# Reducing GHGs from UK Households - An Examination of Local Authority-Level Data

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**Abstract:** As the threat of irreversible climate change has increased over time, the UK has focused on reducing its carbon emission levels. International treaties such as the Kyoto Protocol have informed national targets, directing the UK in reducing its climate impact. In order to achieve this an understanding of the factors that affect carbon emission reductions is vital. Identifying what dictates the success of UK local authorities in reducing their carbon emissions addresses this problem. The research uses secondary data regarding local authorities' carbon emissions and regression analyses to explore the key factors affecting domestic emission levels over time. The research goes into further detail than existing literature through exploring sources of emissions across different sectors and analysing emissions reductions specifically between 2005-2016. Substantial and relatively consistent domestic emissions reductions were achieved in this time frame, exceeding the reductions provided by decarbonisation of the electricity grid. Standard deviations of 3% were observed in this sector, compared with 12% from Industrial & Commercial emissions. While population density demonstrated a statistically significant correlation with domestic GHG reductions, gross disposable household income was not found to be significant; however, it is a relevant indicator of total emissions levels in 2016. Through identifying these factors, suggestions to local government are made such as the implementation of region-specific strategies, tailoring these to the exact characteristics of a local authority. Furthermore, consideration of population density in conjunction with domestic and urban planning will allow for future emissions reductions to occur across the UK

**Keywords:** Greenhouse Gas Mitigation; Low-carbon Housing; Domestic Sector; United Kingdom; Carbon Strategy; Local Authorities

## 1. Introduction

In order to reduce carbon emission levels, a number of targets have been set at a national and international level. The 1997 Kyoto Protocol, was a major international agreement which focused around globally reducing GHG emissions. Furthermore, in terms of the UK specifically, there are a number of existing targets such as an 80% reduction in emissions by 2050 from 1990 levels [1]. In order to meet these targets an understanding of what dictates UK emissions levels is vital. However, myriad factors can influence emission levels. Some of the key drivers include economic activity, industrial activity and population growth which are further explored within the literature review. Furthermore, in order to reduce emission levels, the entirety of the UK has to effectively perform, which relies on positive action across a huge number of local authorities. Each local authority has varying characteristics which impacts upon the success of emissions reductions. Moreover, different strategies are employed throughout the UK to reduce emission levels. The exploration of which authorities have been successful over time will develop an understanding of what has dictated emissions reductions.

The majority of UK local authority carbon emissions can be attributed to the domestic, transport and industrial/commercial sectors [2]. The Department of Business, Energy and industrial strategy (BEIS) states how domestic emissions in the UK are produced largely by natural gas and electricity consumption. Natural gas contributed to 59% of total end user emissions while electricity emissions amounted to 31% [2]. However domestic electricity emissions levels have reduced over time as the usage of coal has decreased in electricity generation.

This study will explore changes in domestic sector emissions levels in UK local authorities and what has affected their changes. This will involve an exploration of factors that have impacted local authorities' carbon emission reductions between 2005 and 2016.

## 2. Materials and Methods

The sources of data used for this study were primarily from government reports and data sets which are outlined in the table below. One of the main sources of data used for analysis included the "UK local authority and regional carbon dioxide emissions statistics; 2005-2016." The report was provided by the Department for Business, Energy and Industrial Strategy (BEIS) and provides estimates across the domestic, transport and industrial and commercial sectors from 2005-2016 (BEIS, 2018a). The data provided in the report is based upon four main sources: BEIS sub national electricity and gas consumption statistics, emissions distribution maps and land use, land use change and forestry regional data [2]. This report allowed for trend analyses to be completed across a disaggregated data set which considers temporal and spatial elements.

**Table 1.** Sources of data used on the analysis of domestic GHG emissions

| Data Set | Source | Data Used |
|---|---|---|
| UK local authority and regional carbon dioxide emissions statistics; 2005-2016 | [2] | Carbon Emission levels across every local authority in UK from 2005-2016 |
| Government Emission Conversion Factors for greenhouse gas company reporting | [3] | Grid Emissions Factor |
| Population Census Data 2011 | [4] | Population Density |

However, there were limitations to the use of the [2] data source. The technical report accompanying the data sets also produced figures identifying the national and geographical estimated error in each sector. The majority of data sets were found to have an estimated error below 15% in each of these categories (Ricardo Energy and Environment for BEIS, 2018).

Grid intensity data were also explored from reports published by BEIS. Data was collected from numerous years in order to identify how grid emissions intensity has changed. This enabled analysis to be completed in regard to the domestic sector and changes in efficiency of the grid over time. Furthermore, it enabled exploration of whether emissions reductions are attributable to absolute reductions in electricity use or broader reductions in grid emissions intensity.

Further sources were explored to enable analysis in regard to population and population density within local authorities. The office of national statistics (ONS) which also provided this in the form of census data. The Office of National Statistics have the "Guidelines for Measuring Statistical Quality," which ensures the data are reliable and accurate [4]. However, the limitations of census data include the frequency of data collection. This is especially an issue within changing (growing/shrinking) cities such as London where the population is particularly dynamic [5]. Further data collected included gross disposable household income (GDHI) in UK local authorities. This refers to the property income, primary and secondary income and social benefits available to a household after taxes (ONS, 2018).

Regression analysis was completed using Microsoft Excel version 16.16.6. This allowed for analysis of $CO_2$ emission reductions and potential emissions drivers through identifying the statistical significance of variables (p values) which outlined whether the relationships found are down to chance or whether the event is likely to occur again. A confidence interval was chosen of 95% ($p$ value $< 0.05$) to identify correlation between variables that is statistically significant.

## 3. Results

Examining domestic emissions reductions in UK local authorities, the North West region showed the greatest emissions reduction of 35%. All regions (except Northern Ireland) across the UK showed average emissions reductions across local authorities between 30-36%. The only region to not show this level of reductions was Northern Ireland which only achieved an average of 23% domestic emissions reduction in its local authorities.

**Table 2.** Emission levels and reductions across major UK region Local Authorities[1], Population[2], Average[3], Standard Deviation[4]

| Region | # of LAs[1] | Pop[2] (000's) | Total Emissions 2016 ($ktCO_2$) | Emissions Reductions 2005-2016 | Avg[3] total Emissions across local authorities in 2016 ($ktCO_2$) | Std Dev[4] of 2016 total emissions across UK | 2016 Sectoral Emission across LAs ($ktCO2_2$) with average changes between 2005-2016 in parentheses | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Industrial & Commercial | Domestic | Transport |
| England | 329 | 55288 | 292249 | 30.7% | 894 | 537 | 107,653 (-41.6%) | 84,285 (-32.9%) | 106,528 (-7.3%) |
| Wales | 22 | 3313 | 24,866 | 24.5% | 1130 | 1432.89 | 14,054.6 (-38.8%) | 5,178.1 (-34.0%) | 6,387.6 (-3.6%) |
| Scotland | 32 | 5405 | 25,196 | 39.3% | 787 | 848.799 | 13,280.9 (-36.6%) | 9,322.8 (-35.3%) | 10,872.2 (-3.4%) |
| N. Ireland | 11 | 1862 | 12,427 | 22.8% | 1130 | 338.917 | 4,680 (-34.3%) | 3,413.3 (-22.7%) | 4135.2 (-8.2%) |

0-10% 10- 20% 20-30% -40% % - blue

Standard deviation across emissions reductions across the UK were assessed, with domestic (3.2%) and transport (6.0%) sectors demonstrating a relatively small variation in emissions reduction levels between local authorities. This may be due to developments in both sectors which has influenced the entirety of the UK emissions-producing technology stock, such as advancements in modern vehicles and increased efficiency of the electricity grid. Conversely, a value of 11.5% was observed in the Industrial and Commercial sector, which suggests a higher level of variation in emissions reduction across UK local authorities.

A rank-order plot presenting the domestic emissions reductions achieved by each local authority across the UK is presented in Figure 1. On average, per capita domestic emissions were reduced by 32.5% across all local authorities; a number of the most successful authorities were located in Greater London, though substantial decreases in emissions across all authorities, as suggested by the mean and standard deviation (Table 2).

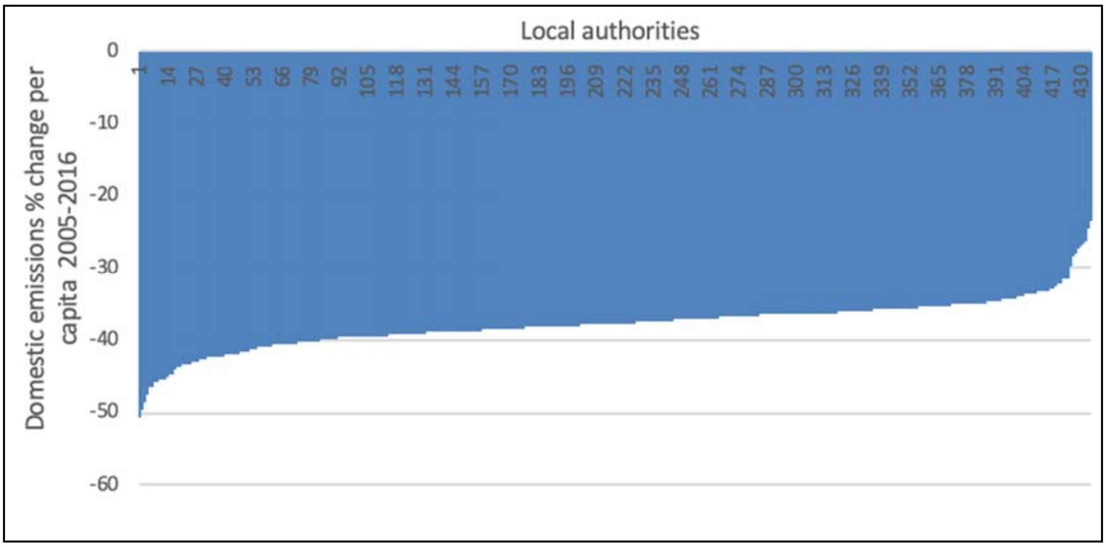


**Figure 1.** Rank-order plot of local for percentage domestic emissions reductions, ranked by per capita emissions reductions achieved 2005-2016

The regression analysis completed in Figure 2 shows the relationship between population density and domestic emissions reduction per capita from 2005-2016. As shown in the graph there is a relationship between the two variables; high population density areas are found to be slightly more successful in reducing domestic emissions than the less dense authorities. The coefficient of determination ($R^2$ value) produced suggests that the model predicted 27% of the domestic emissions reductions, however the p value (6.04E-31) suggests a strong correlation between the two variables.

The anomaly shown is Kensington and Chelsea, which showed the lowest level of domestic emissions reduction across the entirety of the UK. As one of the densest authorities in the UK, it is somewhat surprising that it was the least successful across the country in reducing its domestic emissions levels. There is a high level of unoccupied housing within the borough which may impact the emission levels per capita; a large quantity of the most expensive housing in the borough is identified as "second homes" for very affluent people who are therefore not likely to be considered at the time the census data is collected [6]. According to 2016 statistics, 1.6% of houses are vacant in Kensington and Chelsea, nearly double the national average of 0.9% [7].

Figure 3 highlights the domestic electricity emissions change from 2005-2016 from across the UK, with the orange line highlighting the reduction in emissions intensity of the grid. This is to say that 14% emissions reductions were due to the changes in the grid intensity which would be influenced by schemes such as feed in tariffs. The remaining difference across local authorities can be attributed to other factors such as the retrofitting of housing, change of fuel use, improved efficiency of lighting etc.

and changes in consumption. However, this demonstrates substantial progress in electricity related GHG emissions, which greatly exceeds the upstream impacts of grid decarbonsation [8].

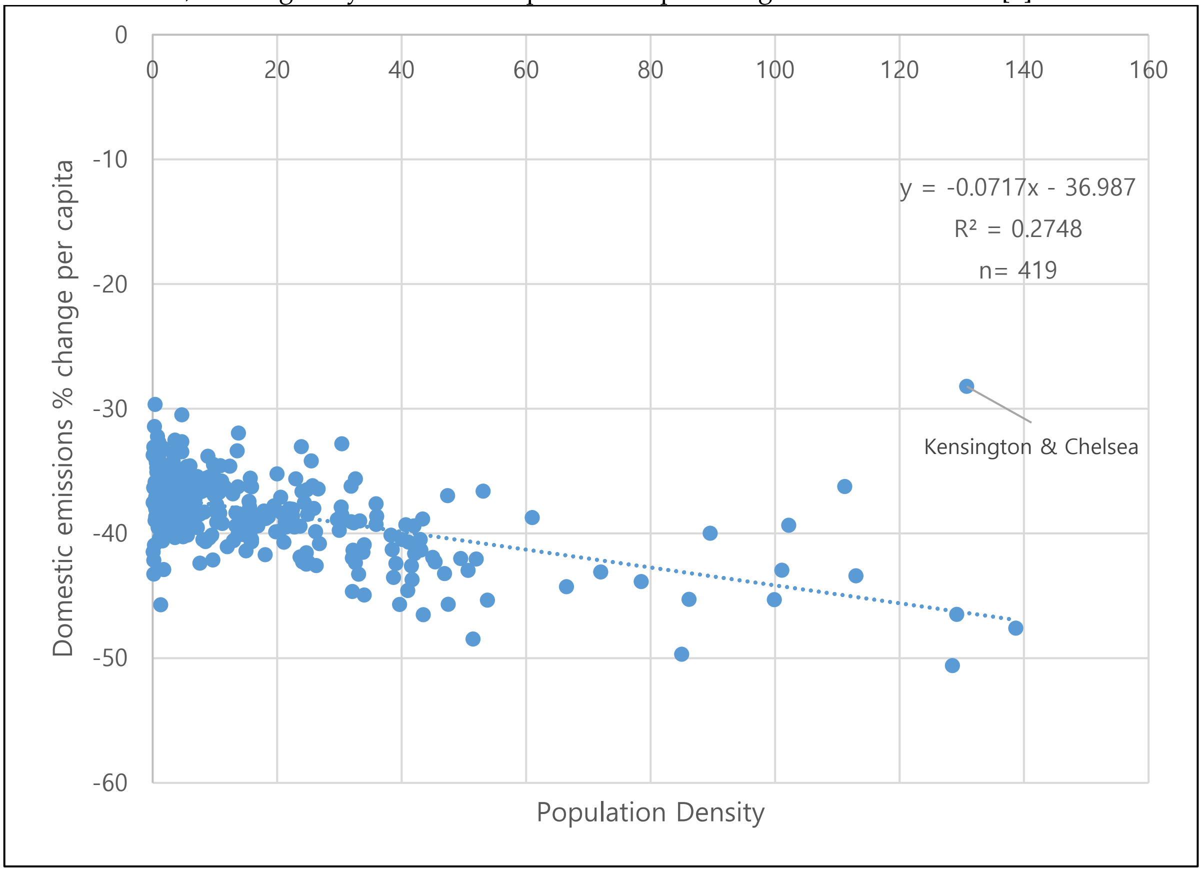


**Figure 2.** Domestic Emissions % change per capita vs Population Density, 2005-2016

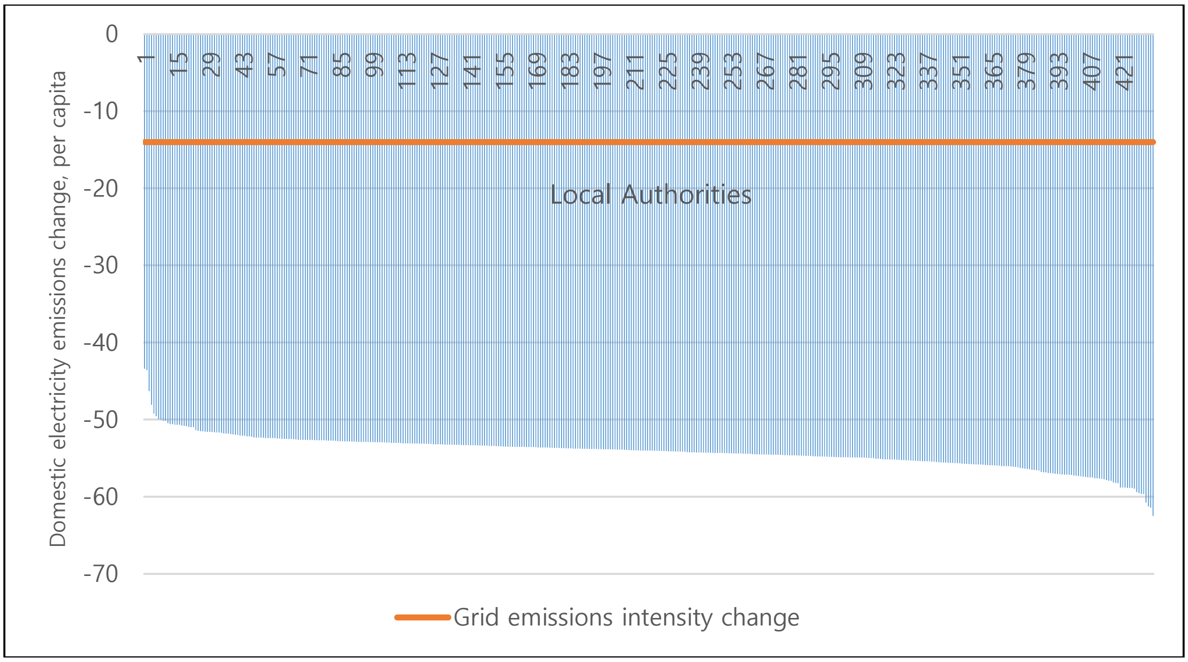


**Figure 3.** Percent change in per capita domestic electricity emissions, compared with change in electricity grid emissions intensity

## 4. Discussion

The analysis of domestic emission reductions and population density highlighted a clear relationship between the variables. Generally, local authorities with higher population densities achieved larger reductions in domestic emissions. The differences in domestic emissions reductions can be explained to some extent by the variability of household sizes in low density areas. As highlighted by Baiocchi and colleagues, settlements in denser authorities will often have similar size and structure which contributes to similarly high levels of reductions [9].

As highlighted there are clearly potential benefits of an increase in an authority's population density as shown previously within literature [9,10]. However, this requires monitoring as there are potential limitations to this, as some of the denser authorities which showed success in transport and domestic emissions reductions were found in London. This can be attributed to the quantity and integration of mitigation strategies. For example, a large majority of local authorities in London have their own plans and policies to reduce emissions levels. Further, "The London Plan" has been implemented, which outlines the strategy for all new domestic structures to be zero carbon from 2016 onwards [11]. Urban areas such as London are often required to report on climate change and produce strategic reports and documents. As a result, large urban areas may be more likely to be more proactive in reducing emissions levels in comparison to more rural authorities which have lower population densities.

The grid intensity is a further factor explored regarding the reduction of emissions within the UK. Table 2 and the domestic reductions rank plot show the UKs' major regions attaining fairly similar emissions reductions from 2005-2016. All regions achieved a reduction in domestic emissions between 30-36% except for Northern Ireland (-22.7%). The similar reductions in domestic emission levels suggests effective changes occurred in this sector across the entirety of the country. One significant change that occurred across the UK from 2005-2016 included the reduction in emissions intensity of the grid. As presented within the graph showing domestic electricity emissions change, the grid intensity reduced by approximately 14% from 2005-2016. As the grid has become more efficient domestic electricity emissions have consequently reduced.

As highlighted by Turk and other, the change from coal to other efficient fuel sources has resulted in decarbonisation of the grid and significant overall emissions reductions [12]. There is clear suggestion within literature of a reduced demand for coal-fired generation and more of a focus towards natural gas. Other key factors such as an increase in renewable energy as well as increased efficiency in technology have also resulted in domestic emissions reductions. In order to further reduce domestic emissions, coal should continue to be discouraged in its use for electricity production. Furthermore, renewable energy schemes should continue to be promoted and utilised as an alternative source of power. This can be achieved through increased funding being made available to local authorities as well as promotion of schemes by the government through incentives such as feed in tariffs.

## 5. Conclusion

The UK has seen significant success in reducing GHG emissions from all sectors, including the domestic sector where a 30% decline has been observed on average across all local authorities. While previous studies have suggested that much decarbonisation could be attributed to out-of-boundary activities (e.g., lower-carbon electricity grid), local authorities have demonstrated substantial GHG reductions within their borders. Population density and related factors seem to facilitate this, and local authorities need to consider barriers to deeper reductions in the absence of sufficient density.

**Conflicts of Interest:** The authors declare no conflict of interest.

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