas say, through the use of solar thermal is shown to be more beneficial, even assuming 100%.

4.6 Additional Considerations

Examples of two additional factors identified but not fully considered in this paper but which may be relevant to a ‘whole system’ analysis of energy generation are the issues of air quality and peak plant demand.

Where a measure reduces air pollution by displacing combustion, such as gas or oil-fired boilers, there is a benefit to local air quality which can be quantified. (However a reduction in local air pollution may mean an increase in air pollution elsewhere.) For example, the use of CHP (combined heat and power) engines increases NO_x emissions compared to gas boilers or heat pumps. This is not accounted for in the analysis. The latest guidance from Defra puts the damage costs of NO_x by domestic sources as being £14,646 per tonne of emission change (12).

It is likely that measures such as high-efficiency lighting will have an impact as they are reducing demand during the period of peak demand (typically 5.30pm on a weekday in the winter). In contrast PVs will not be generating during this period and regardless of their level of deployment they will not reduce peak demand. This is important because peak generation is generally expensive as it is required for only a small amount of time and therefore there is a substantial cost to pay for it to be there when required. Again, this has not been accounted for in this analysis.

4.7 Limitations

There are several limitations and issues which are acknowledged in this analysis:

- There are interactive effects on some of the measures, for example increasing lighting efficiency will also have the effect of increasing heating demand and, if relevant, reducing cooling demand.
- The extent of the daily variation is likely to change and a more detailed analysis may wish to consider that. For example, if solar PV deployment continues the emission factor in the middle of the day during summer may become even lower relative to the average. Alternatively, more wind deployment, which generates more in winter than summer may begin to reduce the difference between winter and summer emission factors.
- This paper has only considered a small number of scenarios in a single location and therefore further work would be required to consider the effects on an expanded number of unit types and locations.
- While a number of different calculation methodologies have been explored, no attempt has been made to combine these and therefore interrelated effects are not considered.
- A 20-year life for the equipment has been considered, but it is acknowledged that this could vary significantly for different measures.

5.0 Conclusions and Recommendations

The purpose of this paper is to consider a more robust approach to the accounting of carbon emissions for buildings. It aims to demonstrate the benefits and complexity of this approach.

The pace of change in the energy generation industry has led to a discrepancy between the CO_2 emissions factors used for building-level calculations and what has been experienced over the 12-month period analysed as part of this work. By considering the CO_2 emissions intensity for every (half) hourly period over the year it is possible to consider differences and comparative benefits between various forms of energy generation and efficiency measures.

This methodology indicates that generation or demand reduction can have varying benefits depending on the profile during the day, inter-seasonally and even inter-annually. Therefore technologies need to be considered in the context of their application (e.g. residential, retail, office etc.) in order to better project CO_2 emissions savings.

The results show that when considering the merit order effect, savings from lighting and solar PV show increases compared to the grid average method. Energy storage however, while displaying savings when considering the real time method, does not if using the merit order method.

When considering building-level energy savings over an extended period (i.e. 20 years) the long term decarbonisation of the grid suggests that measures which reduce gas consumption may be more beneficial than electricity reduction.

While not considered in detail, measures which reduce other external costs to society (such as on air quality, peak demand reduction or system balancing costs) should also be preferred.

The use of static factors for all forms of energy saving/generation oversimplifies the relative merits of technologies and leads to decision making based on flawed data. When considering the CO_2 emissions of a building over its lifetime, static factors do not accurately mirror government's own projections on the decarbonisation of the grid. While these simple calculations have their benefits, they are no longer adequate as an accurate representation of the new and emerging energy network.

Issues such as CO_2 emission factors, when the energy is demanded / used, intermittency of energy generation, 'in-use' factors, (how well a system performs in reality compared to theory) and trying to account for other important issues, such as air quality is not easy and not easy to explain; it is however absolutely crucial that they are as accurate as they can be. If we get them wrong it will be our environment and economy that suffers. If we do it well the benefits are substantial: fewer negative climate change impacts, better air quality, less environmental damage, greater comfort, greater energy efficiency and lower bills for people and companies.

In line with this, it is recommended that moves are made to incorporate intra- and inter-year emissions factor changes in methodologies for calculating CO_2 emissions. In addition, further work quantifying the impact on items such as air quality, location, system balancing and peak generation capacity should also be considered. This could potentially lead the move away from 'neutral' energy markets to one where certain technologies are more beneficial than others under different circumstances.

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