Centre for Alternative Technology
Canolfan y Dechnoleg Amgen

MSc Sustainability and Behaviour Change

The role of localised consumption-based emissions data in formulating emissions reduction policy for Stockport Metropolitan Borough Council

Richard Baker, MSc Dissertation

Lay Summary

It is now well-established that richer people are responsible for more greenhouse gas emissions than poorer people. This study found that households in Stockport are responsible for an extra 727 kg of emissions for every £1,000 of additional income. Emissions from domestic heating are the highest single category and also increase with household income.

Stockport Council declared a Climate Emergency in 2019 and have committed to net-zero for the Borough by 2038 through reducing emissions at 13% per year. The current policy in relation to domestic fuel use was found to focus almost exclusively on supporting poorer households which, whilst worthy, does nothing to reduce the much greater emissions from more affluent households.

This dissertation argues that a new policy objective should be to *work in partnership with homeowners in Stockport to improve the comfort, aesthetics, ease of living and value of their homes in ways that are consistent with the Borough becoming net-zero by 2038.* Current financial incentives and technical information are sufficient. Specific policy recommendations include setting formal targets for reducing domestic emissions, building a Borough wide coalition to promote retrofit, developing specific carbon literacy training for the sector and establishing a showcase of best practice from across the Borough.

Abstract

Stockport Council declared a Climate Emergency in 2019 and have committed to net-zero for the Borough by 2038 through reducing emissions at 13% per year. Emissions reduction policy has evolved since 2019 and has been collated from various public documents. The policy is well structured, coherent, and increasingly science-based, although this process is incomplete with top-level targets yet to be cascaded down to an operational level. It is based on localised territorial emissions data and consequently focuses on technological supply-side solutions.

Recently datasets have been published from which localised consumption-based emissions can be extracted. The aim of this dissertation is to explore how an understanding of such data might affect Council policy. Emissions are known to correlate with income and the Council portrays the Borough as being highly socio-economically polarised. Emissions data have therefore been combined with household income data to explore the relationship between the two.

Consumption-based emissions for the Borough are found to be 119% higher than territorial emissions (compared to 30% for England as a whole). The expected correlation of emissions with income is observed, with each increase of £1,000 in household income associated with an additional 727 kg of emissions (33% higher than for England). Contrary to expectations, income distribution within Stockport is found to be more homogenous than for England.

Emissions resulting from domestic fuel are found to be the highest single category and the implications of consumption-based data on policy in this area explored. Most emissions are produced by owner-occupiers across the income spectrum, whereas current policy focuses on low-income households, particularly social housing. Previous failings of policy to decarbonise owner-occupant households are explored and it is proposed that a new policy objective should be to *work in partnership with homeowners in Stockport to improve the comfort, aesthetics, ease of living and value of their homes in ways that are consistent with the Borough becoming net-zero by 2038.*

A review of relevant literature in the behavioural sciences suggests that policy should focus on developing supportive injunctive and descriptive social norms in a manner that is emotionally as well as cognitively engaging. Current financial incentives are sufficient and further technical information is unnecessary. Specific policy recommendations include setting formal targets for reducing domestic emissions, building a Borough wide coalition to promote retrofit, developing specific carbon literacy training for the sector and establishing a showcase of best practice from across the Borough.

Contents

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Finally, I must express my appreciation for my wife and soulmate Liz for her ongoing encouragement, support and love.

Glossary

CAN	Climate Action Now
EPC	Energy Performance Certificate
EU	European Union
EV	Electric Vehicle
ICCC	Impulse Community Carbon Calculator
IMD	Index of Multiple Deprivation
IPCC	Intergovernmental Panel on Climate Change
GMCA	Greater Manchester Combined Authority
LSOA	Lower Layer Super Output Area
MSOA	Medium Layer Super Output Area
PBCC	Place Based Carbon Calculator
SMBC	Stockport Metropolitan Borough Council
TfGM	Transport for Greater Manchester
UK	United Kingdom
UNFCC	United Nations Framework Convention on Climate Change

1 Introduction

1.1 Climate change & greenhouse gas emissions: from global to local

The Paris Agreement (ONS, 2021) committed world governments to limit global average temperature rises to well below 2°C, and to strive to hold them at 1.5°C, above pre-industrial levels. This can only be achieved by limiting greenhouse gas emissions to a given budget (IPCC, 2021) and the Intergovernmental Panel on Climate Change (IPCC) has now modelled pathways for emission reductions which are compatible with this budget as illustrated in Figure 1.1 (IPCC, 2023c). These can be downscaled to drive policy making at national and sub-national levels.

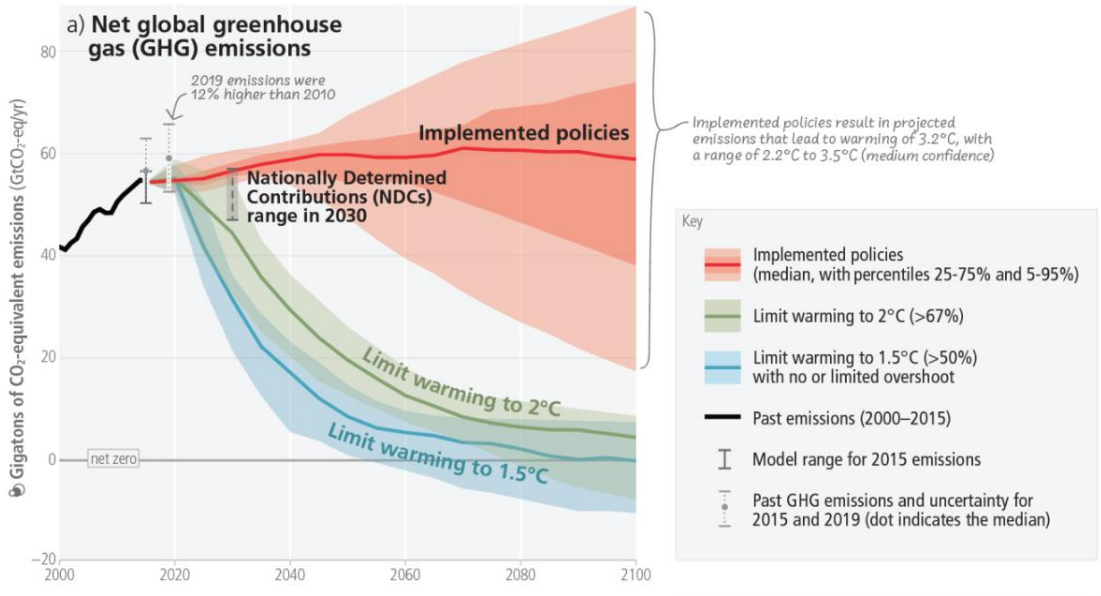

Figure 1.1. Global greenhouse gas emissions pathways consistent with Paris Climate agreement goals and currently implemented pledges (Figure SPM.5 from IPCC, 2023c).

This dissertation will explore the implications of such downscaling for Stockport Metropolitan Borough. The Borough has a population of just under 300,000 inhabitants of whom 87% are white (ONS, 2022b) and its 126 km^2 is a mix of urban and suburban areas. The most recent Council Plan (SMBC, 2023e) describes it as the 8th most socioeconomically polarised borough in England, containing both the most and least deprived suburbs in Greater Manchester (SMBC, 2022c).

The Metropolitan Borough Council (SMBC) provides a single level of local government responsible for running local services including schools, social services, waste collection, and roads. It collaborates with 9 similar metropolitan borough councils through the Greater Manchester Combined Authority (GMCA). Although the local and national government share responsibilities for emissions reduction in the UK there is no formal policy on how these are allocated (Gudde *et al.*, 2021a; Rankl *et al.*, 2023).

1.2 Defining emissions

"Emissions" and "carbon footprint" are now generally used synonymously and often interchangeably (CSE, 2021; Morgan *et al.*, 2021; PBCC, 2023). The "ecological footprint", which emerged in the early 1980s, was defined as the area of land required to support an individual's lifestyle allowing a direct comparison with the land area available on the planet (Loh and Wackernagel, 2004). "Carbon footprint", reported in terms of carbon dioxide emissions, was first used in 2002. It rapidly gained recognition after BP ran television advertising campaigns across the USA and Europe in 2005 asking consumers "What is your carbon footprint?" (Turner, 2014). Ever since it has been criticised for over-emphasising individual responsibility and reducing pressure for systemic change (Chater and Loewenstein, 2023). Although widely recognised, "carbon footprint" is poorly understood with many people relating it to broader environmental impacts rather than specifically to the emission of gases (Whitmarsh *et al.*, 2011; Hartikainen *et al.*, 2014).

"Emissions" is less ambiguous and without the political connotations. It is preferred by those with a physical sciences background and is used almost exclusively in IPCC reports (IPCC, 2023b). Whilst the early focus was on carbon dioxide (Wiedmann and Minx, 2008), there is now general agreement that all greenhouse gases should be included (Minx *et al.*, 2009; Gough *et al.*, 2011; Morgan *et al.*, 2021). "Emissions" will thus be the preferred term for this dissertation and refer to all greenhouse gases emitted in a year unless stated otherwise.

Regional emissions are classified in three ways (Owen *et al.*, 2023). *Territorial* emissions are emitted within a region. *Production-based* emissions are emitted by national residents and industries, regardless of location (useful mainly because it aligns with technical definitions of gross domestic product). *Consumption-based* emissions are allocated to the final consumer of a product. Figure 1.2 illustrates recent UK emissions to demonstrate these definitions. Consumption- and production-based emissions converged in the mid-1990s when emissions attributable to imports balanced those attributable to exports (ONS, DBEIS, DEFRA, 2023). Both include emissions by residents and companies outside the UK so are a little higher than territorial emissions. Since then, UK manufacturing has declined reducing both production-based and territorial emissions. Goods no longer manufactured in the UK had to be imported from abroad, and consumption-based emissions thus continued to grow until the mid-2000s. After that, mainly because of growing decarbonisation of the world's energy supply, consumption-based emissions have also fallen. Internationally carbon dioxide accounts for about three quarters of total emissions (Crippa *et al.*, 2019).

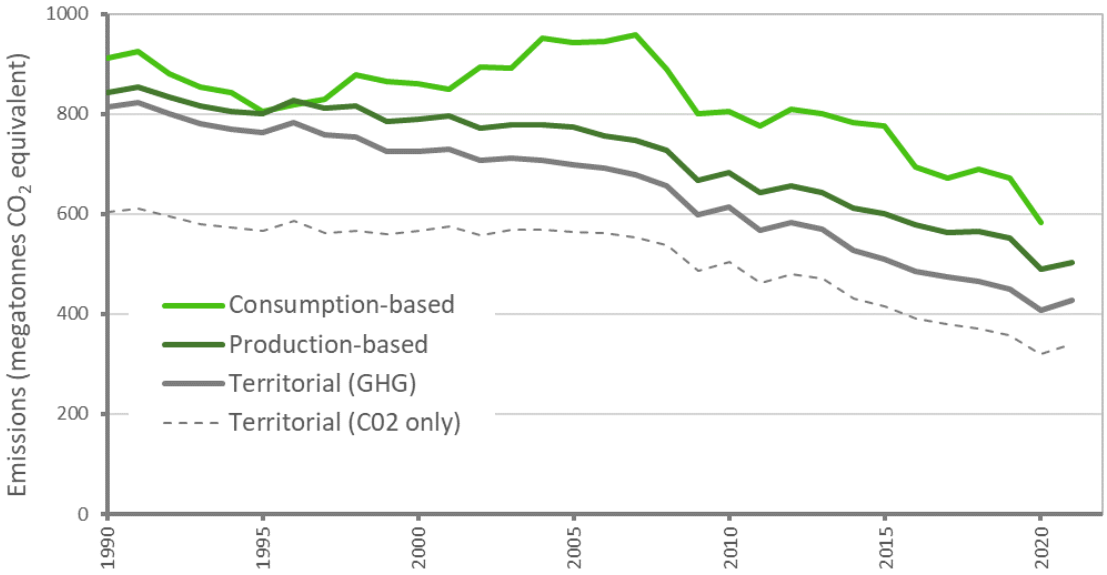

Figure 1.2. UK emissions since 1990 (Collated from ONS, DBEIS, DEFRA, 2023).

Life cycle analysis calculates emissions over a product's lifetime including production, use and disposal (Wiedmann and Minx, 2008). To avoid double accounting, emissions arising at different stages of this lifecycle are attributed to different years. Emissions from production are allocated to the year of production (or purchase), those from use (most often from energy consumed) are distributed over the product's lifetime, and those from disposal are accounted for at the end of the product's life (but are often over-looked).

1.3 Downscaling pathways

The Rio Earth Summit in 1992 acknowledged "common but differentiated responsibilities and respective capabilities" that require developed countries to "take the lead in combatting climate change" (UN, 1992, p. 4). Anderson *et al.* (2020) have suggested that this requires cement process, land-use, land-use change and forestry to be considered as global responsibilities (to avoid unreasonable restrictions on developing countries) and *grandfathering* (allocating the remaining carbon budget for developed nations on the basis of their recent emissions). The Paris Agreement (UNFCC, 2015) then requires countries to pledge non-binding *nationally determined contributions* towards meeting the globally agreed targets. 195 countries have now submitted such pledges (UNFCCC, 2023). Although these will only hold temperature increases to 3.2°C (see Figure 1.1), it is assumed that increasingly ambitious future pledges will reduce this. Thus, in 2019, the UK Government (DBEIS, 2019) increased its original commitment, to reduce emissions by 80% (of 1990 levels) by 2050, to 100% (net-zero).

Whilst setting target dates for carbon neutrality is symbolically significant, it is the shape of the pathway that determines whether emissions are maintained within the Paris Agreement budgets. Accepting recommendations from the Climate Change Committee (Huppmann *et al.*, 2018; CCC, 2020), the UK government has adopted an interim target of 78% reduction

by 2035 which is compatible with the 1.5°C goal (2018) but has not allocated statutory targets to local authorities (Rankl *et al.*, 2023).

By 2021 however, 75% of UK local authorities had declared a "climate emergency" (Gudde *et al.*, 2021a; Dyson and Harvey-Scholes, 2022) and 90% had formally pledged to reach net-zero by 2050 (NAO, 2021a). Through joining the UK100 network (UK 100, 2023b), over a third of local authorities have now pledged to more ambitious targets and pathways, many to a *Tyndall Centre*[1] pathway as originally proposes by Kuriakose *et al.* (2022).

Stockport MBC declared an emergency in 2019 (SMBC, 2019b) and have now committed to net-zero by 2038 and a Tyndall Centre pathway (Kuriakose *et al.*, 2020) commencing in 2019 as depicted in Figure 1.3[2]. Emissions fell in 2020, predominantly because of the pandemic, but rose in 2021 (the latest year for which data is available) to values 25% greater than the pathway recommends.

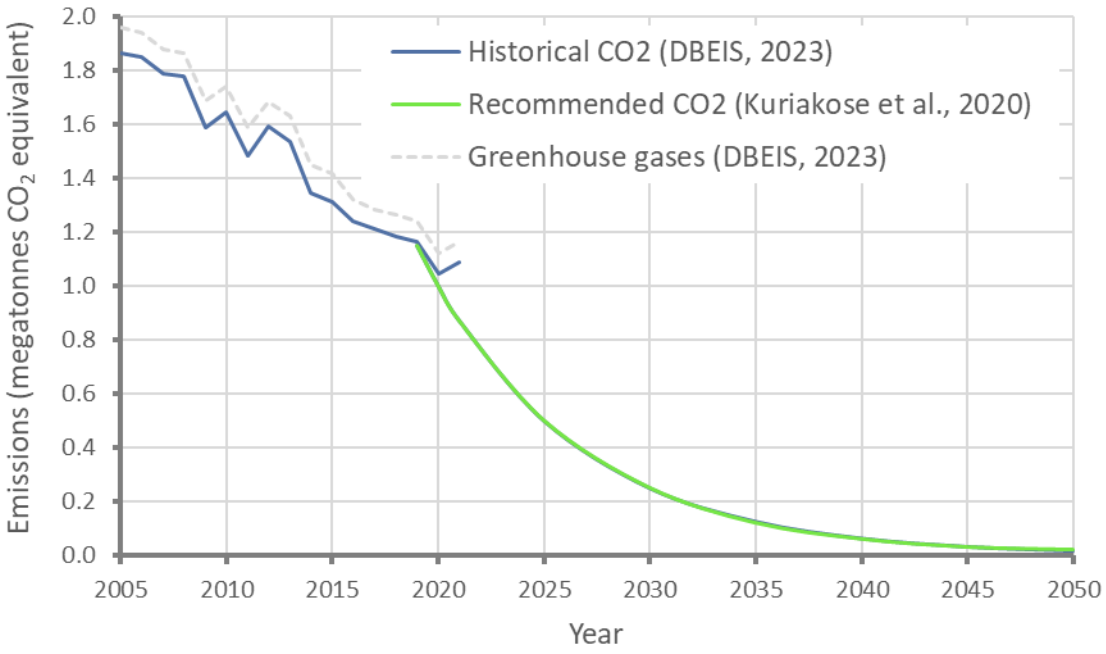

Figure 1.3. Historical carbon emissions and recommended emissions pathway for Stockport.

1.4 Policy options to reduce emissions

National and regional emissions reduction policy has historically focussed on supply-side options (Creutzig *et al.*, 2018). Emissions are reduced during manufacturing of goods and delivery of services, particularly through decarbonisation of the electricity supply, and little

[1] The Tyndall Centre is a partnership of universities including the University of Manchester where this work was done. John Tyndall (1822-1893), an Irish Physicist, was the first person to recognise that the chemical composition of the atmosphere affects how it absorbs heat (Jackson, 2018).

[2] There is some ambiguity in this – see Section 2.3.2.

is required of end-users. Unfortunately, it is highly unlikely that supply-side solutions alone can deliver emissions reductions quickly enough (IPCC, 2022) and there are areas where supply-side solutions are simply unavailable. Despite recent increases in efficiency, for example, there is considerable scepticism that emission free aviation will be possible within Paris Agreement timelines (Lyle, 2018; Larsson *et al.*, 2019; CCC, 2020). Another problem for regional and national policy makers in the UK is that many supply-side emissions occur outside their jurisdiction.

Recently there has been increasing interest in demand-side solutions (Creutzig *et al.*, 2018) and the most recent IPCC Synthesis Report on Mitigation is the first to include a chapter on *Demand, Services and Social Aspects of Mitigation* (IPCC, 2023a). Changes in demand can be categorised as arising from choices to *avoid* (as by turning a thermostat down), *shift* to a new technology (such as a heat pump), or *improve* the efficiency of an existing technology (such as a condensing boiler) (Creutzig *et al.*, 2018). The IPCC (IPCC, 2022) also classify demand-side solutions as *socio-cultural* (shifts in behaviours and norms, such as comfortable indoor temperature), *infrastructure* (such as the relative pricing of electricity and gas) and *end-use technologies* (such as heat pumps). The IPCC estimate that demand side reductions alone could reduce emissions by between 40% and 70% (IPCC, 2022). Figure 1.4 (IPCC, 2023a), for example, illustrates a low energy demand (LED) emissions reduction pathway that requires two thirds less decarbonisation than the best of three supply-side pathways, and is the only one not dependent on unproven carbon capture technology.

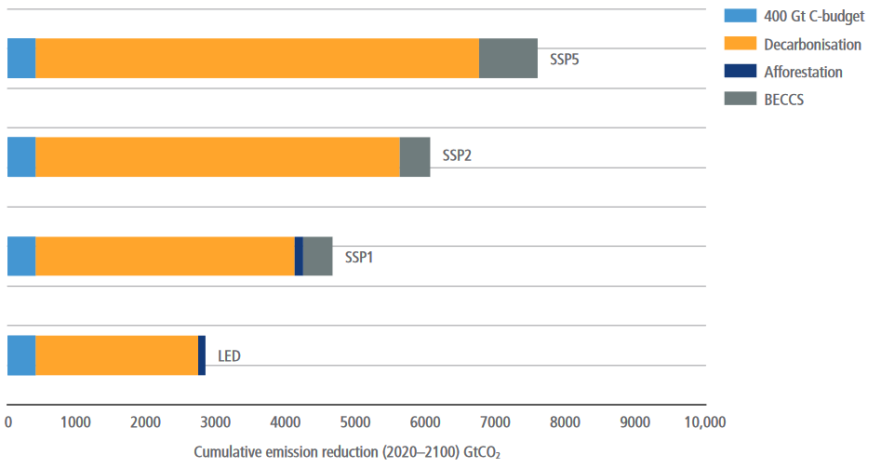

Figure 1.4 Cumulative emissions reduction required by three standard socioeconomic supply-side pathways (SSP 1, 2 and 5) and a fourth that factors in low energy demand (LED(Figure 5.1, IPCC, 2023a). BECCS = bioenergy with carbon capture and storage. (Figure 5.1, IPCC, 2023a)

Reducing demand for products and services has the additional advantage of reducing pressure on a range of other planetary boundaries whereas supply-side solutions tend to focus on emissions (Raworth, 2018). Demand-side approaches also highlight inequalities in responsibility for emissions (Chancel, 2022) and offer pathways that address societal inequality and emissions simultaneously (Millward-Hopkins and Oswald, 2021). Finally

demand-side approaches allow additional behavioural science-based options to augment technological solutions (Creutzig *et al.*, 2018). On the other hand, demand-side approaches have been criticised for over-emphasising individual responsibility and reducing pressure for systemic change (Chater and Loewenstein, 2023). Nevertheless, there is now consensus that both supply- and demand-side policy options are required to meet global targets (Minx *et al.*, 2009; Preston *et al.*, 2013; Turner, 2014; Owen and Barrett, 2020).

Stockport Council published its *Climate Action Now (CAN) Strategy* in 2020 (SMBC, 2020b) and emissions reduction strategy has continued to evolve as documented in a series of *CAN Annual Reports* (SMBC, 2021c, 2022f, 2023c). Throughout these the focus is very largely on supply-side options

1.5 Measuring emissions to support policy making

Designing supply-side or demand-side policy has different data requirements. Supply-side policy is based on understanding where emissions occur geographically and by sector, i.e. territorial emissions. Territorial emissions for the UK and its regions are collated by the government (DESNZ/DBEIS, 2023). Stockport has considerably lower territorial emissions than England as a whole[3] (Figure 1.5) because, as a compact residential area, it has lower emissions from industry, land transport and agriculture (a sub-set of the "other" category).

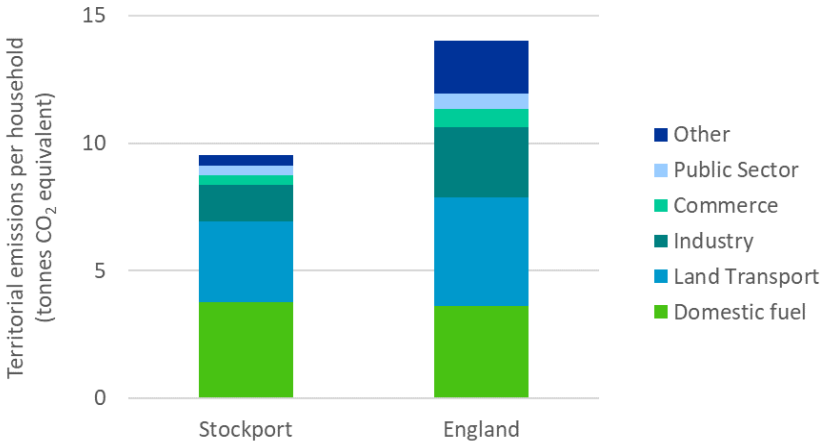

Figure 1.5. Territorial greenhouse gas emissions within Stockport and England for 2021 (latest available data, DESNZ, 2023a). "Other" includes agriculture, land use and waste management.

Demand-side policy is based on understanding how emissions are generated by consumer demand, i.e. consumption-based emissions. Until recently consumption-based emissions data have been unavailable on a regional basis requiring demand-side policy making for Stockport to be based on national data. This data has now been provided however (CSE,

[3] England is chosen as a comparator rather than the UK to maintain consistency across the dissertation as some datasets used later are only available for England.

2021; Morgan *et al.*, 2021), and a major aim of this dissertation is thus to explore differences between Stockport and England and what effect these might have on Council policy.

1.6 Household emissions

There are a growing number of studies of consumption-based emissions (key papers: Gough *et al.*, 2011; Büchs and Schnepf, 2013; Preston *et al.*, 2013; Ivanova and Wood, 2020; CSE, 2021; Morgan *et al.*, 2021) and the majority provide data for households (rather than individuals). Almost all allocate separate categories[4] for domestic fuel, food and transport (although there are differences in sub-categories for transport), but there is less agreement about other categories (see Table 1.1). It is not always clear whether "total" emissions cover all emissions or only those accounted for within designated categories. Some care is thus required in comparing results from different studies.

Table 1.1. Categories and units in key papers quantifying consumption-based emissions.

Consumption category	Gough et al. (2011)	Preston et al. (2013)	Büchs & Schnepf (2013)	Ivanova & Wood (2020)	Morgan et al. (2021)	CSE (2021)
Unit	Individual	Household	Household	Household	Individual	Household
Domestic Fuel	Combined	Combined	Gas Electricity Other	Combined	Combined	Combined
Food	Combined	Not included	Combined	Combined	Combined	Combined
Transport	Combined	Private Public Flights	Motor fuel Public Flights	Land Flights	Private Public Flights	Combined
Services	Private Public	Not included	Not included	Services	Not included	Combined
Consumables	Combined	Not included	Various	Products Clothing	Not included	
Other	Other	Not included	Not included	Not included	Other	Waste

There are two families of methods for calculating carbon emissions. *Process analysis* is a bottom-up approach tracing the emissions associated with different stages of production. As such it is well-suited to analysing individual products and can be extended for full life cycle

[4] A variety of alternative terms have been used including "sectors" (Gough *et al.*, 2011; CSE, 2021), "sources" (Preston *et al.*, 2013) and "areas" (Büchs and Schnepf, 2013) but "category" has been used by two recent and influential papers (Ivanova and Wood, 2020; Morgan *et al.*, 2021) and will preferred in this dissertation.

analysis (Wiedmann and Minx, 2008) using the ISO 14020 family of standards (ISO, 2022). Carbon footprints of food products generally use this approach (Poore and Nemecek, 2018) as do most web-based personal footprint calculators (e.g. Harris *et al.*, 2021; Climate Stewards, 2023). *Environmental input-output analysis* (EIO), by contrast, is a top-down approach based on measurement of emissions associated with different industrial sectors (Leontief, 1970; Bicknell *et al.*, 1998; McDonald and Patterson, 2004). Governments now routinely publish data to support *multi-regional input-output analysis* (MRIO) allowing accounting for national differences in emissions profiles (Miller and Blair, 2009). This is now the standard method for calculating national consumption-based emissions and growing agreement among studies applying it to data from different sources gives increasing confidence in its use (Owen *et al.*, 2023).

Process analysis can thus provide a carbon footprint for an individual or household but is cumbersome and intrusive to apply across a population and is vulnerable to double accounting (Wiedmann and Minx, 2008). Input-output analysis, by contrast, provides a carbon footprint for a nation or region but no information about how this is distributed between individuals. There is no guarantee that the sum of process analysis-based estimates of household emissions will agree with input-output analysis bases estimates of national emissions (Thumin and White, 2008).

Barrett and Wiedmann (2005) were the first to adopt a hybrid approach. In categories where data are available at household level this is incorporated directly. Local household consumption of domestic gas and electricity consumption, for example is collated nationally in the UK (DBEIS, 2023; DoT, 2023c) from which corresponding emissions can be calculated (DEFRA, 2023a). In other categories, modelling is used to distribute national emissions between households. Thus, for example, emissions associated with flying are recorded nationally (CAA, 2023) and the known relationship between flying habits and income (Büchs and Mattioli, 2021) is used to attribute emissions to different households. Although studies are improving, results remain sensitive to the methods and assumptions made in calculations (Gao *et al.*, 2014; Heinonen *et al.*, 2020).

Privacy concerns and modelling limitations prevent publication of data for individuals or households but two studies have recently provided estimates for average household emissions across England at Lower Super Output Area (LSOA, geographical areas with an average of 1500 inhabitants, Morgan *et al.*, 2021) and parish level (CSE, 2021).

1.7 Emissions and income

Barrett and Wiedman (2005, see Figure 1.6) were the first to quantify the relationship between emissions and income (the ratio of emissions to income is also referred to as ‘elasticity’, Ivanova and Wood, 2020) . A 46% rise in income above £130 led to a 35% increase in ecological footprint. Since then several studies have found evidence for a strong dependence of emissions on income deciles (Dresner and Ekins, 2006; Thumin and White, 2008; Büchs and Schnepf, 2013). All, however, also found more variation within income

deciles than between them, with a strong dependence on household size and composition, house size and type, tenure and urban/rural classification. Druckman and Jackson (2009) and Minx et al. (2013) found similarly strong correlations between average emissions and income when households were allocated to socio-economic groups, rather than income deciles.

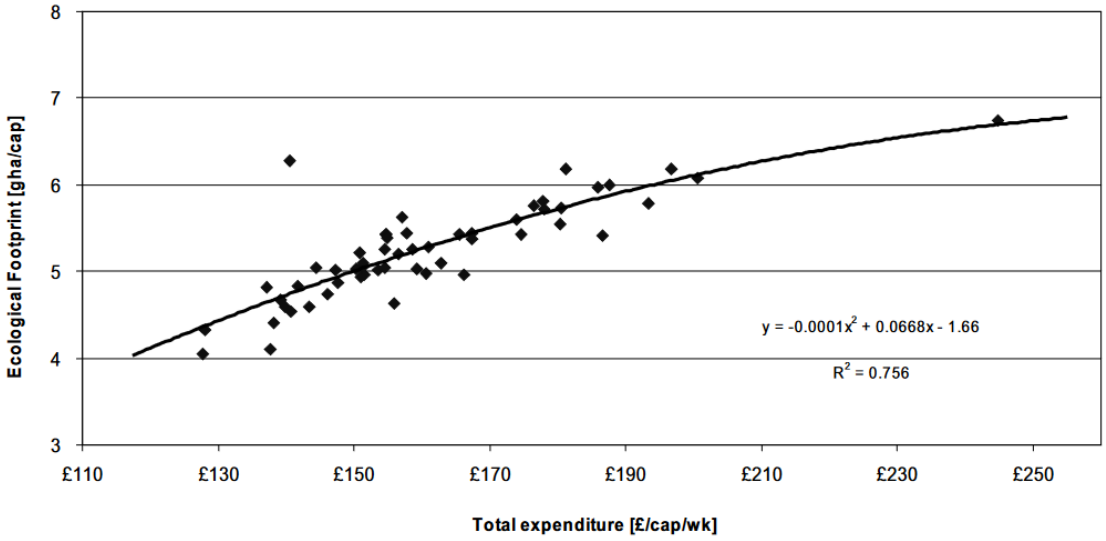

Figure 1.6. Relationship between individual ecological footprint with weekly expenditure for different ACORN types (Barrett and Wiedmann, 2005). (ACORN is a way of classifying households into 54 groups on the basis of socio-economic factors). [Note that the equation of the regression line does not actually fit the curve displayed on the graph].

Two studies in the early 2010s provide estimates of emissions broken down by category and income decile (Gough *et al.*, 2011; Preston *et al.*, 2013). Both used a variety of techniques to impute data from different datasets using models based on socio-economic predictor variables. Whilst detailed comparison is complex given different assumptions, categories and units, the broad trend of increasing emissions with income is clear from both studies (see Figure 1.7). There is good agreement that those in the 10th decile had emissions about 3 times higher than those in the 1st decile (2.8 from Gough et al. and 3.2 from Preston et al.). Both studies also commented on considerable variability with other factors within deciles.

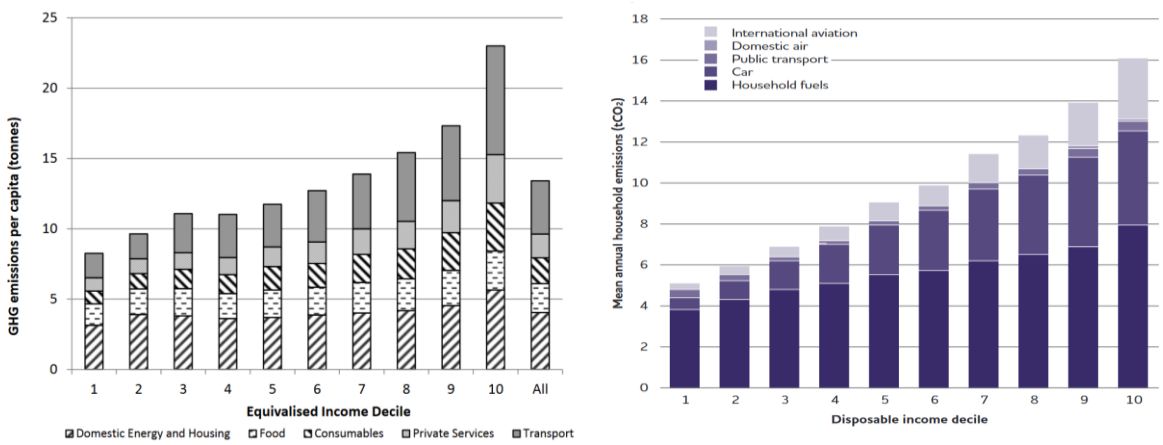

Figure 1.7. Relationship between emissions and income by decile in the United Kingdom in 2006 from Gough et al. (2011, left, GHG per person) and Preston et al (2013 right, CO_2 per household).

A strong correlation between household emissions and income has also been found in the USA (Weber and Matthews, 2008; Jones and Kammen, 2014) and a comprehensive study of emissions across the European Union (EU) by Ivanova and Wood (2020) showed strong correlations across all 26 member states but with markedly different gradients. Their Figure 2 can be digitised to give ratios for emissions from the 10th and 1st deciles by income ranging from 3.1 (Czechoslovakia) to 7.3 (Romania). The figure for the UK (3.9) is in reasonable agreement with both Gough et al. (2011) and Preston et al. (2013) given methodological differences between the studies. The range across the EU is substantial with emissions from the 10th decile in the country with highest emissions (Luxemburg) being over 26 time those from the 1st decile in the country with lowest emissions (Romania).

These distributional issues have profound implications for who emissions reduction policy should address and what measures should be used (Gough *et al.*, 2011; Preston *et al.*, 2013; Ivanova and Wood, 2020). If Stockport is one of the most socioeconomically polarised boroughs in England (SMBC, 2023e), then the distribution of emissions is likely to increase more with income decile than for the country. This dissertation will thus characterise the dependence of emissions on income within Stockport as a tool for local policy making.

A final issue is the growing recognition of the very high emissions of those with very high incomes. Ivanova and Wood (2020) found that average emissions of the top 1% of EU households by income is 2.4 times that of the top decile. Chancel et al. (2022) found the equivalent figure worldwide is 3.5. A report from Oxfam (Khalfan *et al.*, 2023) has gone further calculating that the top 0.1% of the world's population by income have average emissions of over 8.5 time those of the top decile. Whilst these differences are stark, no data has been found to make similar comparisons within Stockport and this issue is thus beyond the scope of this dissertation.

Before moving on, it is pertinent to locate myself as an educated 59-year-old professional engineer living on the edge Stockport who had a household income towards the top end of the 10th decile for the Borough (see Table 3.2) before leaving to study for this degree.

1.8 Summary, research questions and the structure of this dissertation

In summary, there is now a consensus that both supply- and demand-side policy options will be required to meet international targets to limit temperature rises to 1.5°C (or even 2°C). Stockport's current emissions reductions policy focusses heavily on supply-side options but this may be partly because local consumption-based emissions data have only recently become available. The research question driving this dissertation is, "Can localised consumption-based emissions give insights for demand-side policy options to reduce emissions within Stockport?". The sections of this dissertation address the subsidiary questions that this leads on to.

1.8.1 What is Stockport Council's current emissions reduction policy?

The Council's policy was first outlined in the *Climate Action Now (CAN) Strategy* (SMBC, 2020b) and has continued to evolve as recorded in a series of CAN Annual Reports (SMBC, 2021c, 2022f, 2023c) and other documents. Section 2 is thus a collation of information from these sources to give a detailed description of current policy.

1.8.2 How do Stockport's consumption-based emissions compare with those for England?

As described in Section 1.7, two new datasets provide estimates of consumption-based household emissions across England (CSE, 2021; Morgan *et al.*, 2021). Emissions are known to correlate strongly with income with important implications for policy-making which might be particularly significant in a borough that is highly polarised socio-economically (SMBC, 2021a). Section 3 thus describes the combination of one of these datasets with existing datasets of household income (ONS, 2020a, 2022a) to explore how consumption-based emissions differ between Stockport and England with a focus on income effects.

1.8.3 How might this new data be used in policy making to reduce emissions from domestic fuel use within Stockport?

Section 4 briefly discusses the overall implications of the new data with respect to Council policy but then focusses on reducing emissions from domestic fuel use, the biggest single category of emissions. This focuses on demand-side options and the behavioural science that supports them and concludes with policy recommendations.

1.8.4 Overall conclusions and general discussion

The different sections include discussion of specific issues. Section 5 summarises overall conclusions and contains a brief discussion of more general themes.

2 Climate Change Policy within Stockport Borough Council

2.1 Context and history of Stockport's Climate Policy

2.1.1 Stockport Metropolitan Borough Council

Stockport Metropolitan Borough Council is a unitary authority with responsibility for a range of functions[5]. It collaborates with 9 other metropolitan boroughs through the Greater Manchester Combined Authority comprised of a councillor nominated by each borough and the directly elected Mayor of Greater Manchester.

The Council's structure is determined by the Local Government Act 2000 and the Localism Act 2011 (UK Government, 2000, 2011). Elections for a third of the 63 councillors (one from each of 21 wards) are held in May in three of every four years. Over recent years Labour and the Liberal Democrats have been the largest parties but neither has had an overall majority. The *Leader of the Council* forms a *Cabinet* with 7 other councillors who each take responsibility for a different portfolio[6]. Other councillors sit on 5 *Scrutiny Committees*[7] responsible for reviewing a range of reports. The Leader, members of the cabinet and other committees, and the business programme for the year are all approved at the Council's Annual Meeting (the first meeting after the elections).

Periodically the Council agree a *Borough Plan*. The current one, *All together as one* (SMBC, 2021a), was developed during the pandemic and sets out a vision for 2030. Complementing this, the Council approves annual *Council Plans* at its *Budget Meeting* each February (SMBC, 2019c, 2020c, 2021d, 2022g, 2023d) which cascades down to performance indicators specified in *Performance and Resources Agreements* for each portfolio. The following June each portfolio submits an *Annual Report* of progress against the indicators to the appropriate Scrutiny Committee. The Council can take specific initiatives such as *Climate Action Now* (CAN) which also report back through a relevant Scrutiny Committee.

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[5] Education, housing, planning applications, strategic planning, transport planning, passenger transport, highways, fire services, social services, libraries, leisure and recreation, waste collection and disposal, environmental health, revenue collection.

[6] The portfolios get rearranged every few years. Currently they are: Children, Families and Education; Climate Change & Environment; Communities Culture & Sport; Economic Regeneration & Housing; Finance & Resources; Health & Adult Social Care; Parks, Highways and Transport Services.

[7] The portfolios (in parenthesis in this list) report to five Scrutiny Committees: Adult Social Care & Health (H&ASC); Children and Families (CF&E); Communities and Transport (CC&S, PH&T); Corporate, Resource and Government (F&R, Leader of Council); Economy, Regeneration & Climate Change (ER&H, CC&E). These are overseen by an additional Scrutiny Co-ordination Committee.

Policy is implemented by Council employees[8] headed by a corporate leadership team comprising a Chief Executive, two Deputy Chief Executives, and 7 other Directors (SMBC, 2023b). There is a partial correspondence between the responsibilities of Directors and the portfolios outlined in the previous paragraph. Some services are offered through wholly owned arm's length bodies such as *Stockport Homes Group* or the *Totally Local Company* (facilities management and waste disposal) and others by independent contractors. Emissions reduction policy is the responsibility of the *Head of the CAN Service* who reports to the *Director of Place Management*.

2.1.2 Declaration of Climate Change Emergency

Over recent years a trend has grown for national, regional and local governments to declare climate emergencies (well documented by Ruiz-Campillo *et al.*, 2021). The City of Darebin (a suburb in the north of Melbourne, Australia) was the first to declare a Climate Emergency in December 2016. Over 2017 and 2018 the movement spread to cities in the USA and Canada prompted partly by a heat wave that killed 90 people in July 2018 (CACE, 2020). Heat waves and wildfires in Sweden that summer also prompted Greta Thunberg's first *Skolstrejk för klimatet* (school strike for climate) and October 2018 saw the publication of the IPCC report, *Global warming of 1.5°C* (Masson-Delmotte *et al.*, 2018). Through 2019 public concern grew appreciably as indicated by international *Fridays for the Future* protests (arising from Thunberg's initiative) and the first Extinction Rebellion protests in London (Dyson and Harvey-Scholes, 2022). Over 2019 the number of local governments declaring climate emergencies rose from 26 to 919 (Ruiz-Campillo *et al.*, 2021). In December 2020 UN Secretary General, António Guterres, recommended that all governments should declare a state of emergency until net-zero has been achieved (Green and Abnett, 2020). As of December 2023, 2,351 jurisdictions have declared climate emergencies in over 40 countries and covering over a billion citizens (Aidt, 2023).

Since Bristol declared a climate emergency in November 2018 (Dyson and Harvey-Scholes, 2022), the United Kingdom has been particularly influential. By April 2020 45% of all declarations worldwide had been by local authorities within the UK. Stockport made its declaration in March 2019 (SMBC, 2019b) and the Greater Manchester Combined Authority followed in July (GMCA, 2019).

Climate emergency declaration's vary considerably (Gudde *et al.*, 2021b). Stockport's (SMBC, 2019a, p. 4) starts by "noting" the findings of the IPCC report *Global warming of 1.5°C* (Masson-Delmotte et al., 2018) and that at the current level of commitments the world is on course of for a catastrophic 3°C of warming. It then states a belief that governments must make this their top priority, that bold climate action has health, wellbeing and economic

[8] Elected *councillors* are often referred to as *members* and *employees* as *officers*. In both cases the earlier, less ambiguous term will be used in this dissertation.

benefits and that greater consideration of how urban systems can develop sustainably is required. The substantive content is framed by 7 bullet points:

- To declare a “climate emergency” and support GMCA’s 5-year environment plan.
- To ensure the right resources are available to support this work.
- To establish a task and finish group to plan and deliver 5-year carbon budgets.
- To task a director level officer with responsibility for rapid reduction of emissions.
- To equip all staff with an awareness of emissions and how they can be reduced.
- To recognise that the Council takes account of competing policies.
- To write to the Prime Minister informing her of the declaration and requesting resources and powers to address it.

Following the declaration, an all-party Climate Emergency Task Group was established and currently meets quarterly.

2.1.3 Overview of Climate Policy Development

The Council’s policy on the climate and emission reduction in general has developed considerably since 2019 (see Figure 2.1). Neither were mentioned in that year’s performance agreement for the *Communities and Housing* portfolio[9] (SMBC, 2018), or Council Plan (SMBC, 2019c). At the first Annual Meeting after the Climate Emergency Declaration, however, the portfolio was modified and renamed *Sustainable Stockport*, with a specific responsibility for “cross-cutting strategic leadership for Climate Change and the green agenda” (SMBC, 2019a, p. 4). The Declaration came late in the planning cycle for 2019-20 but several changes were introduced into the Portfolio Performance Agreement (SMBC, 2019e): annual territorial CO_2 emissions were introduced as a formal performance measure, a Director Level Officer was appointed with responsibility for reducing emissions “as rapidly as possible” (p.2) and a report on the implications of the Climate Emergency Declaration was commissioned.

[9] This is the portfolio which then had responsibility for environmental issues.

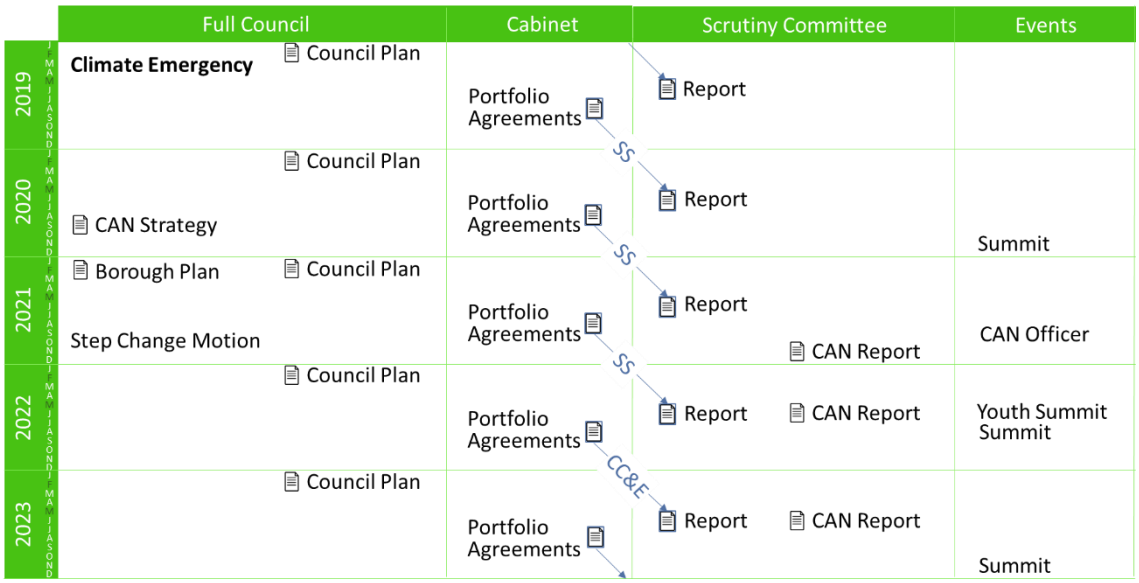

Figure 2.1. Timeline of policy development relevant to emissions reduction since 2019. Entries accompanied with a document icon have all been searched to derive the understanding of current policy as outlined in section 2.2. Portfolio names: SS = Sustainable Stockport, CC&E = Climate Change & Environment.

The report into the implications of the Declaration, became the *Stockport Climate Action Now (CAN) Strategy*, approved by Council in September 2020 (SMBC, 2020b). This set the primary target of making Stockport net-zero by 2038 and established 7 workstreams to achieve this. Both the Borough Plan, *All together as one* (SMBC, 2021a), and the Council Plan for 2021-22 (SMBC, 2021d) were approved in February 2022 including a significant emphasis on climate change. The Borough Plan, for example, has a climate friendly Stockport as one of three *ambitions* in its *One Home* pillar (see Figure 2.2).

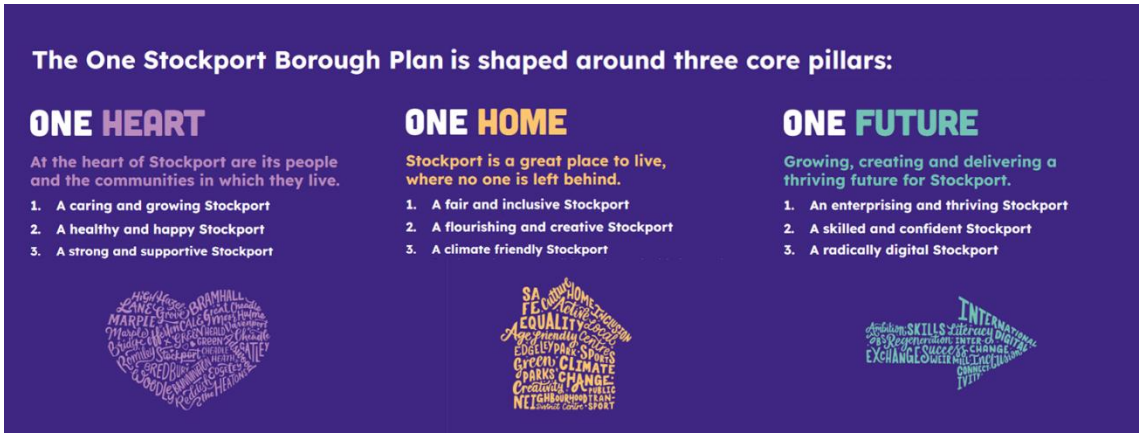

Figure 2.2. Summary of the Borough Plan, *All together as one*, laying out three *pillars*, each with three *ambitions* (adapted from SMBC, 2021a).

At its meeting preceding the CoP 26 summit in Glasgow in November 2021, the Council passed a motion expressing disappointment at the Council's overall rate of progress and

calling for a *Climate Action Now step change* (SMBC, 2021b). During the CoP meeting, the Council held its own first *CAN Summit* at which it committed to a 2030 net-zero target for its own emissions. Later that month the first *CAN Annual Report* (SMBC, 2021c) was published.

Progress has continued as summarised in three CAN Annual Reports (SMBC, 2021c, 2022f, 2023c). The latest major development, perhaps, is that this year's Council Plan (SMBC, 2023d) presents *Climate Action* as one of two themes cross-cutting all Council activities (the other is *Fair and Inclusive Stockport*, see Figure 2.3).

Figure 2.3. Overview of how Stockport Council operates from the Council Plan 2023-34 including Climate Action as a cross-cutting theme (SMBC, 2023d).

2.2 Current Emissions Reduction Policy

As can be seen from Section 2.1.3, Council policy has evolved over time and is not defined in any single document. The CAN Strategy was formalised in 2020 (SMBC, 2020b) and the first two Annual CAN Reports (SMBC, 2021c, 2022f) document both progress towards the original objectives and new initiatives. The third Annual Report (SMBC, 2023c) offers a reformulation of the policy and forms the basis for this section (although some details have had to be extracted from other documents illustrated in Figure 2.1). Formal performance indictors and targets are drawn from the relevant Portfolio Performance and Resources Agreements (SMBC, 2019e, 2020d, 2021e, 2022a, 2023a). This section will focus on emissions reduction policy (and not broader environmental concerns which are also part of the policy).

Current policy is well summarised by Figure 2.4 (taken from the most recent Annual CAN Report, SMBC, 2023c). It is driven by two overall targets, net-zero for Council operations by 2030 and for the Borough by 2038. This requires policy in 6 key areas (previously referred

to as workstreams). *Council CAN* covers internal actions that the Council is taking to facilitate change and *Climate Friendly Borough* is the programme through which it engages with the wider community. *Sustainable Transport*, *Renewable Energy*, *Low Carbon Buildings* the *Natural Environment* are then the focus for emissions reduction both within and outside the Council. The summary in the following sections allocates policies to the most obviously appropriate key areas, although this sometimes differs from how the strategy and reports have been structured (SMBC, 2020b, 2021c, 2022f, 2023c).

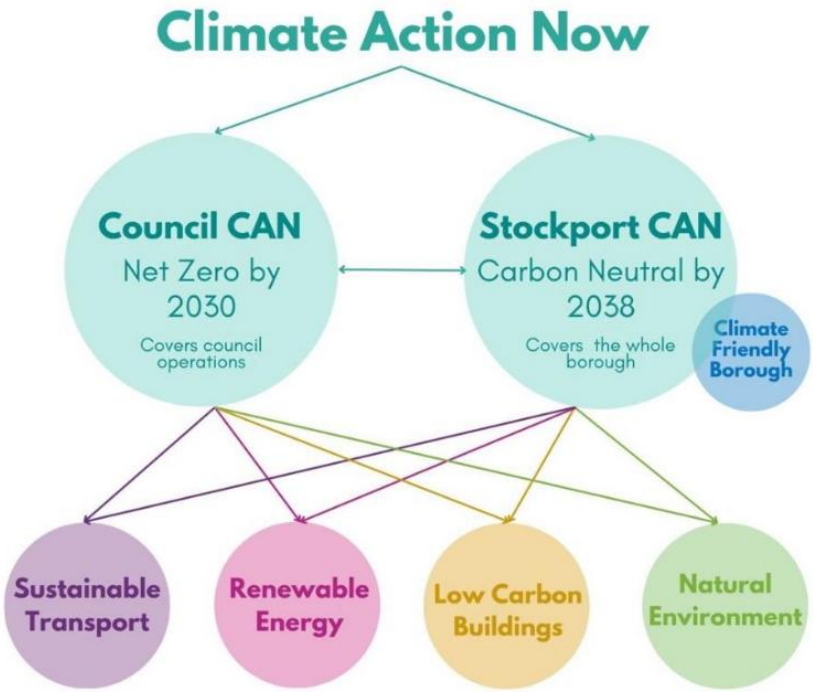

Figure 2.4. Schematic diagram of Stockport Metropolitan Borough Council's CAN Strategy as depicted in the Annual Report for 2022-23 (SMBC, 2023c)

2.2.1 Council CAN

Council CAN focusses on how the Council operates. It regards this as important in reducing its own emissions and through influencing the Borough as an exemplar and catalyst.

Towards this it has adopted a science-based approach to policy formulation and target setting based upon a comprehensive assessment of its emissions over the last five years (SMBC, 2022d). Science-based targets for emissions reduction have been set will be cascaded to more specific key performance indicators. Ongoing monitoring will be used to assess progress against those indicators. The data (Figure 2.5) shows a substantial decrease in total emissions (25% over three years). 80% of this reduction, however, occurred during 2020-21 which included the three national Covid lockdowns. It is encouraging that emissions continued at this level in 2021-22 as operations resumed.

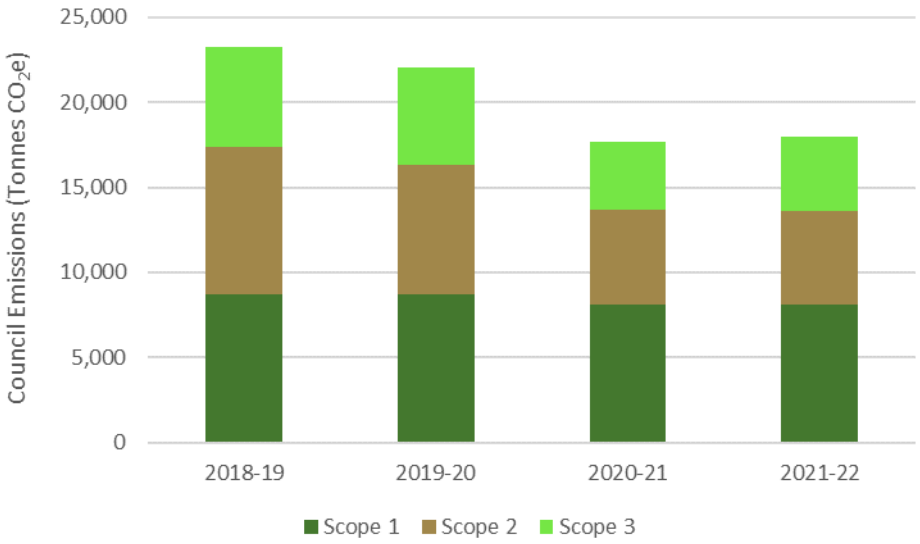

Figure 2.5. Emissions from Stockport Council (including maintained schools and the Totally Local Company) as recorded in the first annual *Greenhouse Gas Emissions Report* (SMBC, 2022d).

The Council has also committed to build environmental impact assessment into all decision making. A financial appraisal model has been developed to guide high-level decision making and emissions data is being integrated with financial reporting to facilitate carbon budgeting. *Environmental Impact Assessments* are now mandatory for all decision-making reports (although the Assessment Template does not include any explicit consideration of greenhouse gas emissions other than those associated with transport, SMBC, 2022b). Stockport shares procurement services with three other councils and these are engaging with suppliers to reduce emissions from supply chains as is required by Stockport's Social Value Charter (SMBC, 2019d). Climate and environment information for bidders has been added and will be reported upon during 2023-24.

The Council has also invested in staff education and development primarily through *Carbon Literacy training* (Carbon Literacy Project, 2023b) with the Council having developed its own bespoke course and currently having bronze status. The CAN report for 2021-22 (SMBC, 2022f) committed to making the course available to all councillors, employees, and to some external organisations, as part of achieving silver status by the end of 2022[10]. A *Climate Response* category has now been added to the Council's *Ambitious Stockport* awards. The 2021 *One Team People Plan* offers staff a flexible hybrid working model to reduce emissions through less commuting and demand for office space. Incentives for sustainable travel are offered to staff who do still travel to work.

The final component is a commitment to **sharing and learning about best practice**. The Council is a member of UK100 (UK 100, 2023b), a network of local authorities pledged to

[10] This commitment is not repeated in the most recent report (SMBC, 2023c) and the Council is still listed as having bronze status on the Carbon Literacy Project website (Carbon Literacy Project, 2023a).

more ambitious net zero targets than the UK government. They are one of 15 councils to have won a place on Democratic Society's *Local Climate Engagement Programme* (Democratic Society, 2024).

2.2.2 Climate Friendly Borough

Climate Friendly Borough covers Council actions to engage with businesses, residents and communities to make positive changes and reduce emissions beyond its own operations.

The flagship of this is a series of **Stockport CAN Summits** (listed Table 2.1), that complement the annual *Big Green Summit* run by the Greater Manchester Combined Authority. There have now been two *Schools and Youth Climate Assemblies* (UK 100, 2023a) at which representatives from different Schools have debated a range of motions within the Council Chamber. From this year, both the Summits and Assemblies will become annual events.

Table 2.1. History of Stockport's CAN Summits.

Event	Themes	Attendance
Youth Climate Conference, Manchester Metropolitan University November 2019		20 Stockport Schools represented
CAN Summit, Stockport Council November 2021	• Council CAN do • Business • Young People • Communities	200 people attended on-line
Schools & Youth Climate Assembly, Stockport Council June 2022	• Debates held in the Council Chamber	29 schools and 4 colleges.
CAN Summit, Stockport Council July 2022	• Council CAN do • Energy • Food	138 people attended in person or on-line
Schools & Youth Climate Assembly, Stockport Council March 2023	• Debates held in the Council Chamber	78 young people from 28 schools.
CAN Summit, Stockport Council November 2023	• Council CAN do • Buildings & Energy • Communities and young people • Biodiversity and Nature	161 people attended in person or on-line

The *Stockport CAN Fund* was announced at the CAN Summit in 2021 allowing community organisations, schools and groups of residents to apply for grants to support community climate action and engagement. 73 projects have been awarded a total of £132,000 which are predicted to result in an annual reduction of 128 tonnes of emissions.

The Council is also engaging with local businesses. The *Climate Action Business Forum* is a peer-to-peer network of 68 Stockport-based businesses that now meets quarterly. Carbon literacy training for small and medium enterprises is being developed. The Council is also partnering with the *Business Growth Hub* (a Greater Manchester social enterprise company) to offer training and advice about transitioning to net zero.

The Stockport Green Network has provided a space for residents and members of voluntary, community, faith and social enterprise groups to meet and plan climate and environmental action. It now meets quarterly and held *Greenstock*, a community fun day, in July 2023 (Stockport Green Network, 2023). The Network collaborated with the Council to offer a carbon literacy training day for this sector in November 2023. Volunteers and council staff united in a two-month *Spring Clean* campaign in early 2023 which included a poster competition for schools and the *Stockport Greenspace Volunteer Awards*.

2.2.3 Low Carbon Buildings

The use of buildings is one of the largest contributions to emissions across the Borough and this is being addressed at several levels from individual buildings to whole neighbourhoods.

The Council has won £5.6 million from the *Public Sector Decarbonisation fund* to retrofit key Council Buildings (Stopford House, Fred Perry House, the Town Hall and Grand Central Life Leisure and four schools). This is estimated to save 600 tonnes of emissions each year. Additional funding from this source will be used to move one of the schools, Dial Park Primary, towards become the first net-zero school in the Borough.

The Council's housing stock is managed by Stockport Homes which has its own Climate Strategy (Stockport Homes Group, 2021) which focuses on retrofit of Council housing. 96% of properties now have an Energy Performance of C or above (up from 91% in 2020) and a target for all properties to be rated C or above by 2025 is in place with funding from the *Social Housing Decarbonisation Fund*.

Several new major sustainable developments are in progress. A 3-hectare industrial estate in Cheadle is being redeveloped into an eco-business park incorporating sustainable construction and operation, and renewable energy generation. The Stockport *Mayoral Development Corporation* (MDC) is regenerating a 130-hectare brownfield site into an urban exemplar neighbourhood maximising energy efficiency and limiting embedded carbon. Perhaps the most ambitious single decarbonisation project is for a *Town Centre Renewable*

Heating Network[11] which, after initial feasibility work, has now attracted funding for detailed project development.

A *Local Area Energy Plan* (Coulsting and Bowick, 2022) has mapped pathways for full decarbonisation of the Borough by 2038. A primary scenario, using existing technologies, is contrasted with a secondary scenario assuming hydrogen for heating buildings becomes available from 2030 onwards. The second option is 13% cheaper but dependent on adoption of hydrogen for heating domestic buildings for which the National Infrastructure Commission have recently concluded there is "no public policy case" (NIC, 2023, p. 11). The primary scenario maps out a programme of basic and deep insulation retrofit, heat pump installation and the development of district heat networks identifying both *priority areas* and *long-term deployment areas*. The plan though comprehensive is essentially advisory. The Council is now using it to inform a strategic review of decarbonisation of the council's civic estates.

The Council are also encouraging residents to upgrade their own properties by retrofitting insulation and installing more efficient heating (primarily heat pumps). Working in partnership, GMCA have developed a new portal, *Your Home Better*, offering residents access to tailored advice on how to retrofit and what grants are available (GMCA, 2023).

2.2.4 Renewable Energy

Given that most of Stockport is built-up and relatively flat, most of the Council's initiatives for renewable energy are for solar PV installations. Working with GMCA, the Council have established *GO Neutral,* a systematic framework for planning new solar installations and obtained external funding for a range of its own buildings (Endeavour House, Stockport Exchange, Grand Central Leisure Centre and Stockport Sports Village, Woodley and four schools have so far been equipped). Planning approval has also been granted for 8 large commercial solar PV schemes (2.1MWp in total). The Local Area Energy Plan envisages 480MWp of capacity from domestic buildings, 160Mwp from non-domestic buildings and 230MWp from ground mounted systems by 2038 (Coulsting and Bowick, 2022).

2.2.5 Sustainable Transport

38% of Stockport's territorial emissions come from transport and the Council has policies to reduce emissions from their own vehicles and those of residents as outlined in their draft *One Stockport Transport Plan* (SMBC, 2022e). The Council's own fleet is managed by the *Totally Local Company* and a joint review of how to decarbonise is currently in progress. Improving the charging infrastructure will be required before more electric vehicles (EV) can be purchased. Solar panels have been installed on six refuse trucks saving a tonne of emissions each year. Stockport Homes has committed to electrification of all its fleet by 2028 (Stockport Homes Group, 2021).

[11] This is listed under Renewable energy projects in the most recent CAN annual report (SMBC, 2023c).

The Council have partnered with Iduna (a commercial company) to develop a network of publicly accessible EV charging infrastructure. The first wave will be 50 charging points across 19 Council owned car parks with longer term development laid out in the Local Area Energy Plan (Coulsting and Bowick, 2022). Three more EV taxi charging sites are being delivered by Transport for Greater Manchester (TfGM).

The Council is a strong supporter of the new Bee Network for public transport under which TfGM has taken responsibility for bus services (and will take responsibility for train services by 2030). TfGM aspires to increase bus use by 30% by 2030 and to have a zero-emission bus fleet by 2032 (TfGM, 2023). Coordinated bus, tram and train services are planned to make travelling by public transport more convenient. A new rail station to serve the suburb of Cheadle and will be completed by 2025.

The Council are also encouraging active transport (walking and cycling). Locations for 14 *Active Neighbourhoods* have been identified and the GMCA City Region Sustainable Transport Settlement and Mayor's Challenge Fund Scheme continue to fund delivery of projects. A Walking and Cycling Forum now meets quarterly to discuss options for active travel. There has been a particular focus on encouraging families to complete school runs on foot or by bicycle or scooter and to turn engines off whilst waiting outside schools.

Replacement of street lighting with low-energy LED alternatives is now essentially complete and has led to electricity consumption of 40% below a 2017-18 baseline.

2.2.6 Natural Environment

A 10-year plan to enhance biodiversity and enhance the green canopy across the borough has driven a programme of creating new woodlands, orchards and meadows, and planting trees more widely. Whilst this will lead to some uptake of carbon dioxide, this will be small in comparison to the other initiatives and will not be considered further in relation to emissions reduction policies.

2.2.7 Formal targets and indicators

Over the last three years there has been considerable progress in formalising and quantifying the performance indicators. These are laid out in the Annual Performance and Resources Agreement for the Climate Change and Environment Portfolio within three priorities, *Mainstreaming CAN*, *Renewable Energy & Efficiency* and *Council CAN Engagement* (see Table 2.2).

Table 2.2. Current priorities, performance indicators and targets for Stockport Metropolitan Borough Council as specified in the Annual Climate Change and Environmental Portfolio Performance and Resources Agreement (SMBC, 2023a).

	Performance indicator	2020/1 Actual	2021/2 Actual	2022/3 Actual	2023/4 Target
Priority 1: Mainstreaming CAN					
1.1	Decrease in scope 1&2 emissions compared to 2018/19 baseline (percentage).	-28%	-37%	-36%	SBT (TBC)[a]
1.2	No of Council officers and members accredited Carbon Literate (cumulative)	0	0	49	100
Priority 2: Renewable Energy and Efficiency					
GMS[b]	Boroughwide emissions per year (megatonnes CO_2 equivalent)	1.31[c]	1.2[c]	1.15[c]	Aim to minimise
2.1	Council's Scope 1& 2 emissions (kilotonnes CO_2 equivalent)	6.1	5.3	5.4	SBT (TBC)[a]
2.2	Council's Scope 3 emissions (kilotonnes CO_2 equivalent)	6.8	7.6	6.3	SBT (TBC)[a]
Priority 3: Council CAN Engagement					
3.1	Number of people attending Climate Action Business Forum	n/a	n/a	118	150
3.2	Number of people attending Carbon Literacy training for businesses	n/a	n/a	n/a	40
3.3	Participation in Schools Climate Assembly				
	3.3.1 Schools/colleges	n/a	35	49	60
	3.3.2 Young people	n/a	1050	1570	1800
3.4	Participation in Stockport Green Network				
	3.4.1 Groups	n/a	n/a	43	60
	3.4.2 People	n/a	n/a	60	80

Notes: [a] SBT (TBC) = science-based target (to be confirmed). [b] GMS = target set within Greater Manchester Strategy (GMCA, 2022b). [c] Boroughwide emissions are from UK wide annual figures released two years in arrears, so these three figures are for 2018, 2019 and 2020.

2.3 Discussion

2.3.1 Progress since the Declaration of a Climate Emergency.

Given that no explicit reference to reducing emissions has been identified in records of Council business prior to 2019, there has been considerable progress to the point at which Climate Action is now regarded as a cross-cutting theme across all the Council's activities (SMBC, 2023d). The influence of the Head of CAN Services is clear from the increased evidence of a structured science-based approach in documents dating from after his appointment in September 2021. Although science-based targets have yet to be set and cascaded down to performance indicators at an operational level, this has been highlighted as a priority for the coming year (SMBC, 2023a).

2.3.2 Targets and pathways

There is still some ambiguity about what the overall target for the Borough is. This has been set by the Greater Manchester Strategy as net-zero by 2038 without defining what net-zero means (GMCA, 2022b). The current target is stated rather vaguely as "aim to minimise". The SMBC Climate Change Strategy (2020a) referred to two levels of SCATTER (Setting City Area Targets and Trajectories for Emissions Reductions) pathways which commence in 2015 (and would require implausible levels of carbon capture) as well as a variant of the Tyndall Centre pathway (Kuriakose *et al.*, 2020) modified to start in 2015 (and achieving net-zero with very little reliance on carbon capture). Recent CAN Annual Reports (SMBC, 2022f, 2023c) have dropped references to the SCATTER pathways and retained illustrations of the Kuriakose pathway but it is not clear if this has been formally adopted anywhere.

The Tyndall Centre pathway (Kuriakose *et al.*, 2020) requires a sustained reduction of emissions by 13.1% each year from a 2019 baseline. Scope 1 and 2 emissions from the Council's own activities have reduced by 36% since 2018/19 which is almost exactly in line with the required reduction but most of this occurred during the year of the three Covid lockdowns (2020/21, see Figure 2.5). Last year's figures actually show a slight increase in emissions. Boroughwide emissions are only available to 2020 but show average decreases of only 6% per year over the preceding two years (see see Table 2.2).

Table 2.2). Considerably greater emissions reductions will be required to meet science-based targets when they are formalised.

2.3.3 Clarity of policy

Any policy in any organisation will evolve over time and maintaining a clear statement of current policy is a challenge. The series of CAN Reports have risen to that challenge well and the most recent presents a good summary of current policy. Some areas, however, require reference to earlier documents to be fully understood. There is a particular issue with initiatives that have been proposed in earlier documents but are not referred to again such as plans to build several dwellings to Passivhaus standards mentioned in the 2020-21 CAN Report (SMBC, 2021c) or for 14 walking and cycling schemes proposed in the CAN Strategy (SMBC, 2020b). It is not clear whether these have been implemented, are still pending or have been dropped.

There are considerable differences between the clarity of policies designed to reduce the Council's own emissions and those to reduce emissions more widely across the Borough. Mechanisms for reduction of its own emissions are reasonably explicit and targets are directly related to emissions reductions. The mechanisms by which externally directed policies, such as engaging with the local community, will be delivered are much less clearly defined and targets are often only defined indirectly through measures such as the number of people engaged. To a certain extent this is inevitable given that the Council has considerably more control of its own emissions. On the other hand Council emissions account for only 5% of those across the Borough (SMBC, 2020b) and more explicit emissions reduction policies will be required at some stage to meet these wider targets.

2.3.4 Limitations

The primary limitation of this description of council policy is that it has been derived entirely from publicly available documents. Given the Council's commitments to transparency in how it operates (SMBC, 2023f), however, there are a considerable number of these, including many working documents that would not be available for other organisations, and it would appear that this picture is reasonably complete[12]. A related issue is that of how reliable the information is. Much of it is well evidenced and there seems little reason to suspect undue intentional bias. Perhaps the biggest issue is the tendency to report selectively on initiatives that have been successful (see Section 2.3.3). More explicit reporting of initiatives that have not worked, and some analysis of why not, would almost certainly allow valuable learning which is not available from the current documentation.

Finally, although environmental impact assessments are required for all policy initiatives and should include an analysis of potential emissions reductions (SMBC, 2022b), neither these, nor estimates of emissions reductions from previous initiatives, are collated (although

[12] This has been confirmed by a review of this chapter by the Council's CAN programme manager.

several are recorded in an *ad hoc* manner across the suite of documentation). This makes it extremely difficult to assess the relative success of different initiatives or the extent to which they contribute to overall targets. (A particularly challenging metric would be to present potential savings as a percentage of Council or even Borough emissions).

3 The relationship between household emissions and income in Stockport

3.1 Introduction

The aims of this study are to extract data specific to Stockport from recently compiled localised consumption-based emissions datasets (CSE, 2021; Morgan *et al.*, 2021), to explore the relationship between emissions and income within this data, and to compare this with national data to as a basis for policy making with the Metropolitan Borough Council.

Table 3.1. Characteristics of two recent datasets for local household emissions.

	Place-based carbon calculator - PBCC Morgan et al. (2021)	**Impulse Community Carbon Calculator -ICCC** CSE (2021)
Unit	Person	Household
Smallest area	LSOA	Parish
Source data	2011-2020	2017-2019
Access	Open Data Commons Attribution License	Free, open source
Categories & sub-categories	Housing Electricity Gas Other heating Other housing	Housing Electricity Gas Oil LPG Coal Biomass
	Food and Diet	Food and Diet Meat and fish Other Food
	Travel Private Cars Private Vans Public transport Flights	Travel Private Public transport Flights
	Consumption Goods Services Recreation	Consumption Goods Services Other
		Waste

The characteristics of the two new datasets are summarised in Table 3.1. The *Place-based Carbon Calculator* (PBCC, Morgan *et al.*, 2021) provides average emissions for individuals within Lower Layer Super Output Areas (LSOAs). The *Impulse Community Carbon Calculator* (ICCC, CSE, 2021) provides similar data for households within parishes. The 190 LSOAs in Stockport are part of the UK's hierarchy of census geographies and each include

400-1,200 households (ONS, 2021). Parishes, having evolved over centuries, are much less regular with many urban regions, including Stockport, being “unparished”. Data for wards are available but there are only 22 of these. This analysis will thus use the PBCC.

Estimates of household income based on the *Family Resources Survey* (FRS, DWP, 2019) are published every two years by the Office for National Statistics (ONS, 2020a) at Middle Super Output Area (MSOA[13]). An alternative dataset of *Admin-based income statistics* (ABIS) drawing on data from the tax and benefit systems at LSOA level is now available but regarded as experimental (ONS, 2022a). Preliminary exploration of this dataset (included in Appendix A1) suggested that a substantial number of improbable outliers were influencing correlations with emissions and this study is thus restricted to the FRS based data.

3.2 Methods

3.2.1 Household emissions

The Place-based Carbon Calculator provides data at LSOA level on 6 categories of emissions. Actual consumption data is used where available at this level otherwise estimates are modelled from various surveys. Data used is for 2018 (the latest available) unless otherwise specified.

3.2.1.1 **Domestic fuel** (primary source for methodology: CREDS, 2023)

Data on domestic gas and electricity consumption at LSOA level published annually by the UK government (DBEIS, 2023) are combined with emissions factors (DEFRA, 2023a) to calculate emissions. Households with other heating types (within the LSOA) are identified from the 2011 census (ONS, 2014) and assumed to have the same heating requirement as the average gas heated home.

3.2.1.2 **Private transport** (primary source for methodology: CREDS, 2023)

Although the UK Department for Transport collate the kilometres driven per LSOA from MOT certificates[14], these data were last published in 2011 (Cairns *et al.*, 2017). Since then data has only been published for much wider areas defined by the first two letters of the postcode (DoT, 2023a). These data are used to evaluate regional changes in driving behaviour, allowing modifications to update the 2011 data.

[13] An MSOA is a group of about 5 LSOAs with an average population of 7,200 (ONS, 2021).

[14] The MOT (Ministry of Transport) certificate is the annual roadworthiness certificate required for all vehicles in the UK.

3.2.1.3 **Public transport** (primary source for methodology: Morgan *et al.*, 2021)

The documentation on how public transport emissions are obtained is ambiguous. Morgan et al. (2021) refer to unspecified datasets available for 2011 at LSOA level and modelling to update this data (again unspecified).

3.2.1.4 **Flights** (primary source for methodology: CREDS, 2023)

Flight information from UK Civil Aviation Authority airports and punctuality datasets (CAA, 2023) includes number of flights, passengers and passenger miles which are combined with emissions factors (DEFRA, 2023a) to calculate emissions (including radiative forcing). This is distributed amongst LSOAs in relation to income based on the Gini coefficient for flying (Büchs and Mattioli, 2021) which is in turn based on data from the Living Costs and Food Survey (ONS, 2017) and the National Travel Survey (DoT, 2023b).

3.2.1.5 **Food & drink and "other"** (primary source for methodology: CREDS, 2023)

The UK Consumption Based Carbon Footprint (DEFRA, 2023b) is distributed to LSOAs based on household income. Food and drink categories are separated out and everything else is allocated to the "other" category.

3.2.2 Household incomes

Household income estimates for England are published every two years by the Office for National Statistics (ONS, 2020a). Data from the Family Resources Survey of 19,000 households across the UK is modelled using a range of covariates from other sources to estimate values for each MSOA.

3.2.3 Harmonisation of datasets

A range of steps was required to harmonise and clean the datasets.

1. Data from the PBCC is calculated for individuals so these were multiplied by the average household size for each LSOA (ONS, 2013).
2. Some emissions categories have data for a range of years with 2018 being the most recent. As far as possible data from other datasets were chosen to match these data.
3. Amongst the emissions data for private transport are several extreme outliers (LSOAs with average private transport emissions of over 100 tonnes per year). These can be attributed to commercial vehicles inappropriately assigned to domestic households (Cairns *et al.*, 2017). Household private transport emissions were thus capped at 10 tonnes per household per year. This affects less than 0.2% of LSOAs. It has a negligible effect on correlations but does remove some clearly spurious standard deviations.

4. Household income data are available for total income, net income, and net equivalised[15] income before and after housing costs for 2018 (ONS, 2020a). These four measures should give increasingly accurate estimates of disposable income which might be expected to correlate increasingly strongly with emissions. The derivation of these data, particularly in how they are modelled to MSOA level, however, increases in complexity which might be expected to reduce the strength of correlations. Appendix A1 reports a preliminary analysis of total household incomes against all four measures which found only small differences between correlations based on different income measures for both Stockport and England. Gross income was selected as more widely understood.
5. All LSOAs within a given MSOA were assumed to have the same household income. This grouping can be seen in the geographical distribution of incomes in Figure 3.5 and in the vertical alignment of some datapoints graphs.

3.2.4 Analysis

The primary focus of the analysis is on exploring the relationship between emissions and income using scatterplots (with each point representing a single LSOA) to give a visual representation of the relationship which is quantified in terms of the gradient of the least squares line of regression. Statistical evidence for differences in gradient between Stockport and England is presented as p-values calculated using standard statistical methods (Bland, 2009, pp. 367–8). The coefficient of determination (r^2) which expresses the proportion of the variance in emissions that is explained by the relationship with income is taken as a measure of the strength of the correlation. Grouping data by LSOA should only have a minimal effect on the line of regression but will lead to artificially high values of r^2 which are thus only used for comparing data within the study. Error bars, here plotted represent standard deviations.

Decile plots have been used to illustrate how emissions vary with income (Gough *et al.*, 2011; Preston *et al.*, 2013, 2013) and it was assumed that this would be an appropriate tool to explore differences in this relationship between Stockport and England. A preliminary investigation (Appendix A2), however, found this to give misleading results because the income decile ranges vary between Stockport and England as well as the emissions data. Decile plots are therefore used to illustrate findings but not to make comparisons.

[15] Equivalisation is a method for taking account of the economies of living in households of different sizes and compositions

3.3 Results

3.3.1 Overview of data

3.3.1.1 Emissions

Average household emissions across LSOAs in Stockport (20.9 tonnes) and England (19.9 tonnes) are very close (see Figure 3.1). In both there is some suggestion of a bimodal distribution with values in the range 16-18 tonnes being less frequent than lower or higher values. In Stockport fewer households have low emissions (only 36% have emissions less than the median for England) but more have moderately high emissions (35% have emissions falling in the third quartile for England). There appear to be more irregularities in the data from Stockport which is probably a consequence of the much smaller dataset.

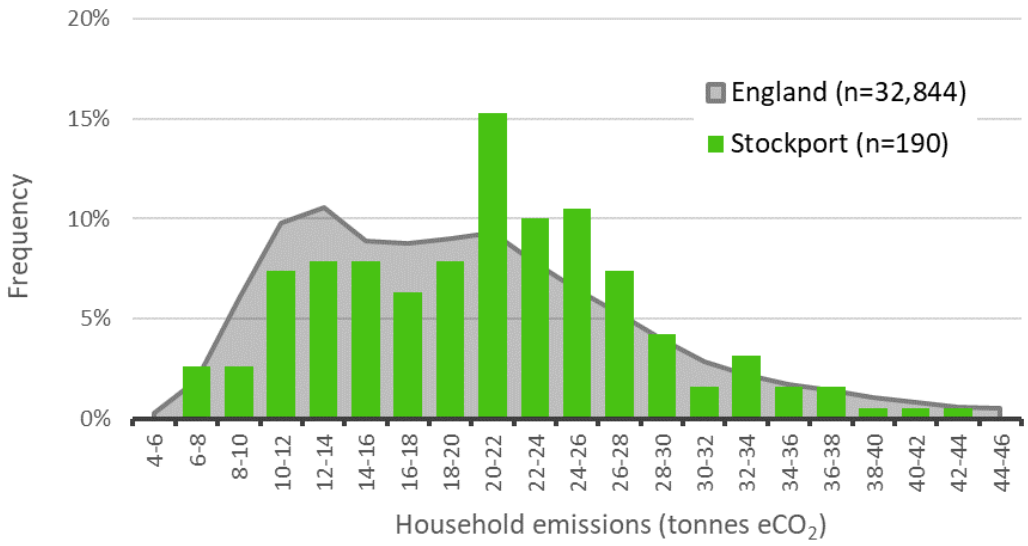

Figure 3.1. Frequency distribution of average household emissions across LSOAs in Stockport and England. Stockport data plotted as columns because of fewer datapoints.

3.3.1.2 Income

Average incomes for Stockport (£43.2k) and England (£43.9k) are also similar (see Figure 3.2). The data from England are mildly skewed whereas data from Stockport are more likely to be in the central range (62% fall within the interquartile range for England). There are, however, clusters of LSOAs with both lower (£26-30k) and higher incomes (£56-58k).

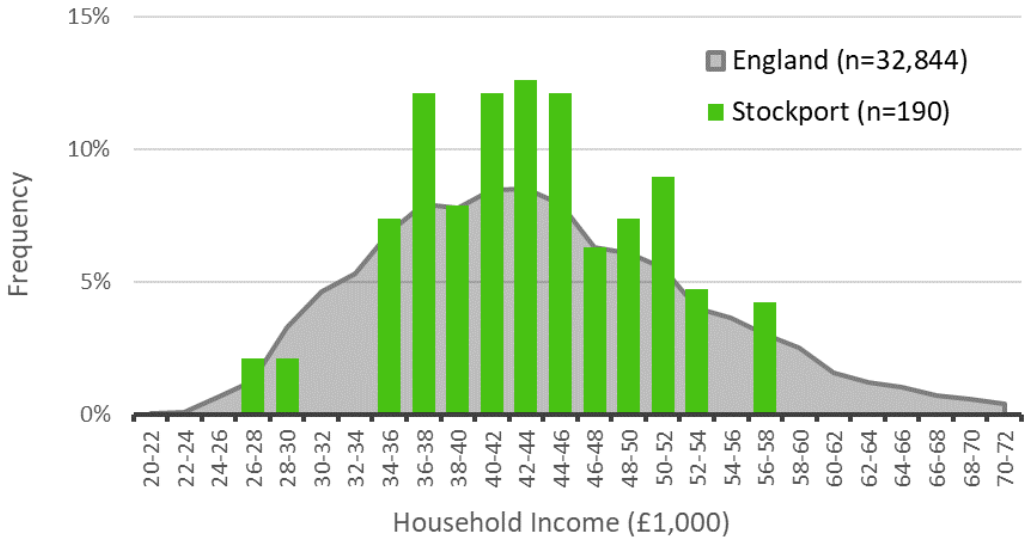

Figure 3.2. Frequency distribution for average total household income for LSOAs within Stockport and England. Stockport data plotted as columns because of fewer datapoints.

Decile ranges for household income for England and Stockport are displayed in Table 3.2. Stockport has a smaller range of salaries with a minimum salary £5k higher and maximum salary £35k lower than for England. The decile ranges vary but are smaller for Stockport (leading to the issues with decile plots described in Section 3.2.4)

Table 3.2. Decile ranges for average household income for LSOAs across Stockport and England.

	Stockport		England	
Decile	Limits	Range	Limits	Range
10	£51.5k - £56.9k	£5.4k	£57.0k - £86.1k	£29.1k
9	£49.4k - £51.5k	£2.1k	£51.7k - £57.0k	£5.3k
8	£47.2k - £49.4k	£2.2k	£48.3k - £51.7k	£3.4k
7	£44.1k - £47.2k	£3.1k	£45.3k - £48.3k	£3.0k
6	£43.3k - £44.1k	£0.8k	£42.8k - £45.3k	£2.5k
5	£41.7k - £43.3k	£1.6k	£40.5k - £42.8k	£2.3k
4	£39.8k - £41.7k	£1.9k	£37.9k - £40.5k	£2.6k
3	£37.4k - £39.8k	£2.4k	£35.4k - £37.9k	£2.5k
2	£35.1k - £37.4k	£2.3k	£32.0k - £35.4k	£3.4k
1	£26.3k - £35.1k	£8.8k	£21.3k - £32.0k	£10.7k

3.3.1.3 Relationship between total emissions and income

As expected, household emissions and income show a moderate correlation for LSOAs across England (r^2=0.36) and Stockport (r^2=0.40) with the gradient being 35% higher in Stockport (see Figure 3.3). The graph reinforces the observation from Figure 3.2 that there are fewer LSOAs with either low or high incomes than for England as a whole.

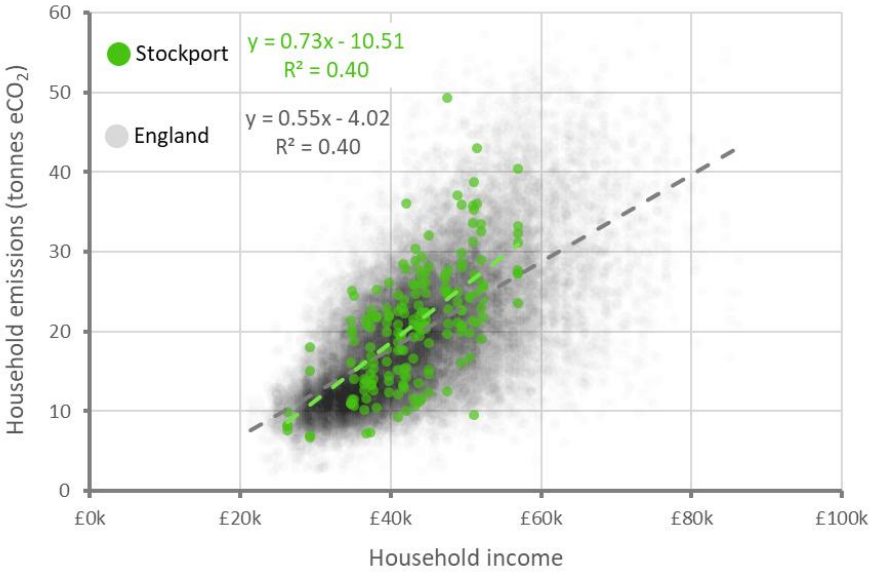

Figure 3.3. Household emissions and income for LSOAs across England and Stockport.

The general pattern of LSOA average household emissions rising with income is reinforced by grouping by income deciles (see Figure 3.4). Emissions in the 10th decile across England are about 2.5 times greater than those in the 1st decile. The general pattern in Stockport is very similar to that in England. The average increment per decile is lower in Stockport (1.6 tonnes) than in England (1.8 tonnes) despite the gradient of emissions on income being higher (see Figure 3.3). This is a good example of how decile plots can give mis-leading comparisons.

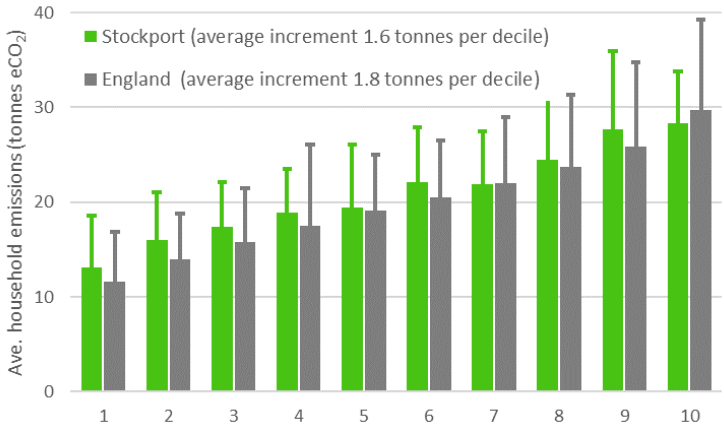

Figure 3.4. Average household emissions for LSOAs within deciles of average house income for Stockport and England (error bars represent standard deviations).

The generally similar distribution of emissions and income across England is displayed in Figure 3.5 . Both are high in the south-east and lower elsewhere and in urban areas. Across Stockport, both are high in the south and east. It is also clear however that there are considerable differences in the detail of the distribution which corresponds to the considerable scatter on the data presented in Figure 3.3. The grouping of the income data for Stockport arises because data for MSOAs have been extrapolated to LSOAs.

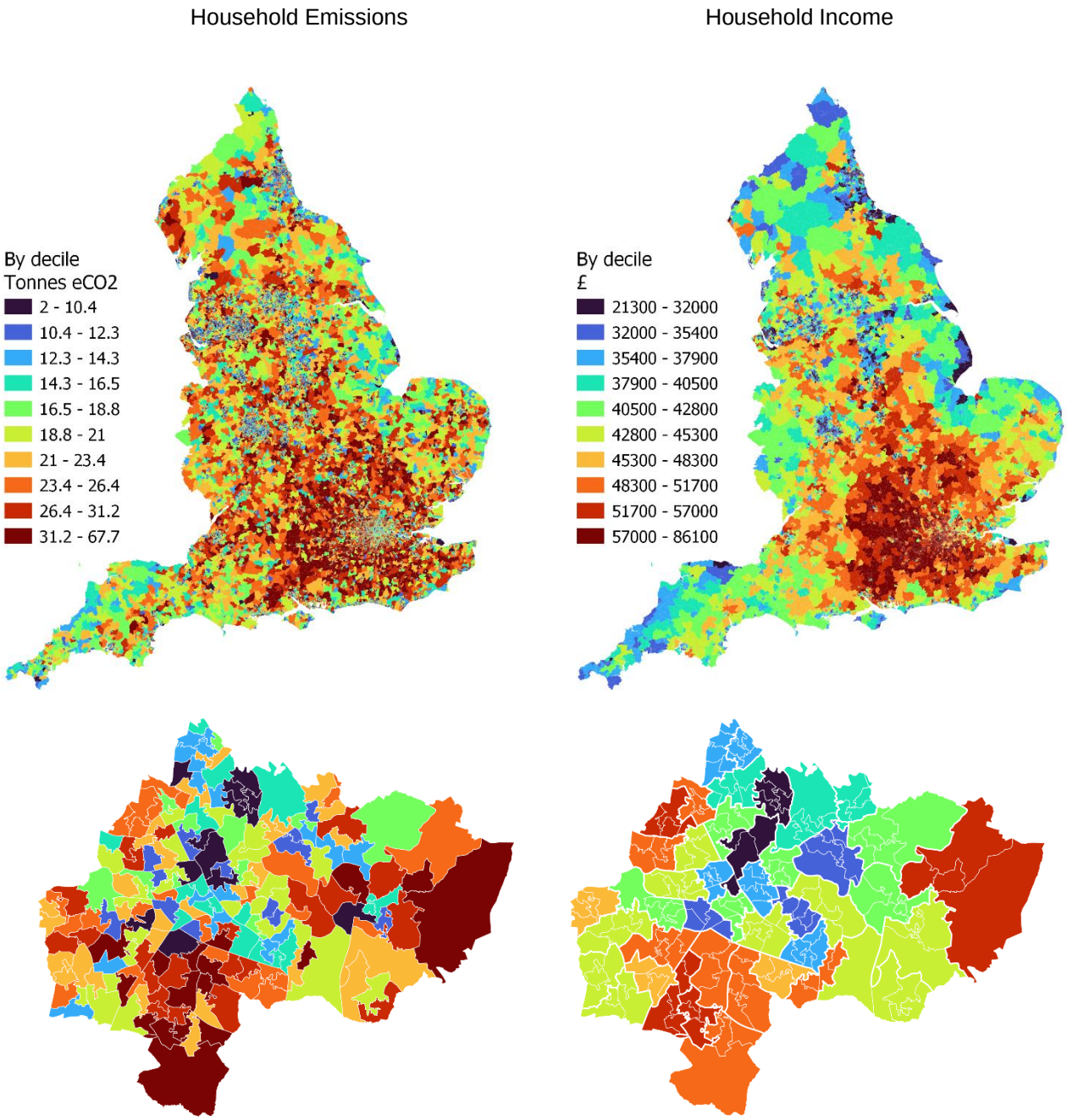

Figure 3.5. Geographical distributions of emissions and incomes LSOAs in England (top) and Stockport (bottom) colour coded by deciles by income for England. MSOA borders for Stockport depicted by thicker white boundaries.

3.3.2 Emissions by category

There are also general similarities in household emissions decomposed into different categories (Figure 3.6) although there do appear to be some differences in the detail.

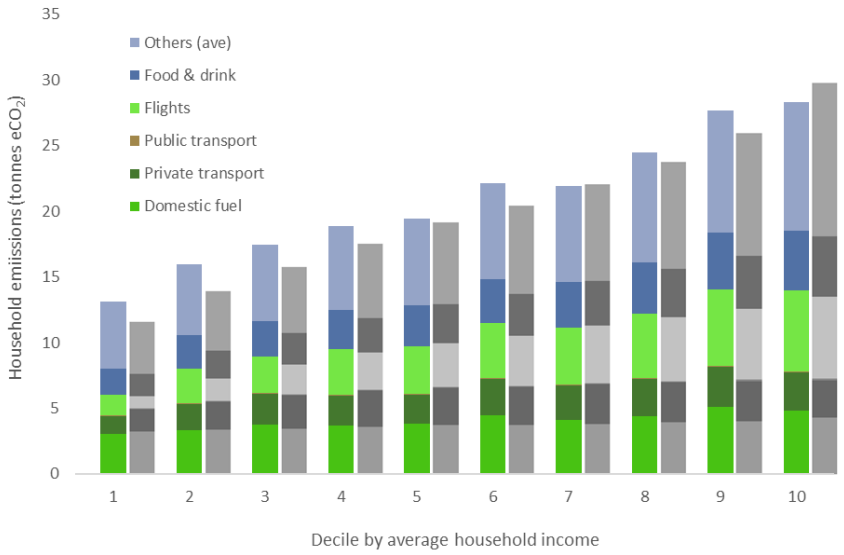

Figure 3.6. Average household emissions by average household income deciles for LSOAs for Stockport (coloured) and England (greyscale).

3.3.2.1 Domestic fuel

20% of total emissions arise from domestic fuel use in England and Stockport. Those from England vary less with income (32kg per £1,000) than any of the other categories (Figure 3.7). The low r^2 value (0.12) suggests that, across the country, factors such as house size, type and regional weather patterns, are more important than income. The higher r^2 value for Stockport (0.4) probably reflects that, in a more homogenous area, income is a more important determinant of fuel use. Emissions rise three times as steeply with income in Stockport (90kg per £5,000) for which there is no obvious explanation.

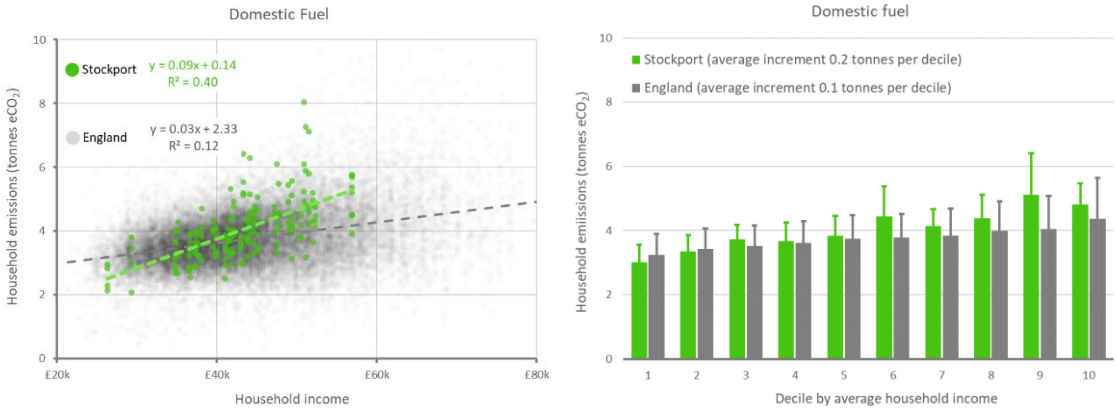

Figure 3.7. Average domestic fuel emissions against average household income for Stockport and England, ungrouped (left) and by decile (right). Error bars are standard deviations.

3.3.2.2 Private transport

Emissions from private transport account for 13% of total emissions across England and Stockport. The line of linear least squares regression for England does not appear to align with the data cloud (Figure 3.8, left) and there is a very low r^2 value (0.07). This appears to be caused by a considerable number of LSOAs with average incomes of more than £40k and low private transport emissions (<2 tonnes). Examination of the underlying data shows that most of these are from affluent inner-city areas (particularly in London).

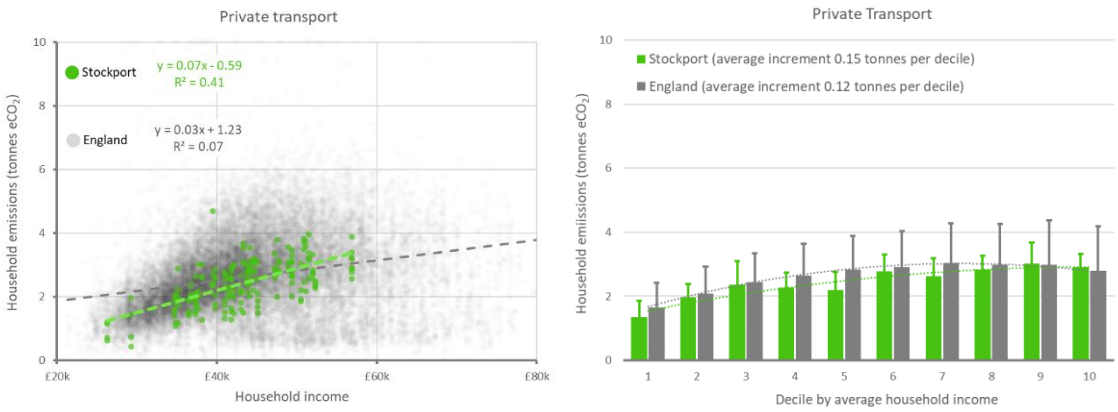

Figure 3.8. Average household private transport emissions against average household income for Stockport and England, ungrouped (left) and by decile (right). Error bars are standard deviations.

Fitting a second order linear regression only improves the fit for ungrouped LSOAs across England by a small amount but brings substantial improvement for the same data grouped by deciles (from r^2=0.68 to r^2=0.99, Figure 3.8, right). This suggests that, once other sources of variation have been averaged out, the relationship is not linear. Emissions from private transport grow across the lower incomes (deciles 1-4) but remain broadly constant from above this (deciles 5 to 10). This is levelling out is also much less apparent if data from affluent inner-city areas in London is removed.

Emissions from private transport in Stockport rise with income 119% more steeply than for England (Figure 3.8, left). This difference is reduced to less than 5% if London is removed from the English data, suggesting that it is London that is atypical rather than Stockport.

3.3.2.3 Public transport

Public transport accounts for a very small percentage of household emissions (less than 0.5%). Within this there is a very weak trend for an increase of emissions with income across England but no increase at all within Stockport (see Figure 3.9).

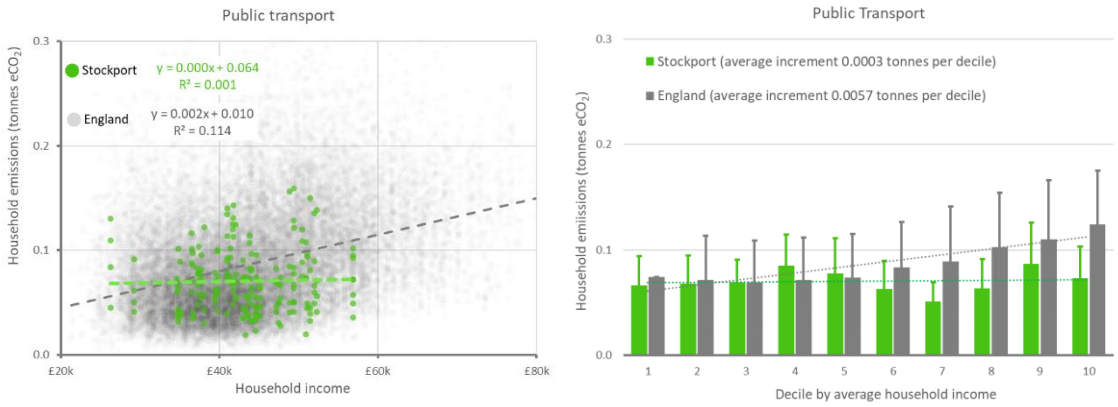

Figure 3.9. Average household public transport emissions against average household income for Stockport and England, ungrouped (left) and by decile (right). Error bars are standard deviations. Values are small compared with other categories and axes have been altered accordingly.

3.3.2.4 Flights

Flights make up 18% of total household emissions for England (and 19% for Stockport, Figure 3.10). They show the steepest trend with income of any category with many low-income LSOAs not registering any emissions from flying at all. Average emissions for flying from the 10th decile are over 6 times those in the 1st decile for England. The gradient is even steeper for LSOAs in Stockport.

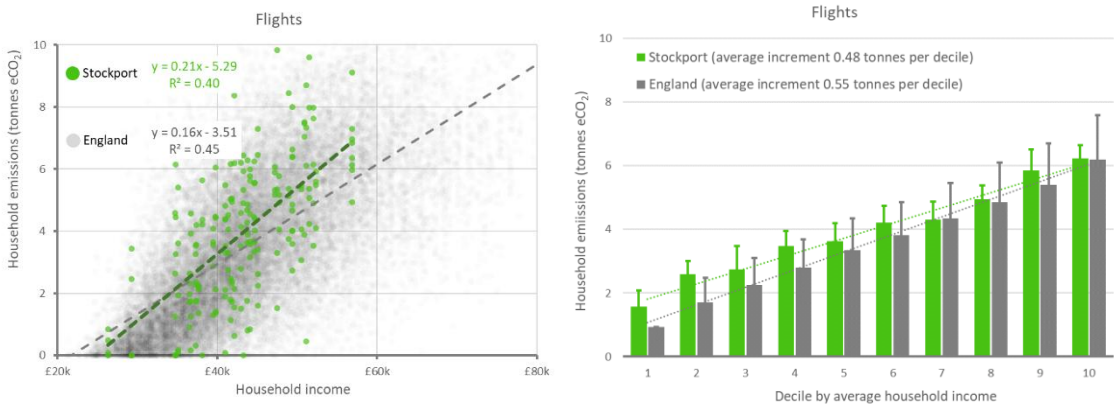

Figure 3.10. Average household flight emissions against average household income for Stockport and England, ungrouped (left) and by decile (right). Error bars are standard deviations.

3.3.2.5 Food and drink

Emissions from food and drink constitute 16% of total household emissions in England (and 15% in Stockport, Figure 3.11). Both rise steadily across the income spectrum with a 35% steeper gradient in Stockport.

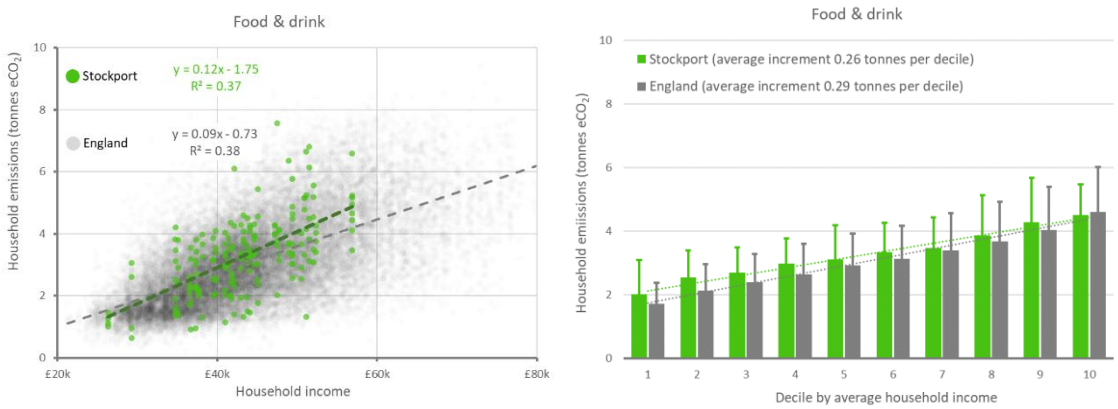

Figure 3.11. Average household food and drink emissions against average household income for Stockport and England, ungrouped (left) and by decile (right). Error bars are standard deviations.

3.3.2.6 Other emissions

Emissions from other sources make up 34% of total household emissions in England and Stockport (Figure 3.12). Both the gradient and amount of scatter are similar across both areas.

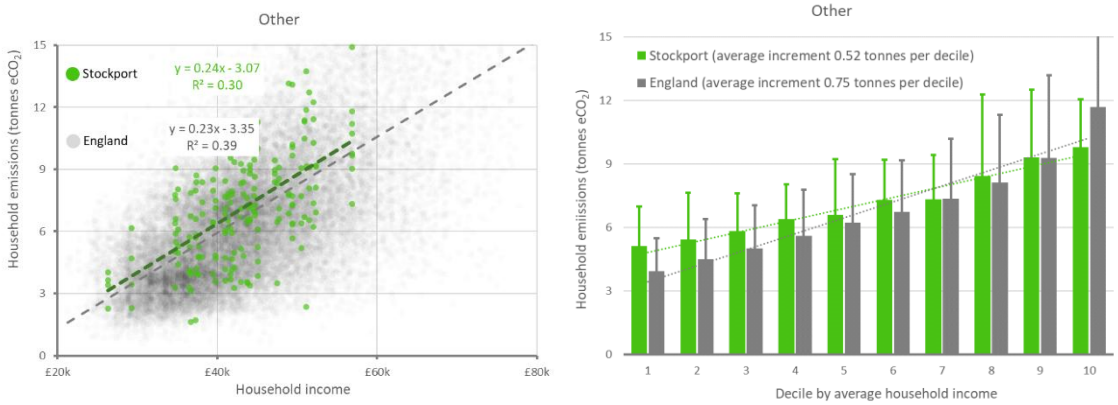

Figure 3.12. Average household “other” emissions against average household income for Stockport and England, ungrouped (left) and by decile (right). Error bars are standard deviations.

3.3.2.7 Statistical significance

The large number of data points for England (32,844) and Stockport (190) means that even relatively small gradients, and differences in gradients, of the line of least squares regression of emissions on income will be statistically significant. Table 3.3 reflects this with most p-values being extremely small. Differences of all gradients from zero were very highly statistically significant except for that for public transport for Stockport. Similarly, differences

between the gradients for data from Stockport and England were all highly significant apart from that for “other emissions”.

The possibility of these differences arising for methodological reasons was explored further. Changing the measure of income (total/net/equivalised before/after housing) had little effect suggesting that this was not a consequence of differences in how disposable income relates to total income. Restricting the data for England to LSOAs with average incomes within the range found in Stockport had little effect either, suggesting the differences were not driven by outliers in the England dataset. Comparing Stockport against either the north-west, or north of England did substantially reduce the differences in gradient to a level where they were not significant for total emissions and the three modelled categories (flights, food & drink, and other) and differences for measured categories (domestic fuel and private transport), whilst still statistically significant, were very much smaller.

Table 3.3. P-values for gradients of lines of least squares regression for different categories of household emissions against income. Note that although quoted to three significant figures most of the values are extremely small (the largest value recorded below as <0.001 was $1x10^{-6}$).

Category	Gradient differs from zero		Gradient higher in Stockport than England	
	Stockport	England		
	p-value	p-value	p-value	%
Total	<0.001	<0.001	0.005	33%
Domestic fuel	<0.001	<0.001	<0.001	179%
Private transport	<0.001	<0.001	<0.001	118%
Public transport	0.676	<0.001	<0.001	-92%
Flights	<0.001	<0.001	0.006	33%
Food & drink	<0.001	<0.001	0.007	35%
Other	<0.001	<0.001	0.863	2%

3.4 Discussion

This section focusses on discussion of the overall findings and the limitations of this type of analysis. Section 4 has a more detailed discussion of how results might affect Council policy.

3.4.1 Overview of data

Despite the Council presenting the Borough as one of the most socio-economically polarised within England (SMBC, 2021a, p. 13) the results show fewer LSOAs with either particularly low or high average household incomes than England (see Figure 3.2). The basis of the Council’s claim is unclear but appears to be that 4 LSOAs falling in the first percentile by Index of Multiple Deprivation (IMD, MHCLG, 2019) for England is twice the number expected (SMBC, 2022c). These LSOAs are obvious as outliers in Figure 3.2 with low average household incomes. Stockport, however, ranks at almost exactly middle of the range for

English local authorities on the basis of the Gini Index, the most widely used metric of inequality (Rae and Nyanzu, 2019), and is probably better described as relatively homogenous socio-economically apart from four pockets of severe deprivation.

Although the data confirms a correlation between total household emissions and income, the r^2 values suggest that the relationship only explains 40% of the variance in emissions (see Figure 3.3). Grouping data by LSOA, inflates r^2 values, suggesting even less of the variance between individual households might be accounted for by income. This is an important reminder that although income is the most important single determinant of emissions, a combination of other less well understood factors is at least as important.

Table 3.4 summarises the results for all emissions categories. Five of the categories seem well chosen in that they represent substantial and different contributions to overall emissions. Public transport, by contrast, represents less than 0.5% of all emissions and adds little to the overview. Emissions from all categories rise with income but by quite different amounts (Table 3.4). Emissions from essentials (domestic fuel, land transport and food & drink) rise relatively modestly with income whereas discretionary categories (flights and "other") rise more steeply.

Table 3.4. Summary of principal findings of study. Average emissions for Stockport and London by category and the increase in emissions for each £5,000 increase in household income. ** indicates difference between Stockport and England is significant ($p<0.01$).

Average household emissions (tonnes eCO_2)

	Increase per £1,000 income (kg CO_2e per household)		
	Stockport	England	p
Total	727	546	**
Other	236	232	
Food & Drink	116	86	**
Flights	214	161	**
Public transport	0	2	**
Private transport	70	32	**
Domestic Fuel	90	32	**

Although average household emissions are only 5% higher for Stockport than England, gradients for total emissions (and most categories) with income are significantly higher. An exploratory analysis suggests that this is a characteristic of the North of England rather than specific to Stockport. Given than the North is less affluent, this agrees with data from Ivanova and Wood (2020, Fig 6a) suggesting that emissions rise more steeply with income in less affluent states across Europe. Private transport emissions increase less with income across England, probably because of the influence of the large population living in and around

London who are more dependent on public transport whatever their income. Domestic fuel emissions rise three times more steeply with income than across England but there is no obvious explanation for this.

Analysing emissions by decile has limitations (see Appendix A2) but does allow comparison with previous studies. The ratio of emissions from the 10th and 1st deciles across England is 2.6 for this study which agrees reasonably well with 2.8 from Gough *et al.* (2011) and 3.2 from Preston *et al.* (2013), and a little less well with 4.6 from Ivanova and Wood (2020), who used a quite different methodology. More quantitative comparisons are not appropriate because of the range of different methodologies and units of reporting. Likewise qualitative trends within different categories reflect previous studies cannot be compared quantitatively.

3.4.2 Limitations

Perhaps the most important limitation of this study is the unknown accuracy of the emissions data. Domestic fuel use is collated at postcode level (DESNZ/DBEIS, 2022) but allocating all other emissions to LSOAs requires substantial modelling from quite limited datasets. Although broad geographic trends in the data appear reasonable, there have been no validation studies to explore how reliable data is at a more granular level. Using estimates of income that are only specific to the larger MSOAs also reduces the granularity of data.

A particularly concerning issue arises from estimates of emissions in the three categories (flights, food & drink and other) that are modelled on the basis of household income (Morgan *et al.*, 2021). This should result in a well-defined (although not necessarily linear) relationship between emissions and income. Instead, the scatter on the plots (Figures 3.10, 3.11 and 3.12) looks quite random and the r^2 values suggest that less than half the variance can be attributed to income. Dr Morgan was contacted about this and explained that in the absence of income data for LSOAs from government sources their group had purchased commercially available estimates, and that emissions data was modelled separately and non-linearly for different sub-categories. Whilst this would explain some scatter, it is still surprising that there is so much and undermines confidence in this modelling approach[16]. The broad conclusions of this study are from data across 190 LSOAs are probably still valid but data for individual LOSAs should be treated with some caution.

It has already been observed that plotting emissions data by decile tends to underemphasize differences between Stockport and England (in comparison to scatter plots of the underlying data). This is because the decile plots mask the component of emissions that is driven by differences in relative rather than absolute incomes. It confirms that decile plots present a poor method for comparing the relationship between income and emissions for different areas (although they are still very useful for communicating general trends).

[16] Although comparisons reported here are for total income, similar analyses were conducted for net income and equivalises income before and after housing costs and all showed similar levels of scatter within the data.

3.4.3 Suggestions for further work

The general usefulness of localised data in relation to policy making at a Council level is discussed in Section 5. The most useful extension of this work would be some local data gathering to validate the accuracy of the modelled data. It would also be useful to use income estimates that are specific to individual LOSAs. An alternative dataset, *Admin-based income statistics* (ONS, 2022a) is currently being developed drawing on data from the tax and benefit systems but is still regarded as experimental and still contains obvious anomalies (see Appendix A1).

It would be useful to repeat some parts of this analysis over different areas both to explore how much variation there is between regions and to determine whether differences between Stockport and England are specific to Stockport or to Greater Manchester or the North of England (as suggested by the exploratory analysis of the total emissions data).

4 How might a localised understanding of consumption-based emissions influence Stockport Metropolitan Borough Council policies to reduce emissions from domestic fuel?

4.1 Policy focus

4.1.1 Categories

Effective emissions reduction policy will focus on high-impact categories and high-emitting groups (Whitmarsh *et al.*, 2021) and the analysis presented in this dissertation can help to identify what and who these are within Stockport. Figure 1.4, shows that average consumption-based emissions are 119%[17] higher than territorial emissions (as described in Section 1.5). Both estimates of emissions from domestic fuel are similar (as expected), and consumption-based private and public transport emissions are only a little less than territorial land transport emissions (because these include commercial vehicles). Consumption-based emissions from flights, food & drink and "other" categories however, are over 5 times greater than the combination of territorial emissions for industry, commerce, public sector and "other" categories.

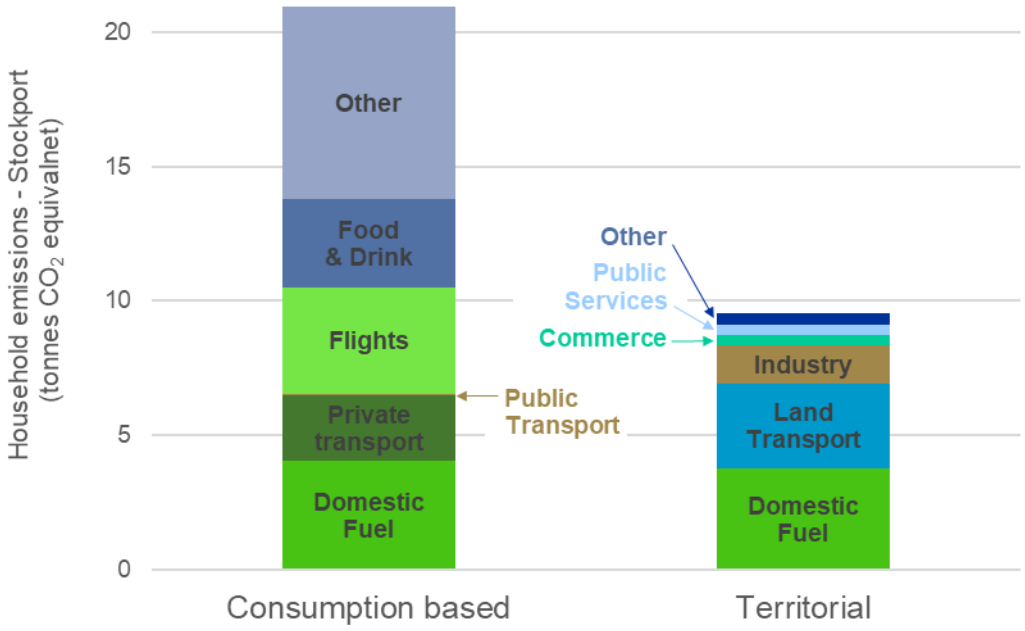

Figure 4.1. Consumption-based and territorial emissions for Stockport (compiled from data already presented in Figure 3.6 and Figure 1.5).

[17] The equivalent figure for England as a whole is 42% which is so much lower because, despite having very similar consumption-based emissions to England as a whole (Section 3.3.1.1), Stockport has much lower territorial emissions (Section 1.5).

Council policy will be most effective in categories with the highest emissions but also depends on what influence it can exert. Unfortunately, these vary reciprocally. The Council has little control over most of the emissions which occur outside the Borough, more control over those within the Borough, and even more over its own emissions (which are only 5% of boroughwide emissions, SMBC, 2020b). A balanced policy portfolio will thus contain measures across all three of these domains. Achieving net-zero for the Council by 2030 and Borough by 2038 are presented as targets of equal importance in the most recent CAN Annual Report (SMBC, 2023c) which allocates an approximately equal number of paragraphs to initiatives addressing each. It makes no reference, however, to consumption-based emissions arising outside the Borough.

As an example of data-informed policy making, the rest of this section will focus on domestic fuel, the biggest single category of consumption-based (19% of total) and territorial emissions (40%). 74% of these come from heating fuels and rest comes from electricity use, which will include some heating (Morgan *et al.*, 2021). This reinforces at a local level the Committee on Climate Change's recent statement that "reducing energy demand in UK buildings is now the biggest gap in current energy policy" (CCC, 2022, p. 1). It is thus appropriate that the CAN Strategy focuses on the area of *Low Carbon Buildings,* but the tendency to focus on retrofit of Council buildings (including schools), develop an eco-business park and redevelop Town Centre West (although this will include some housing) is doing little to address most emissions which are from domestic buildings.

4.1.2 Groups

Domestic fuel emissions for Stockport rise with income by 0.2 tonnes per decile group on average (see Figure 4.2), and figures from the 2021 census (ONS, 2023) reveal that Stockport has high levels of home ownership (71% compared to 61% for England as a whole). The target group for emissions reduction policy should thus be middle- and high-income homeowners.

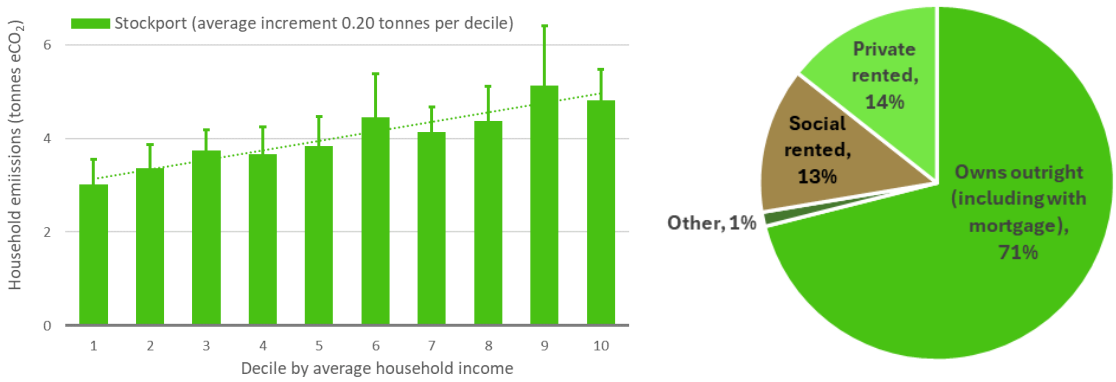

Figure 4.2. Emissions from domestic fuel use by income decile (extracted from Figure 3.7) and percentage of households by tenure for Stockport and England from 2021 census (ONS, 2023).

Where Council policy does address domestic fuel use, however, the focus is on retrofit of properties owned by Stockport Homes (SMBC, 2020b, 2023c) for social renting. Assuming

tenants are within the 1st decile by income then the 10% of homes managed by Stockport Homes (Stockport Homes, 2023) will be responsible for only 8% of total domestic fuel emissions. The CAN Annual Report (SMBC, 2023c) does refer to the partnership with the Greater Manchester Retrofit Task Force but this also focuses on low-income households (GMCA, 2022a). Without undermining the importance of supporting those affected by fuel property, emissions are disproportionately driven by wealthier households and any emissions reduction strategy must include policies to reduce their emissions as well.

At an international level, the Rio Declaration (UN, 1992) places an emphasis on high income countries who are most responsible for emissions to take the lead in addressing climate change. There is a strong argument to apply this to high-income groups within countries which would further support an increased emphasis on wealthier households.

4.2 Reducing emissions from domestic fuels for middle- and high income homeowners

4.2.1 Context

The UK made considerable progress in reducing total domestic energy consumption by 20% between 2005 and 2015 (DESNZ, 2023c, see Figure 4.3) despite an 8% increase in the population (ONS, 2024a). Reductions were larger in Stockport (25%), partly because its population only rose by 2%. Changes were driven by public policies focussing on retrofit (improving insulation and the efficiency of heating) in existing properties, primarily those of low-income families (Rosenow *et al.*, 2018; DBEIS, 2021b; Glew *et al.*, 2021).

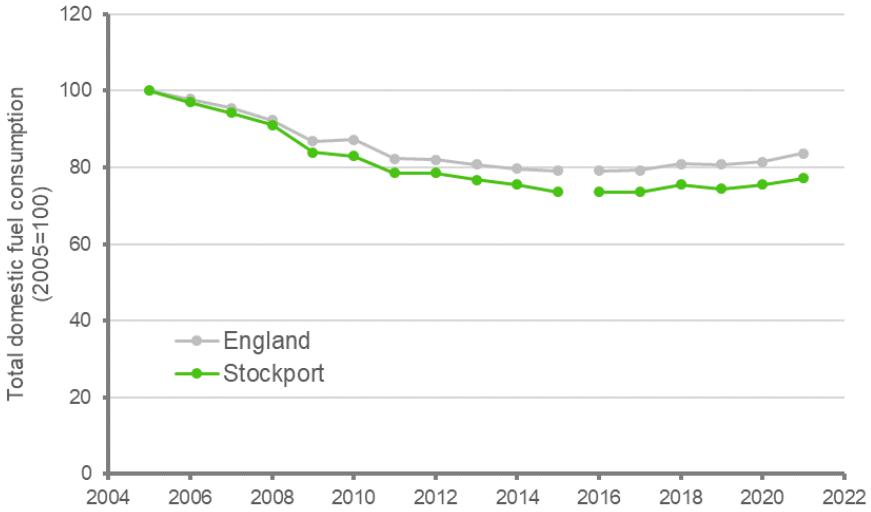

Figure 4.3. Total domestic fuel use referred to a 2005 baseline for England and Stockport. Break in line between 2014/5 is to emphasize difference in trends at about that time (Glew *et al.*, 2021).

Unfortunately, reductions stopped in about 2015 (see Figure 4.3) after funding for the *Energy Company Obligation Scheme* (Adcock and Hinson, 2020) was reduced by over 50% (Glew

et al., 2021) at a time of increasing costs because most easier to treat properties had already been upgraded (Environmental Audit Committee, 2021; Morgan *et al.*, 2023). This was compounded by the announcement of the *Green Deal* (Morse, 2016). Homeowners delayed and cancelled orders in the expectation of generous future financial support, but many orders were not reinstated when the actual loan package failed to deliver this, "inflicting lasting damage to the retrofit sector" (Bergman and Foxon, 2020, p. 6). The government was also criticised for policy that was inadequate (BEIS Committee, 2019), stop-start and poorly implemented (Environmental Audit Committee, 2021).

There is still considerable potential for further improvements. Only 34% of Energy Performance Certificates (EPC) for domestic buildings in Stockport (42% for England) are in the top three bands (DLUHC, 2023) and ensuring that all properties meet this standard by 2035 is a key component of the Government's Clean Energy Strategy (DBEIS/DESNZ, 2018; DBEIS, 2021a). Rosenow *et al.* (2018) suggest that between a quarter and half of all energy used in UK households could be cost-effectively saved by 2035 (and this was before recent rises in domestic energy prices which make improvements even more cost-effective). As a result of previous government support focussing on low-income families (Glew *et al.*, 2021), households in less deprived areas (most of Stockport) now offer twice the potential to reduce emissions through retrofit at a lower cost per tonne of emissions reduction (see Figure 4.4, Ampatzidis *et al.*, 2023).

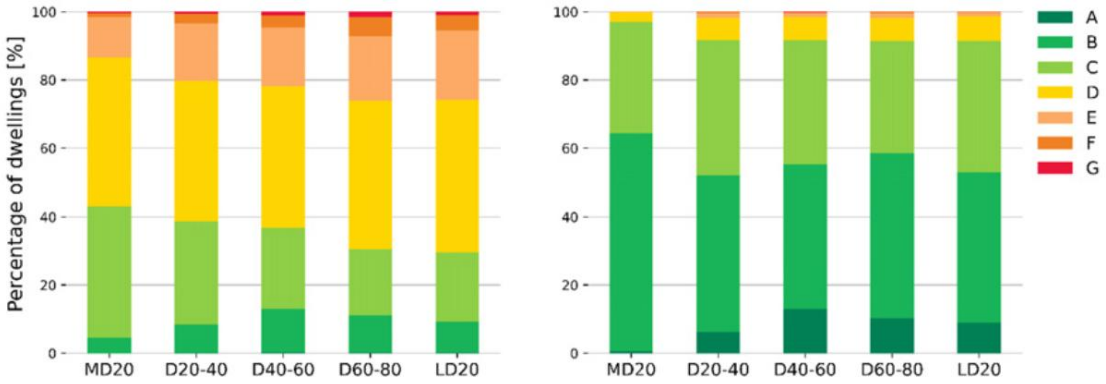

Figure 4.4. Actual (left) and potential (right) households by Energy Performance Certificate ratings grouped (A is most energy efficient) into quintiles according to the Index of Deprivation from most deprived (MD) to least deprived (LD) in England and Wales (Ampatzidis *et al.*, 2023).

Several national trends are offering a window of opportunity to promote retrofit. The *Great British Insulation Scheme* (OFGEM, 2023b) offers grants for insulation (until 2026) and the *Boiler Upgrade Scheme* (OFGEM, 2023a) for heat pumps or biomass boilers (until 2028). Both are available regardless of income. Government figures suggest that uptake on both schemes is rising (DESNZ, 2023b, 2023a) but still far less than budgeted for. A further factor is that higher-income groups, who are responsible for the largest emissions, have accumulated substantial wealth over the last 15 years despite stagnation in the rest of the economy (Bourquin *et al.*, 2022). Recent rises in domestic fuel prices have added to a

renewed interest in retrofit and installations of air source heat pumps were 150% higher in 2023 than 2020 and the number of certified contractors is rising correspondingly (MCS Foundation, 2024). Finally, the government has now committed to “rebalance” gas and electricity prices (HM Government, 2023) which will make fuel pumps even more cost effective.

4.2.2 Policy Framing and Objective

Given that national government has established the Great British Insulation and Boiler Upgrade schemes, the primary requirement of the council is to encourage residents to use them and start retrofitting. This change in behaviour can be enhanced by learning lessons from both previous experience and the behaviour change literature.

Several scathing reports identify weaknesses in the Green Deal (2013-15) and Green Homes Grant (2020-22) which led to very low levels of take-up (Morse, 2016; Bergman and Foxon, 2020; Environmental Audit Committee, 2021). Morgan et al. (2023) make a strong case that the fundamental problem was framing the schemes as investment for a financial return for the householder, effectively translating a collective emissions reduction policy into an individual economic decision. Unfortunately, although simple measures like loft and cavity wall insulation, draught exclusion and energy efficient lighting are cost-effective, other measures like double-glazing, solid-wall insulation and heat pumps take much longer to payback (Hall and Caldecot, 2016). Informed and motivated residents have already taken cost-effective measures and are unlikely invest in those that are less cost-effective.

The most obvious alternative framing is as a response to climate change. In a comprehensive review, however, Hornsey *et al.* (2016) found a only a small to moderate link between climate change beliefs and pro-environmental action (the “environmental attitude-behaviour gap”). Several studies (Setton, 2019; Hornsey and Fielding, 2020; Venghaus *et al.*, 2022) now suggest that this is particularly pronounced when the desired behaviour is costly (either financially or in other ways). A second possible re-framing, as an infrastructure issue (Bergman and Foxon, 2020), is useful for directing government policy but offers little to enthuse public engagement.

More recently, framing retrofit as a mainstream home improvement that enhances a house’s aesthetics, ease of living and value has been suggested (Hall and Caldecot, 2016, p. 14; Bobrova *et al.*, 2024). This aligns retrofit with something familiar and understood rather than new and challenging and with the £28 billion that was spent on private sector domestic renovation, maintenance and improvement in the UK in 2022 (ONS, 2024b). This dwarfs the £150 million allocated annually by the government for the Boiler Upgrade Scheme (OFGEM, 2023a). Scaling up retrofit will also be easier if this is managed as a natural extension of the already mature building industry rather than as a new sector of the economy that must be grown (Killip *et al.*, 2021).

Framed in this way the policy objective might be:

> *To work in partnership with homeowners in Stockport to improve the comfort, aesthetics, ease of living and value of their homes in ways that are consistent with the Borough becoming net-zero by 2038.*

The following sections explore how a policy framed like this might be implemented.

4.2.3 Policy Principles

4.2.3.1 Multiple approaches and channels

Policy to influence the behaviour of homeowners must be based on an understanding of what drives their decision-making. Perhaps most important is recognition that different people are driven by different concerns and that within households decisions will often be taken jointly by individuals who have differing perspectives. There have been a number of attempts to categorise potential retrofitters to provide a framework for tailoring policy (Haines and Mitchell, 2014; Poortinga and Darnton, 2016; Ben and Steemers, 2018; Broers *et al.*, 2021; Dolšak, 2023) but there is little agreement between studies and a more pragmatic approach is to accept that a variety of different approaches and different channels of communication will be needed. (It is also interesting that none of these studies found concern for the climate to be a widespread driver for decision-making, confirming that framing policy in terms of home improvement is likely to have wider reach.) Care should be taken that different messages for different audiences are presented as reinforcing rather than contradictory. Whilst the overall requirement is for plurality, financial, technical and pro-environmental messaging are already strongly represented. The primary requirement is thus for messaging that focuses on retrofit as home improvement.

4.2.3.2 Appealing to emotion as well as cognition

Retrofit has generally been promoted as a rational response to financial, technical and environmental understanding (Dolšak, 2023; Morgan *et al.*, 2023). The word “home”, however, has personal, familial and social connotations, and framing retrofit as a *home* improvement is a reminder that emotional factors are also important (Hall and Caldecot, 2016; Tjørring and Gausset, 2019; Bobrova *et al.*, 2024). Bobrova et al. (2024), have proposed a *Home for the Common Future Heuristic* which focuses on *happiness in everyday life*, a *caring identity* and *future-resilience*, although the general concept of engaging with people’s emotions is probably more important than the precise choice of language. Ensuring emotional appeal should include consideration of video, images and broader graphic design.

4.2.3.3 Behavioural science-based interventions

Since 2015, organisations have shown increasing interest in setting science-based targets (Bjørn *et al.*, 2023) but less attention to selecting science-based interventions. A recent second-order meta-analysis (Bergquist *et al.*, 2023), has confirmed a growing consensus regarding the relative effectiveness of different categories of interventions to promote

climate change behaviours (see Table 4.1). These categories will be used to explore how policy can be informed by the emerging evidence base from the behavioural sciences.

Table 4.1. Comparative effectiveness of different interventions for climate change behaviours (Bergquist *et al.*, 2023). The overall effect size (d) is the improvement in a measure divided by its standard deviation and can thus be used to give an indication of relative effect between quite different studies (more effective interventions have larger overall effects).

Intervention	Number of primary studies	Overall effect (d)
Social comparison	199	0.37
Financial Incentives	73	0.32
Appeals	10	0.28
Commitment	67	0.27
Feedback	120	0.16
Education	121	0.09
Overall	1,178	0.31

Social comparison

Pro-environmental behaviours are heavily influenced by social norms defined as how people perceive behaviour and opinions of others (Schultz *et al.*, 2007; Frederiks *et al.*, 2015; Cialdini and Jacobson, 2021; Whitmarsh *et al.*, 2021). Cialdini (2003) distinguished between *descriptive* norms (what people think their peers are doing) and *injunctive* norms (what people think their peers approve or disapprove of). He and Qian (2023) have recently concluded that the decision to retrofit is primarily driven by injunctive norms, whereas the extent of retrofit is more influenced by descriptive norms.

A prerequisite of the formation of any social norms is that behaviour is visible (He and Qian, 2023). Bolllinger et al. (2022), for example, showed greater adoption of new solar panels in neighbourhoods where existing panels were visible from the road and Tjørring and Gausset (2019) provide anecdotal evidence of home owners prioritising visible renovations over more cost-effective invisible ones. Several of the most effective energy saving measures, however, are invisible (wall and loft insulation) or internal (low-energy lighting), and most heat pumps are designed to be unobtrusive and positioned to minimise visibility[18].

Visibility has an impact on *pluralistic ignorance* (Miller and McFarland, 1987), which leads people to under-estimate the support for pro-environmental views among their peers (even in they hold strong pro-environmental views themselves, Sparkman *et al.*, 2022). This can

[18] As opposed to many electric vehicles which are designed to be eye-catching and parked at the front of a house.

be reinforced if pro-environmental actions that are taken by others are not visible (Hoffmann *et al.*, 2024).

Fostering peer-interaction is important to diffuse innovative ideas (Rogers *et al.*, 2014; Southwell and Murphy, 2014; Bolton *et al.*, 2023). Brobova et al. (2021, p. 1) state that "the positive retrofit experience of homeowners is crucial to develop capacity and to convince others to retrofit their homes". McMichael and Shipworth (2013) found that seeking information amongst personal contacts increased the likelihood of adopting innovations up to four times.

It is also important to understand potential pitfalls. Schultz et al. (2007), first described the *boomerang effect*[19] by which information about average energy consumption was found to reduce demand among households using more than that average but increase it in those using less. Fortunately, they also found that supplementing injunctive messaging alongside the descriptive information minimised the effect. *Reactance* is a negative response to policy perceived as threatening individual rights or freedoms (Brehm, 1966; Steindl *et al.*, 2015). *Moral licencing* occurs when people who have taken one positive action feel entitled to take a different negative action (Miller and Effron, 2010). Tiefenbeck *et al.* (2013) for example, found that a group of residents who decreased water consumption in response to metering data actually increase electricity consumption.

Policy, and particularly messaging, thus need to be formulated to reinforce supportive descriptive and injunctive norms, or to modify unhelpful ones. In this there should be a particular emphasis on increasing the visibility, whether physical or metaphorical, of invisible measures such as wall and loft insulation and heat pumps.

Financial incentives

The Great British Insulation and Boiler Replacement schemes, high fuel prices and the government's intention to a future rebalancing of gas and electricity pricing, combine to create the strongest financial incentives for retrofit that have been available in the UK for middle- and high-income homeowners. Although the cost-of-living crisis has hit many sectors of the economy extremely hard, expenditure on domestic renovations, maintenance and improvements is now 40% higher than before the pandemic (ONS, 2024b). Framing retrofit as home improvement will reduce the emphasis on return on investment as renovation is driven primarily to improve comfort, aesthetics and ease of living (Hall and Caldecot, 2016). Having said this, Fuerst et al. (2016) found that house prices are 3% higher for each EPC category, equivalent to over £8,000 for the average house price in Stockport (£280,000, Rightmove, 2024). More recent commercial analyses of objective data suggest even higher premiums for energy performance (KnightFrank, 2024; Lloyds, 2024) although subjective surveys of estate agents tend to be less positive (e.g. estateagenttoday, 2024).

[19] Schultz et al. (2007) referred to this as *the* boomerang effect although the term is also used much more generally to describe any unintended consequence (e.g. Byrne and Hart, 2009)

On balance, council policy should focus on promoting existing incentives rather than providing new ones (for which it has limited resources anyway).

Appeals and Commitment

Appeals urge or demand people to act and *commitments* allows them to formalise their response and these appear only a little less effective than financial incentives (Bergquist *et al.*, 2023). Most research, however, has been into maintaining ongoing behaviours rather than engaging in a single activity such as a retrofit. There may also be some publication bias as studies often focus on those who have committed rather than the whole population (Nisa *et al.*, 2019). On balance, appeals and commitments will probably not play a large part in policy for Stockport but should be considered as options.

Information and Feedback

There is a strong consensus in the literature that information alone has a limited effect on pro-environmental behaviours (Schultz, 2014; Nisa *et al.*, 2019; Bergquist *et al.*, 2023). Bergquist et al. (2023) assume this is because knowledge is a necessary but insufficient driver for behaviour change. Kerr and Winskel (2020) reviewed formalised information, such as Energy Performance Certificates and energy assessments, and found it has limited effect because it is too specific and technical for those who are unaware of the issues and not specific enough for those that are. Developing the home improvements framing, most renovators will decide what they want to do using quite general and superficial knowledge, and then seek out tradespeople to carry it out without needing more detailed knowledge themselves (Gram-Hanssen, 2014). Christensen et al. (2014) suggest that signposting to qualified tradespeople (or detailed DIY instructions) could be more useful than providing information directly. Paradoxically, despite being the least effective policy instrument, providing information is probably the most widely adopted. There is almost certainly no need for the Council to provide more technical information.

4.2.3.4 One Stockport

A final principle is that any new policy in this area should complement existing policy. Whilst this area clearly links most closely with the *Low Carbon Buildings* and to a lesser extent with the *Renewable Energy* areas of the CAN Strategy (SMBC, 2020b), the focus on the domestic properties also suggests links to *Climate Friendly Borough*. Within the broader *One Stockport* plan (SMBC, 2021a) a focus on home improvement also links strongly to *Wellbeing in Neighbourhoods* and *Investment, Regeneration and Creating Jobs*. Wherever possible policy should be refined and implemented in partnership with private, public and the third sectors.

4.2.4 Policy recommendations

4.2.4.1 Target

The Council should adopt a formal target to reduce domestic fuel emissions that is compatible with the Tyndall Centre pathway for overall emissions (Kuriakose *et al.*, 2020). The salient features of this are a 13.1% reduction each year from a 2019 baseline as depicted in Figure 4.5. It is reassuring that required reductions in total emissions are not that different from those achieved between 2005 and 2020. The minimal change in gas consumption since 2015, however, is a reminder that much of this progress has come from decarbonisation of the electricity[20] supply and that any future progress will require reducing demand through retrofit and transitioning from gas to electric heating (mostly heat pumps).

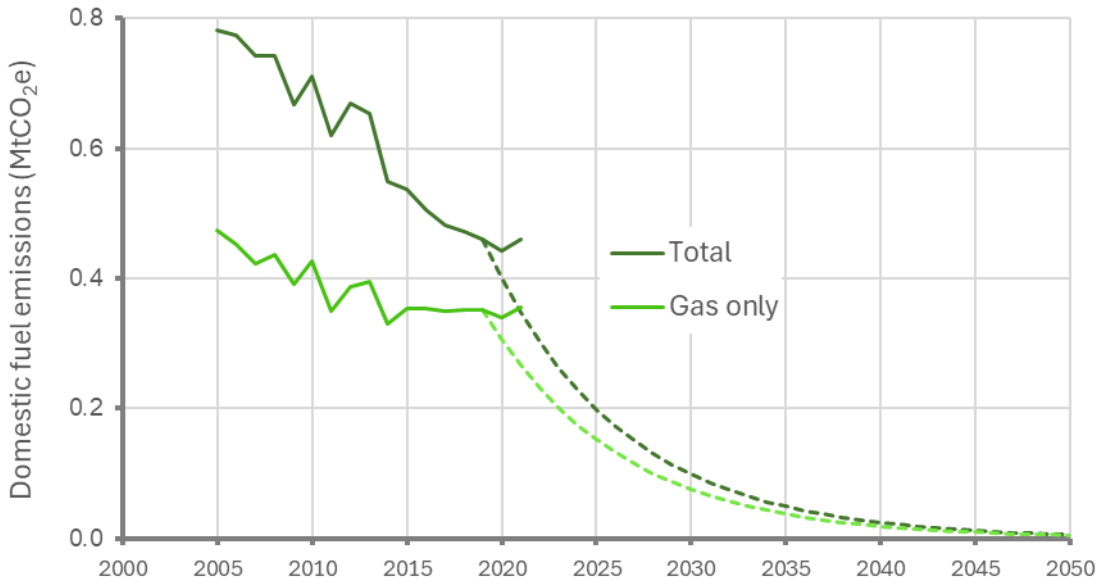

Figure 4.5. Tyndall aligned target for domestic fuel consumption (Kuriakose *et al.*, 2020; DBEIS, 2023).

4.2.4.2 Build a CAN Homes Coalition

The Council should nurture a coalition of homeowners, retrofit professionals, home improvement businesses, estate agents, community groups (Putnam and Brown, 2021), behavioural scientists, educators, and communications specialists to promote home improvement as a mechanism for delivering net-zero. This could mirror the development of existing groups such as the *Climate Action Business Forum* and the *Stockport Green Network* (see Section 2.2.2) and might overlap with these in membership. A prominent

[20] Gas and electricity make up over 98% of the total curve. The remainer is heating fuels such as biomass or oil most often in houses that are off the gas grid.

launch event should be held to initiate the coalition with ongoing progress showcased at subsequent CAN Summits.

4.2.4.3 CAN Homes Carbon Literacy

The Council has already developed a bespoke Carbon Literacy course (Carbon Literacy Project, 2023b) for its own staff (see Section 3.2.1) and should support the development of a course for staff of local businesses (homeowners, home improvement businesses, architects, builders, heating engineers, estate agents etc.) focussing on how home improvements can be aligned with net-zero objectives. A shorter session could be developed for homeowners who would like some exposure to the issues but do not feel the need for the full course.

4.2.4.4 CAN Homes Showcase

The Council should support development of a platform to inspire engagement in emissions-reducing home improvements by exposure to past success stories from local renovators. The showcase should feature a regular blog to maintain freshness and strong visual images that can be shared on Instagram and TikTok. Facebook (or a similar platform) should be used to allow peer-support amongst past and potential home improvers. Press releases should aim to engage mainstream media such as a recent article in the Guardian entitled, "'Greener, cheaper, much warmer', heat pump owners laud their new system" (Skopeliti, 2024) and community web-sites such as I love Bramhall (I Love Bramhall, 2024).

To augment this, the Council should consider nurturing "Superhomes". This is a national network of homeowners who have successfully reduced emissions through home improvement and are enthusiastic to offer their homes as exemplars of what can be achieved (Fawcett and Killip, 2014), some are even prepared to hold open home events for local residents (Berry *et al.*, 2014).

Activity in this area should include homes with all types of tenure. Some of the best examples of retrofit within Stockport are social housing projects with Stockport Homes winning the "Best retrofit programme" at the Northern Housing Awards in 2022 (Stockport Homes, 2022).

4.2.4.5 CAN Homes Badges, Awards and Challenges

The Council should develop a range of badges, awards and challenges aimed at increasing the visibility (both physical and metaphorical) of energy saving home improvements. Ideas could include:

- A small plaque designed to be attached to an exterior wall issued to the 156 houses within Stockport who have been issued a EPC certificate at grade A, or the 7,783 at grade B (DLUHC, 2024).
- Green street signs for any streets where all the properties have an EPC certificate of Grade C or above.

- A door/window sticker (like those promoting Neighbourhood Watch) that specifies the depth of loft insulation in the property and/or the extent of cavity wall insulation.
- An “I’m pumped” sticker for anyone who has installed a heat pump.

4.3 Discussion

Moving away from the historic policy focus on improving the housing of low-income groups has implications for a Council like Stockport which is committed to both reducing socio-economic inequality and emissions (both are regarded as ‘cross-cutting themes’ of overall policy, SMBC, 2023d). There is a temptation to focus on areas that address both, such as retrofitting social housing (SMBC, 2020b, 2023c). People in social housing, however, are likely to be in the first decile by income and thus emit considerably less through domestic fuel use than wealthier residents. In this and other areas, it is thus important that emissions reduction policies are not restricted to those that also reduce inequality.

The relationship between home improvement and environmental protection is two sided. On one side is home improvement as the renovation of buildings that are no longer fit for purpose. Life cycle analysis generally concludes that renovation is better for the environment than rebuild (Gaspar and Santos, 2015; Struhala and Ostrý, 2021). On the other side is non-essential renovation to improve aesthetics, lifestyles or social status. The embedded energy cost of such renovation can be significant and non-essential home improvement can be seen as part of the human behavioural crisis that is driving the current ecological overshoot (Merz *et al.*, 2023). Moral licensing may be a particular issue given that house size is the biggest single factor determining energy emissions (Huebner *et al.*, 2015). A renovation that uses a 10% improvement in energy efficiency to justify a 10% increase in floor area is unlikely to lead to a net reduction in emissions. Care will be needed with messaging to ensure that coupling retrofit with home improvement does not encourage non-essential home improvement. The proposed carbon literacy programme will be important in raising awareness of such issues within the sector (Densley Tingley, 2022).

The behaviour being encouraged by the policy is a one-off adoption of technological solutions and largely ignores the potential of changes in routine behaviours (Hampton and Whitmarsh, 2023). Reducing domestic thermostat settings from the current UK average of 20°C (Huebner *et al.*, 2021) to the 18°C recommended by the World Health Organisation as “safe and well-balanced” (WHO, 2018, p. 34), for example, could reduce emissions by 20%[21] and optimising other settings can save even more energy (Palmer *et al.*, 2012). Although this is not the focus of these policy recommendations, advocacy for optimal heating regimes within homes, and other changes in routine behaviour should be a key aspect of the Council’s response.

[21] Most of this dissertation was written quite comfortably in a room heated to between 15 and 16°C.

Although improved thermal comfort is reported as the most important reason for undertaking home renovation (Christensen *et al.*, 2014), increased energy efficiency should not be seen as an excuse for inappropriate or wasteful heating. Fortunately Gram-Hanssen *et al.* (2012) found that only 20% of potential savings of heat pump installation were used by householders to improve comfort and Sorrell et al. (2009) suggest this "rebound" effect should generally be less than 30%. These 80% and 70% reductions suggest that improved comfort and emissions reduction are both possible.

A final concern might be that linking emissions reduction to home improvement disguises its overall importance and risks missing an opportunity to project more explicit pro-environmental messaging that might spillover to reduce emissions in other areas. Previous research, however, has shown that pro-environmental spillover effects are quite limited (Geiger *et al.*, 2021; 2022; Bergquist *et al.*, 2023) so this may not be a particularly important issue.

5 Conclusions, limitations and suggestions for further work

This dissertation has achieved three objectives; a review of the emissions reduction policy of Stockport Council, the first description of consumption-based emissions for the Borough and a detailed analysis of how the consumption-based data might influence policy to reduce emissions from domestic fuel. These have been covered in separate sections, each of which includes discussion of specific implications. This section will therefore focus on more general issues.

5.1 Conclusions and the issues that they raise

5.1.1 Insights from consumption-based data on demand-side emissions reduction

Consumption-based emissions data do clearly give valuable insights into how overall emissions can be reduced. Just understanding that Stockport residents are responsible for twice the emissions that are generated within the Borough gives important context. Presenting data from the perspective of consumption prompts a reflection on what drives emissions rather than how they are produced which is largely missing from current Council policy. In relation to domestic fuel use, current local and national policy largely focusses on the technical solutions that can be offered to households to reduce emissions. A consumption-based approach encourages consideration of what drives residents to adopt these. It is this that has led to the alternative framing of retrofit as a home improvement.

This perspective highlights the potential for changes in behaviour to offer demand-side solutions that can augment largely technological supply-side solutions. These should not be seen as alternatives. If the Council is to take its own declaration of an emergency seriously, it will engage all tools that are available, indeed holding temperature rises to 1.5°C almost certainly now requires substantial demand-side measures (see Section 1.4). There is a particular issue with timing, remaining within carbon budgets requires radical early reductions in emissions (13% per year, Kuriakose *et al.*, 2020). It is thus essential to encourage the 72% of households within Stockport who are homeowners to engage in retrofit now.

This is not to assume that changing behaviour is easy. Fortunately there is a rapidly growing understanding and appreciation of the potential of behavioural sciences to address emissions reduction (Creutzig *et al.*, 2018; IPCC, 2023a). Section 4 illustrates how insights from the behavioural sciences, such as the importance of descriptive and injunctive social norms in facilitating pro-environmental actions, can be used to develop Council policy.

The overarching issue is of where responsibility lies for instigating demand-side solutions. Most demand-side solutions and 59% of all emissions reductions in the Climate Change Committee's *Sixth Carbon Budget* (CCC, 2020) depend on behaviour change, yet there is political reluctance to ask, let alone require, people to change behaviour. The first of four priorities that headed the national *Net Zero Strategy Build Back Greener* (DBEIS, 2021b, p. 16) for example, is "We will work with the grain of consumer choice". This is exacerbated by

lack of any detailed agreement between local and national governments as to how carbon budgets and related responsibilities should be allocated or how different levels of government should work together. There have been various proposals as to how this could be achieved (Gudde *et al.*, 2021b; Housing, Communities and Local Government Committee, 2021; NAO, 2021b; Nice and Sasse, 2023) but so far the government has been reluctant to take definitive action (DLUHC, 2022; Rankl *et al.*, 2023). Accepting that behaviour change must play a key role in any plan to meet existing commitments to the Paris Agreement and exploring how responsibility for this should be shared between different levels of government should be a high priority for the UK government.

Alternative models of government may be required, with a move towards consultative and inclusive decision-making at both a national and local level. The House of Commons sponsored UK Climate Assembly (Climate Assembly, UK, 2020) was an excellent example of how this could be implemented and demonstrated that the public, when given appropriate information and time for reflection, will support more radical action than any of the mainstream political parties within the UK. It is disappointing that none of those parties appear to acknowledge its findings or its way of working. Stockport Council have an annual programme of School and Youth Climate Assemblies and it would be interesting to see them experiment also with equivalents drawing from the wider electorate.

5.1.2 Income is important

This study has revealed that emissions rise with income 35% more steeply in Stockport (and the North of England generally) than for England as a whole. In the case of emissions from use of domestic fuel it is higher income groups who are both more responsible for higher levels of emissions and more able to afford retrofit measures (particularly given current government incentive schemes). Using consumption-based emissions data presented by income decile conveys the importance of engaging with higher-income households in emissions reduction.

A particular issue arises for more progressive political parties and local authorities, such as Stockport, who are committed to alleviation of fuel poverty and see an opportunity to link this to emission reduction policy, particularly regarding domestic fuel use. While upgrading of the housing of lower-income families has an important role in both, climate change objectives will not be met without also addressing households across the income spectrum and particularly the 72% that are owner occupiers.

5.1.3 The importance of local data?

This study was driven in part by an assumption that using localised consumption-based emissions data would be important to drive development of local emissions reduction policy. Table 3.4 however shows that there are minimal differences between Stockport and England in average household emissions across all six categories. There are statistically significant differences in the elasticity of emissions in all categories, but the qualitative trends are the

same[22] and the available policy options are quite blunt. On balance and despite the original assumption, localised data does not appear to have offered any significant insights into policy to reduce emissions from domestic fuel use that were not already available in the national data. It is likely that this will be the case in other areas of policy.

Having said this there may be strong psychological drivers for using local data. Presenting data that is specific to a region can be an important engagement tool even if the data varies little from national trends. Presenting data visually on graphs of recognisable areas (as in Figure 3.3 can be particularly motivating. This is evidenced by the very positive reaction from Council officers when informed about this project and their invitation for me to present the results to a meeting of senior staff (in March). I suspect this would not have been offered had the study been based on generic national data.

Of course, local data would be particularly useful if it could be used to monitor local progress against specific targets. Unfortunately, a range of issues with the data, which are identified in the next section place significant limitations on the potential for this.

5.2 Limitations

The major limitation of using local consumption-based emissions data lies in the nature of the data. Some of the data, principally those on domestic gas and electricity consumption, are measured directly at a local level (DESNZ/DBEIS, 2022). These data will give an accurate representation of local emissions. Most of the data, however, are based on modelling to extrapolate the results of relatively small national surveys to LSOAs across the country. There are more LSOAs (32,844 in England) than respondents in any of these surveys and it is unrealistic to expect that modelled results for individual LSOAs are anywhere near as accurate. This is reflected in the concerns raised in Section 3.4.2 about the unexpectedly low correlation with income of emissions data that has been modelled predominantly based on income. There is some protection in looking for trends within the subset of 190 LSOAs that make up Stockport but without any validation of the quality of modelling even this is speculative.

There are further issues with using these data for monitoring progress. Modelled data is drawn from surveys conducted across the country and can thus give no indication of the effect of local initiatives. In reality domestic consumption is the only data that could currently be used for monitoring purposes but it is only published 18-24 months in arrears (DESNZ/DBEIS, 2022)[23]. Waiting that long for feedback would be a considerably demotivator for local emissions reductions initiatives. Before 2011 mileage for private vehicles was published at LSOA level (Cairns *et al.*, 2017) and reinstituting this might give

[22] Except for public transport emissions which are a negligible contributor to consumption-based emissions.

[23] Given that power companies bill most customers quarterly the reason for this delay is not clear – indeed they may be avenues by which local authorities could access them more quickly.

useful and motivating information about changing private vehicle use (especially if the data which is taken from MOT certificates could be combined with details of the vehicle's engines to give estimates of emissions).

5.3 Suggestions for further work

The most obvious extension of the current work would be to explore how consumption-based data might influence policy in areas other than domestic fuel use. The data suggest, for example, that reducing the substantial emissions (13% of total, see Table 3.4) from private transport should have a much higher priority than further reduction of the already minimal emissions from public transport (less than 0.5%).

Current council policy does not address emissions associated with food & drink, flights and other consumption in any significant way, probably because of ambiguity of where responsibility lies for encouraging people to reduce emissions in these areas. It is unclear, for example, what responsibility the Council should assume for reducing emissions from flying (19% of consumption-based emissions, Table 3.4) given that Stockport doesn't have an airport! Further analysis of the data and its policy implications might be useful, however, in stimulating a debate about whether and how the council should act to reduce emissions from these categories which together represent over two-thirds of consumption-base emissions for the Borough.

Another useful extension would be to explore how the data changes across different regions of the country. Although the case has been made in Section 5.1.3 that policymaking would not have been different had it been based on national data, it may be that, for some local authorities, regional variations are significant. An exploratory analysis of overall emissions suggested that differences with national data were characteristic of the north of England rather than specific to Stockport (see Section 3.4.1) and exploring at what level differences appear might be useful (although given the comments in Section 5.2, this might reveal more about how data has been modelled than about the real distribution of emissions.

The analysis presented in Section 3 found that emissions in Stockport (probably as a region of the north of England) increase more rapidly with income than for England. This agrees with data from Ivanova and Wood (2020) that suggests that across Europe less affluent areas have higher emissions elasticity. It is not, however, clear why this should be the case. Further work to understand why emissions appear to be driven more by relative income than absolute income within nations and regions, might give useful insights into how emissions could be reduced both locally and internationally.

The other extension of the work is to present the results of this work to policymakers within Stockport Council and explore whether there is any enthusiasm in using consumption-based emissions to augment current policymaking. A meeting has been arranged to do this on Friday 8th March.

5.4 Reflection

I've been encouraged by my supervisor to conclude this dissertation with some subjective reflection on my experience of conducting the research. Generally, it has raised a variety of different emotions at different times about the scale of the problems that we (the global community) are facing. Re-reading the documents that provide the general context for this study has reminded me of the immensity of the challenge and been profoundly depressing at times, particularly given that towards the end of my research it was announced that 2023 came within 0.02°C of being the first year with an average global temperature of 1.5°C above the pre-industrial average. Downscaling pathways, focussing on specific categories of emissions and scanning the available policy options, however, gives confidence that solutions do exist. Then reflecting on the limited time available, the lack of political commitment to fully acknowledge or address the issues, and the growing distractions of geo-political instability and national socio-economic breakdown saps that confidence. Overall, I remain generally pessimistic, but personally optimistic that if I continue with this work, particularly through engaging with Stockport Council that I can still have a role in working positively for change.

Coming from a background in the physical sciences within healthcare it has been challenging to engage with the behavioural sciences. Conducting this research has confirmed to me that the predominant challenge in responding to climate change is to change people's attitudes and behaviours. I remain sceptical, however, of the process of first generalising from a relatively small number of specific observations to theoretical concepts and then reversing this in applying those concepts to (different) specific applications. The process appears highly subjective and vulnerable to misdirection. The field is clearly maturing though and provides the best set of tools that are available to address the presenting problem. I must learn how to use them.

My choice to focus on the relationship between emissions and income interests me. As I commented earlier (Section 1.7), I'm a datapoint in the tenth decile by income of my own decile plots. Conducting this research has convinced me, taking the language of the Rio Earth Summit, that against a background of "common but differentiated responsibilities and respective capabilities" it is people like me who should "take the lead in combatting climate change" (UN, 1992, p. 4). This must include a commitment to individual behaviour change, but will only be useful if done in a way that contributes to societal behaviour change.

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Appendix 1 Income measures

A1.1 Introduction

The Office for National Statistics publish two datasets providing a total of six measures of local household income. The first, based on the *Family Resources Survey* (FRS, DWP, 2019), estimates average total and net income, and net equivalised[24] income before and after housing costs (ONS, 2020a). An alternative dataset, *Admin-based income statistics* (ABIS) is being developed drawing on data from the tax and benefit systems to estimate median total and net individual equivalised income (ONS, 2022a).

The four measures of the FRS data should give improving estimates of disposable income and might thus be expected to give better correlations with emissions. On the other hand, the modelling increases in complexity and modelling errors might reduce the correlation. This preliminary study was conducted to establish whether any of the six measures should be preferred for the definitive study.

A1.2 Method

The FRS data are based on results of the 2017/8 Family Resources Survey with linear modelling of a range of covariates from other source used to estimate values for each MSOA (ONS, 2020b). These MSOA level data can mapped on to Lower Super Output Areas with little loss of granularity (there are an average of 4.8 LSOAs for every MSOA). The ABIS data isfor 2018 and is published at LSOA level (ONS, 2022a).

Pairwise comparison of the different income measures was conducted to exmplore relationships between the different measures. Household emissions from the Placed-Based Carbon Calculator (Morgan *et al.*, 2021) where then plotted against the different measures to explore how this affected their relationship with income. The endpoint of the analysis is a comparison of data grouped by income deciles, so this was explored for the different income measures. All analyses were conducted for data from England and Stockport separately.

During the analyses, it became clear that the ABIS data for England contained obviously spurious values. A measure of the completeness of data within each LSOA was used to give insights into this.

[24] Equivalisation adjusts incomes to account for the size and composition of households.

A1.3 Results - England

Pairwise comparison (Figure A1.1) suggests that all FRS measures are strongly correlated but contain different information (on average each measure only explains 80% of the variation in the other measures).

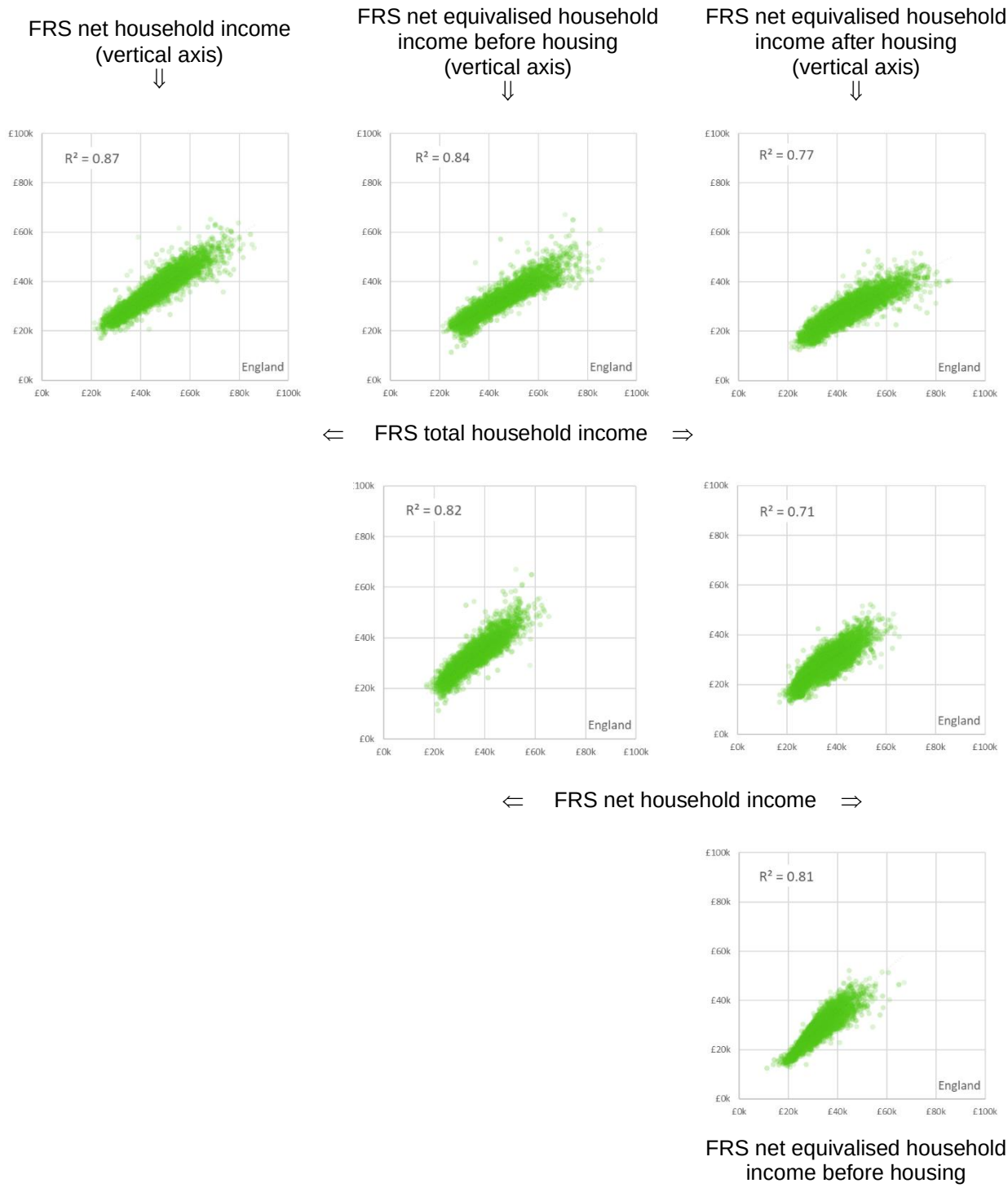

Figure A1.1 Pairwise comparisons of four FRS measures of income for LSOAs across England. Average r^2 value = 0.80 (range 0.71–0.87). The different measures have different values and all the axes for graphs in this appendix are thus scaled differently to give a broadly comparable indication of the correlations.

Pairwise comparison of the FRS and ABIS data (Figure A1.2) shows only modest agreement for both total (r^2=0.56) and net (r^2=0.48). The correlation between total and net income for the ABIS data is much stronger than for FRS data because ABIS is derived from estimates of both for individuals whereas the FRS data models these separately at MSOA level. The magnitudes of income measures are not directly comparable as FRS estimates are for households whereas ABIS measures are for individuals. ABIS measures show some values for personal income (both total and net) which appear too low to be genuine.

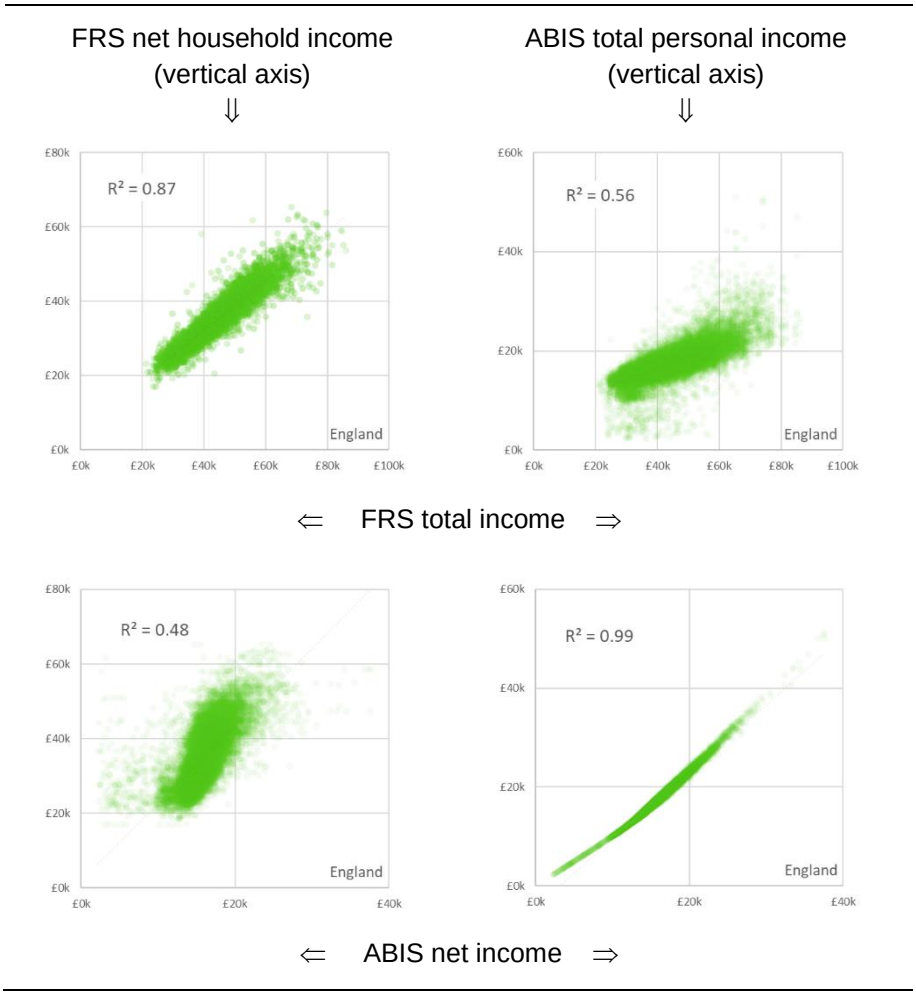

Figure A1.2. Pairwise comparison on FRS and ABIS income data for LSOAs across England.

Household emissions show similar correlations with the different measures of income (Figure A1.3) with r^2 values suggesting that income accounts for between 25% and 36% of the variation in emissions. The visual impression is that the trendlines for ABIS measures are being skewed by the data representing the improbably low personal income estimates.

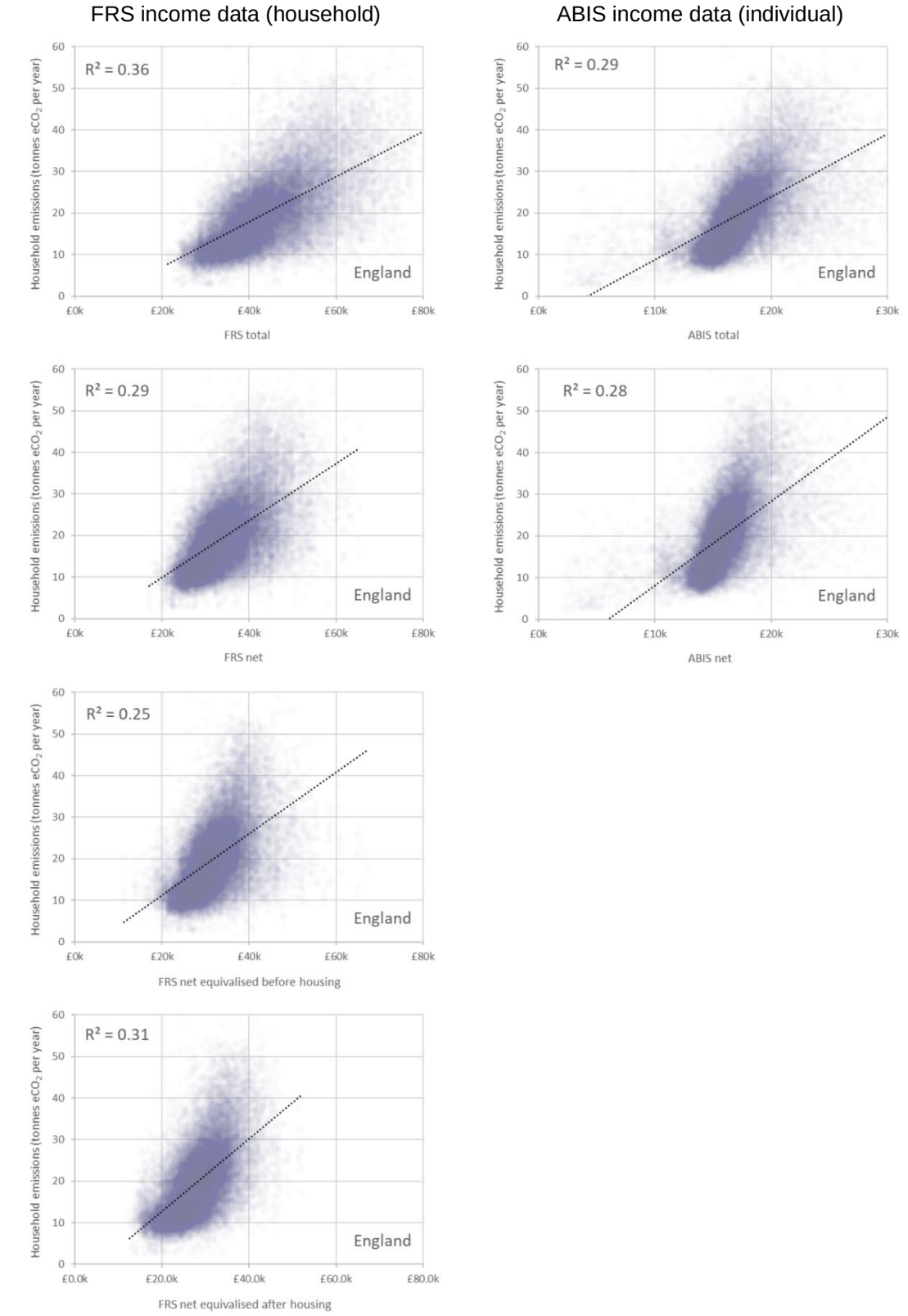

Figure A1.3. Household emissions plotted against the different income measures.

Plotting income or emissions by decile shows very similar patterns regardless of the income measure (Figure A1.4). The linear correlation between emissions and income is extremely high ($r^2 \geq .92$) confirming the importance of income in determining emissions but should not be over-interpreted as producing the income decile averages has filtered out much of the variability from other sources, as revealed by the considerably lower r^2 values for the relationship between income and emissions without decile binning (Figure A1.3).

Deviations from linearity are often more marked for the 1st and 10th decile and correlations across the 2nd to 8th deciles are even higher ($r^2 \geq 0.99$). This is particularly pronounced in the ABIS measures ($r^2 \approx 0.92$). Income in the 1st decile appears to be under-estimated which agrees with the observation of some improbably low-income values as already remarked upon. Income in the 10th Decile appears higher than FRS estimates (in relation to the other 9 deciles). This may also reflect poor data quality but could be a genuine consequence of the ABIS methodology being more likely to include individuals with very high incomes.

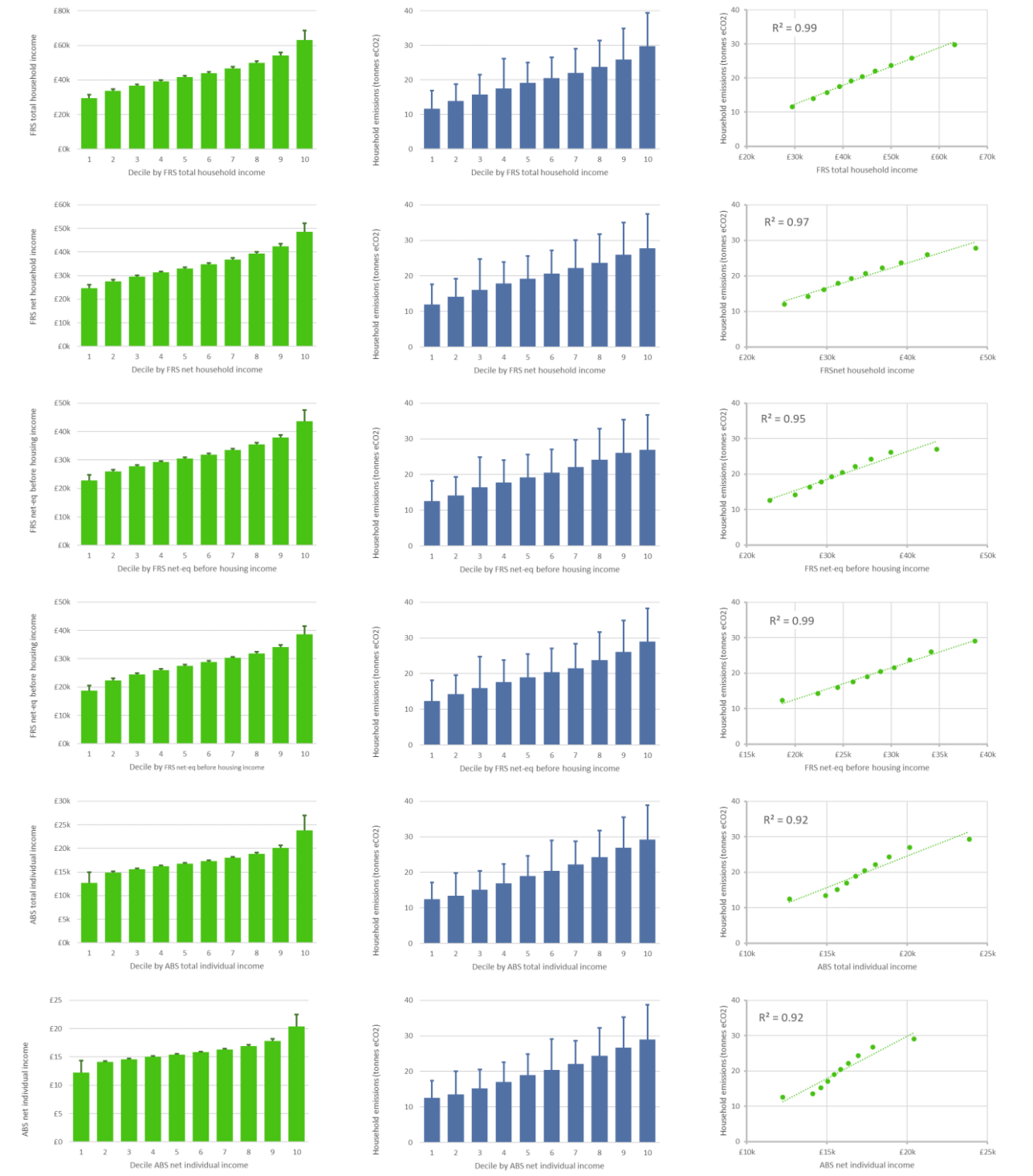

Figure A1.4. Income and emissions by decile for LOSAs in England when different measures of income are used and plot of emissions against income for the same measure. Error bars represent standard deviations (across LSOAs). Differences in r^2 values are almost entirely reflective of outlying 1st and 10th decile data, repeating analysis with deciles 2-8 only gives uniform r^2=0.99 for all measures.

A1.4 Results – Stockport

Similar analyses to those reported above for the whole of England have been repeated looking only at data from LSOAs within Stockport. Through all measures maximum average income in Stockport LSOAs is about 25% less than for England. Pairwise comparison of the different FRS measures (Figure A1.5) show that the Stockport follows the same pattern as for England but with much less scatter on the data (average $r^2 = 0.89$ as opposed to 0.80 for England) probably because much of the regional variation across the country has been eliminated. The ABIS measures, by contrast show only slightly less scatter (Figure A1.6). The biggest difference here is that no LSOAs show improbably low values of income.

Household emissions show slightly steeper gradients with all FRS measures of income (Figure A1.7) but similar scatter (as indicated by r^2 values) as the English data (Figure A1.3). The ABIS data for Stockport shows much steeper gradients and considerably less scatter ($r^2 \approx 0.57$ as opposed to 0.28). The visual impression (Figure 1.8) is that most of the English data (darker area) lies along the steeper gradient of the Stockport data but that outliers in the data lead to a much shallower trendline.

The average household income within each decile shows a very similar pattern regardless of the measure of income (Figure 1.9) for LSOAs in Stockport. The general pattern of emissions across the income deciles is like that for England but there is more variability. There does not appear to be any consistent pattern in that increased variability which may reflect the susceptibility of smaller datasets to random variation or modelling errors.

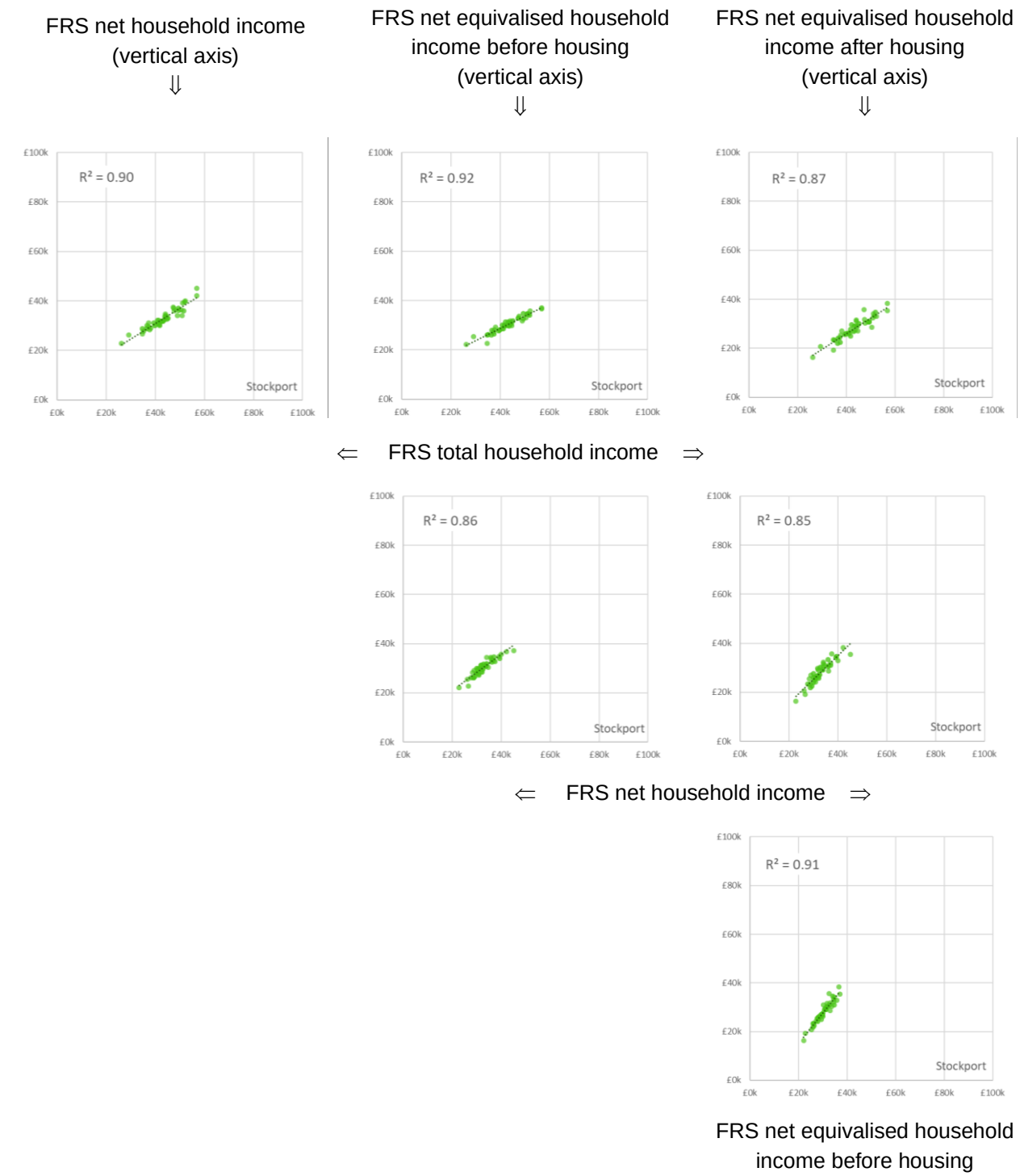

Figure A1.5. Pairwise comparisons of four FRS measures of income for LSOAs across Stockport. Average r^2 value = 0.89 (range 0.85–0.92). Scaling of graphs is identical to previous graphs presenting equivalent date for England to facilitate comparison.

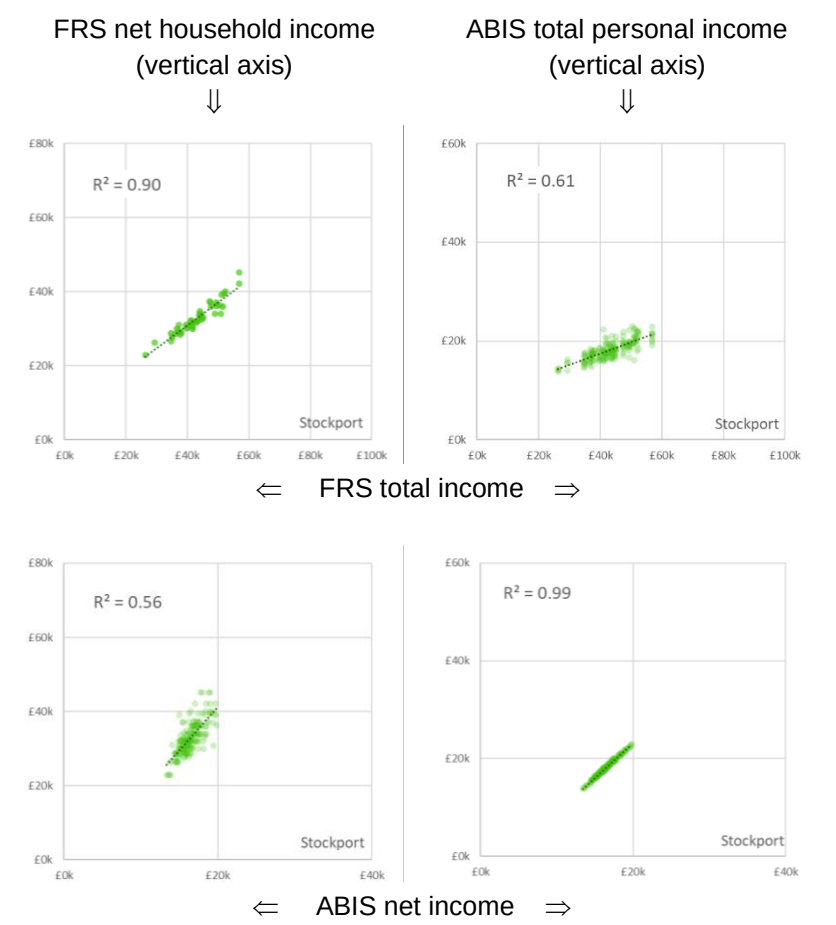

Figure A1.6. Pairwise comparison on FRS and ABIS income data for LSOAs across Stockport.

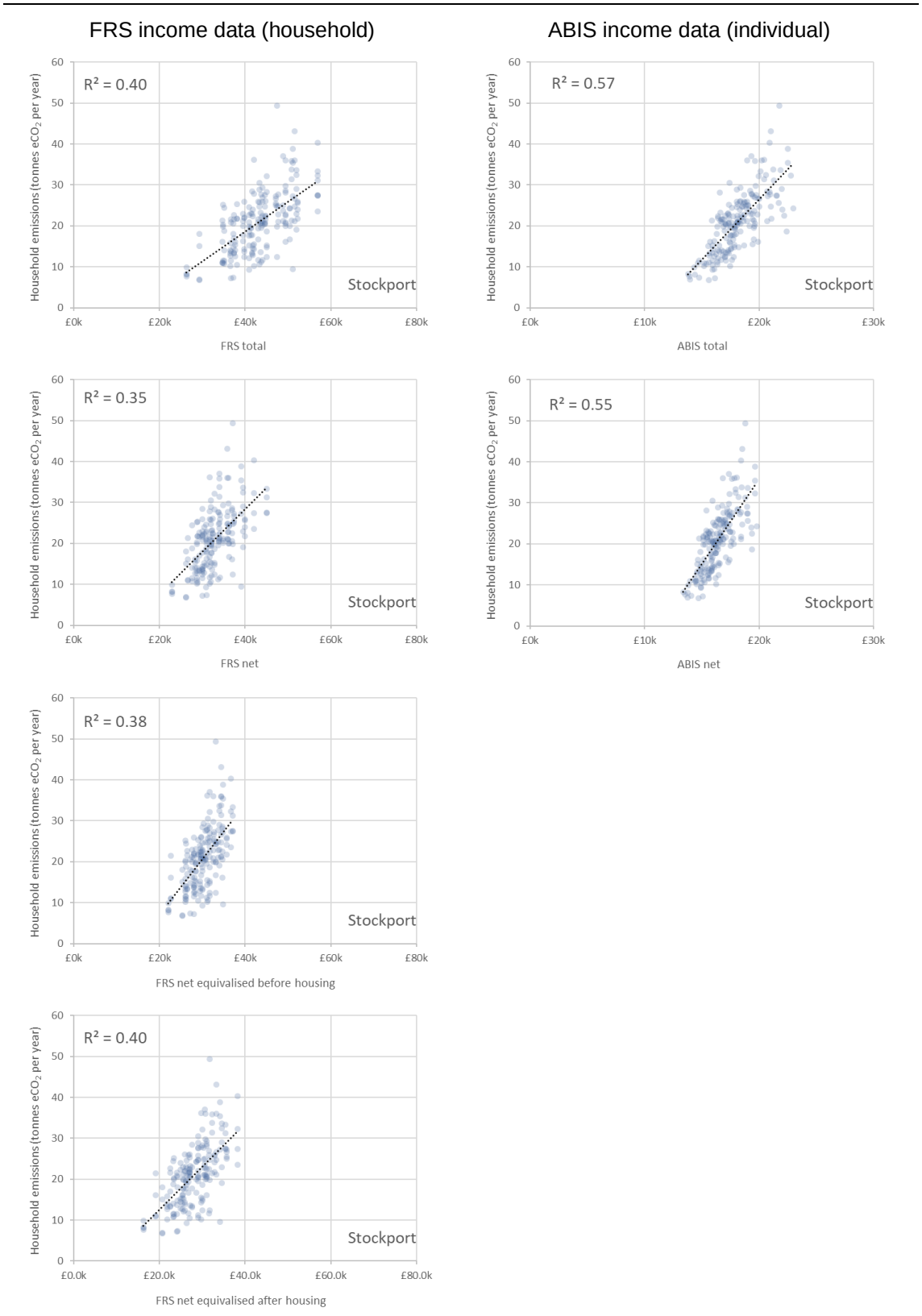

Figure A1.7. Household emissions plotted against the different income measures for Stockport

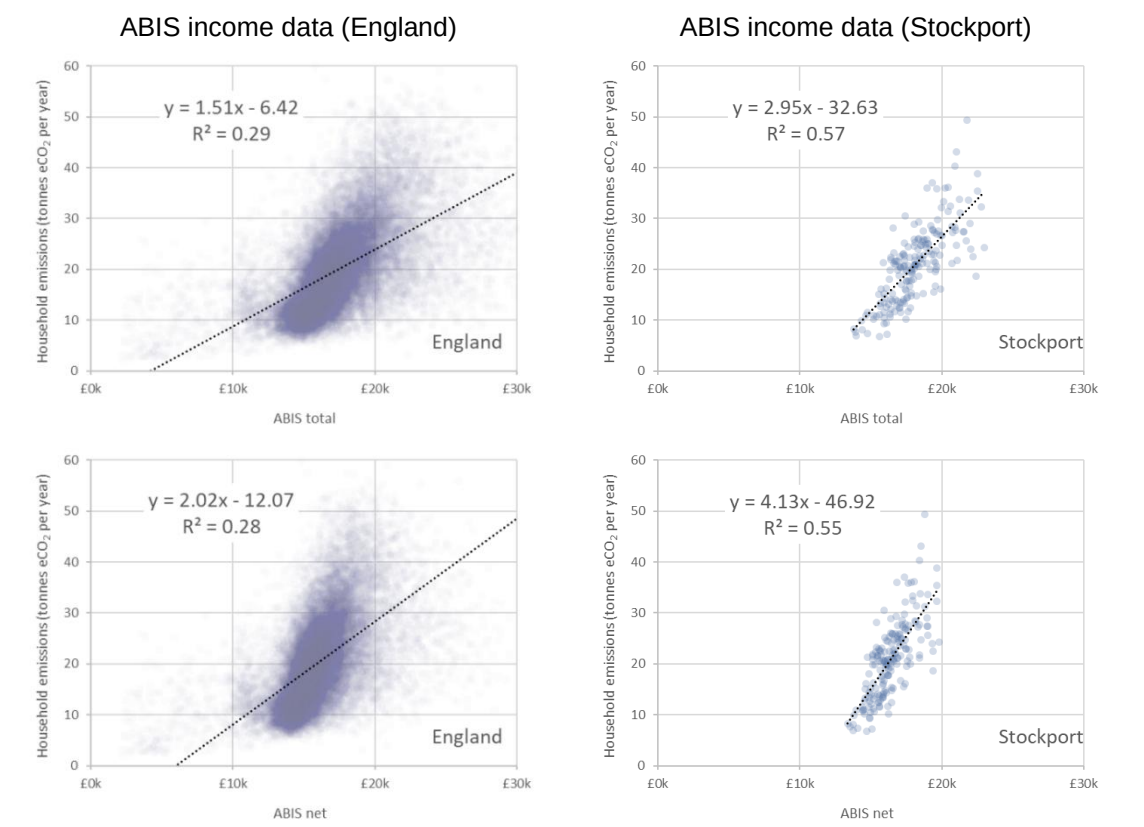

Figure A1.8. Comparison of ABIS income data for England and Stockport.

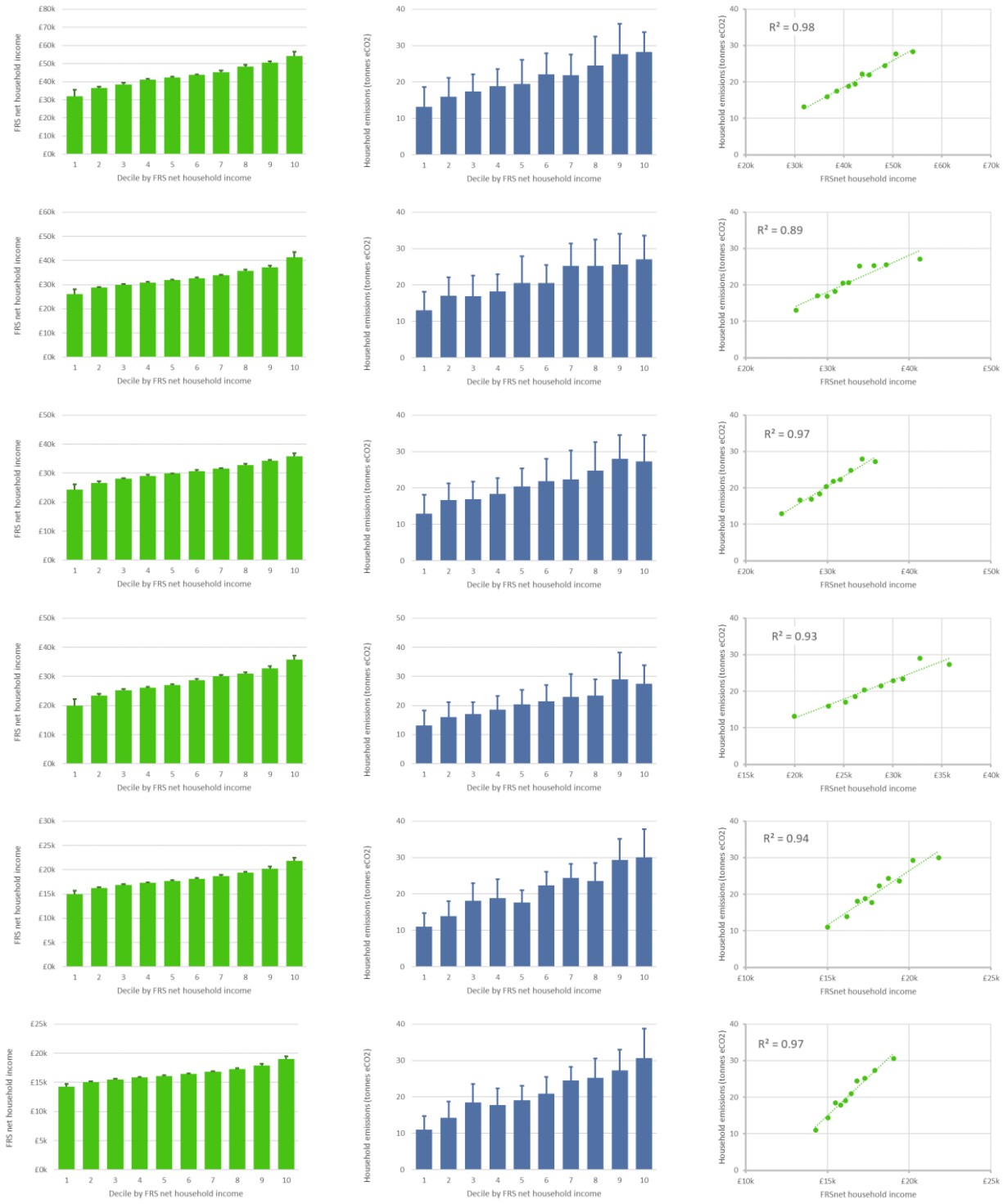

Figure A1.9. Income and emissions by decile for LOSAs in Stockport when different measures of income are used and plot of emissions against income for the same measure.

It is possible that the improbably low-income values observed in the ASIS data are a consequence of the incompleteness of the data. This was investigated by repeating the analysis for correlation of emissions with income with subsets of the ABIS data for England with greater than 90% and 95% completeness. It can be seen from Figure A1.10 that applying these filters excludes the low-income values, results in a higher gradient to the line of least squares regression and gives higher r^2 values. Even with the most restrictive filter, however, the visual impression is that the line of least squares regression is not aligned with the cloud of data points suggesting some skewing by outliers. Data from Stockport show even less evidence of outliers and has an even higher gradient r^2 value.

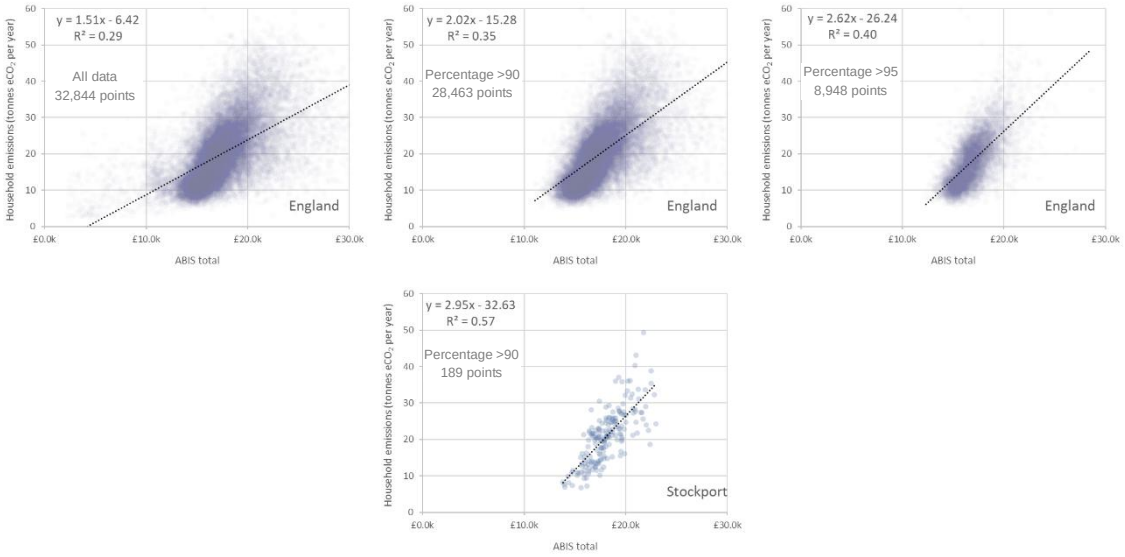

Figure A1.10. Comparison of increasing completeness threshold for ABS total individual income for England (top line) with data for Stockport (bottom line).

A1.5 Discussion

The purpose of this analysis has been to explore whether the data suggests any reason for preferring one measure of income over another either in choosing between the two data sets (FRS or ABIS) or the different measures available within either.

There are considerable differences between FRS and ABIS measures as given by the modest r^2 value for the relationship between the two measures of both total and net income (Figures A1.2 and A1.6). This is to be expected given that that the FRS measures are extrapolated from complete data from a modest sample whereas ABIS measures are derived from partial data for the whole population. FRS measures are reported for households, which matches the emissions data but only at MSOA level. ABIS data are reported for at LSOA level but only for individuals. The two measures are thus clearly quite different and cannot be used interchangeably.

The correlation between household emissions and income is well established from the literature (references) and thus a measure of income that correlates substantially more with emissions (as quantified by the r^2 value) should perhaps be preferred. (Even if the relationship was not already established it is unlikely that substantial increases in correlation will occur if such a relationship did not exist.) It might be expected that measures that are more indicative of household disposable income will correlate more strongly with emissions. Alternatively, derivative measures are more difficult to estimate or model which would lead to a stronger correlation with a direct measure such as gross income.

Scatter plots of emissions with income across England (Figure A1.3) show considerable variability for both ABIS and FRS measures. The data cloud for the ABIS measures appear more diffuse with improbably low-income values for some data points. The line of least squares regression generally appears to fit the data cloud better for FRS than ABIS measures suggesting it may be influenced by those points. Having said this, although the correlation of emissions is strongest with FRS total income ($r^2 = 0.36$), those with the other measures are only a little lower ($0.25 \leq r^2 \leq 0.31$).

Exploration of how scatter plots of emissions with ABIS income for England are affected by data quality show that applying successively more stringent filters improves the correlation but also leads to a marked increase in the gradient of the line of least squares regression (Figure A1.10). This suggests that there are data quality issues with the ABIS dataset which affect both the quality and the nature of the relationship between emissions and income.

r^2 values for FRS measures for Stockport ($0.35 \leq r^2 \leq 0.40$, Figure A1.7). are a little higher than for England ($0.25 \leq r^2 \leq 0.31$, Figure A1.3). which is expected given the elimination of much regional variation. Those for ABIS measures, by contrast are considerably higher for Stockport ($r^2 \approx 0.56$) than for England ($r^2 \approx 0.29$). This suggests that the ABIS data is of higher quality within Stockport than across England, although the reason for this is not clear.

A further issue comes when considering the emissions data grouped by deciles of income. Data from across England (Figure A1.4) shows a smooth increase of emissions with income data regardless of the income measure. The data from Stockport (Figure A1.9) is less smooth, which might be expected given the susceptibility of smaller datasets to data or modelling errors or variability. This is observed particularly with the ABIS measure with some decile groups showing lower emissions than a lower decile group.

For data from Stockport the correlation between emissions and income is strongest for ABIS measures suggesting that these should be preferred. Several observations, however, suggest that there are quality issues with ABIS measures across England. This confirms the warning (ONS, 2022a) that these data should only be treated as experimental. A particular concern is that the gradient of the line of least squares regression is sensitive to these quality issues. This makes it impossible to compare results from Stockport with those from England which is one of the aims of this study. The FRS data will therefore be used in this study.

There is much less difference between measures within the FRS group. FRS total income shows a slightly correlation with emissions for both England and Stockport suggesting that the advantages of using such a direct measure outweigh those of using measures that appear better designed to indicate disposable income. Total income has the additional advantage that is more easily understood identified with than derivative measures such as net income, equivalised income or income after housing costs. On this bases FRS total income will be taken as the primary measure of income for this study.

Appendix 2 Analysing data by decile

A2.1 Introduction

Much of the literature exploring the relationship between emissions and income, and particularly the two studies which have motivated this analysis (Gough *et al.*, 2011; Preston *et al.*, 2013), has been based on data grouped by income deciles. Whilst this can give important insights, it was observed that performing the same analysis on ungrouped data or data grouped by deciles appeared to give contradictory results. This appendix illustrates and explains the issue.

A2.2 Methods

This analysis uses the same data as Section 3 to explore the relationship between household emissions (Morgan *et al.*, 2021) and average total household incomes (ONS, 2020a) for LSOAs across England and Stockport (Figure 3.3). Three correlation analyses were performed using:

1. Ungrouped data – each datapoint represents a single LSOA
2. Data grouped by income decile – each datapoint represents average emissions and income for the group of LSOAs in each decile
3. A decile plot – each datapoint represents average emissions with data plotted as ten equally spaced columns.

A2.3 Results

Figure A2.1 shows the results of the three analyses. Figure A2.1a is the same as Figure 3.3 and shows that ungrouped data shows moderate correlations (r^2 = 0.36 for Stockport and 0.40 for England) and that the gradient of emissions with income is about 35% greater for Stockport (0.73 tonnes CO_2 equivalent per £1,000) than for England (0.54 tonnes per £1,000). Figure A2.1b shows that grouping data by income decile increases the strength of the correlations markedly (r^2 = 0.98 and 0.99) but that the lines of regression are very nearly identical as in Figure A2.1a.

Finally Figure A2.1v shows data grouped by deciles but plotted as equally spaced columns. The strength of correlations are identical to Figure A2.1b (r^2 = 0.98 and 0.99) but, in apparent contrast, to Figure A2.1 the emissions rise about 12% less per income decile for Stockport (1.6 tonnes per income decile) than for England (1.8 tonnes per decile).

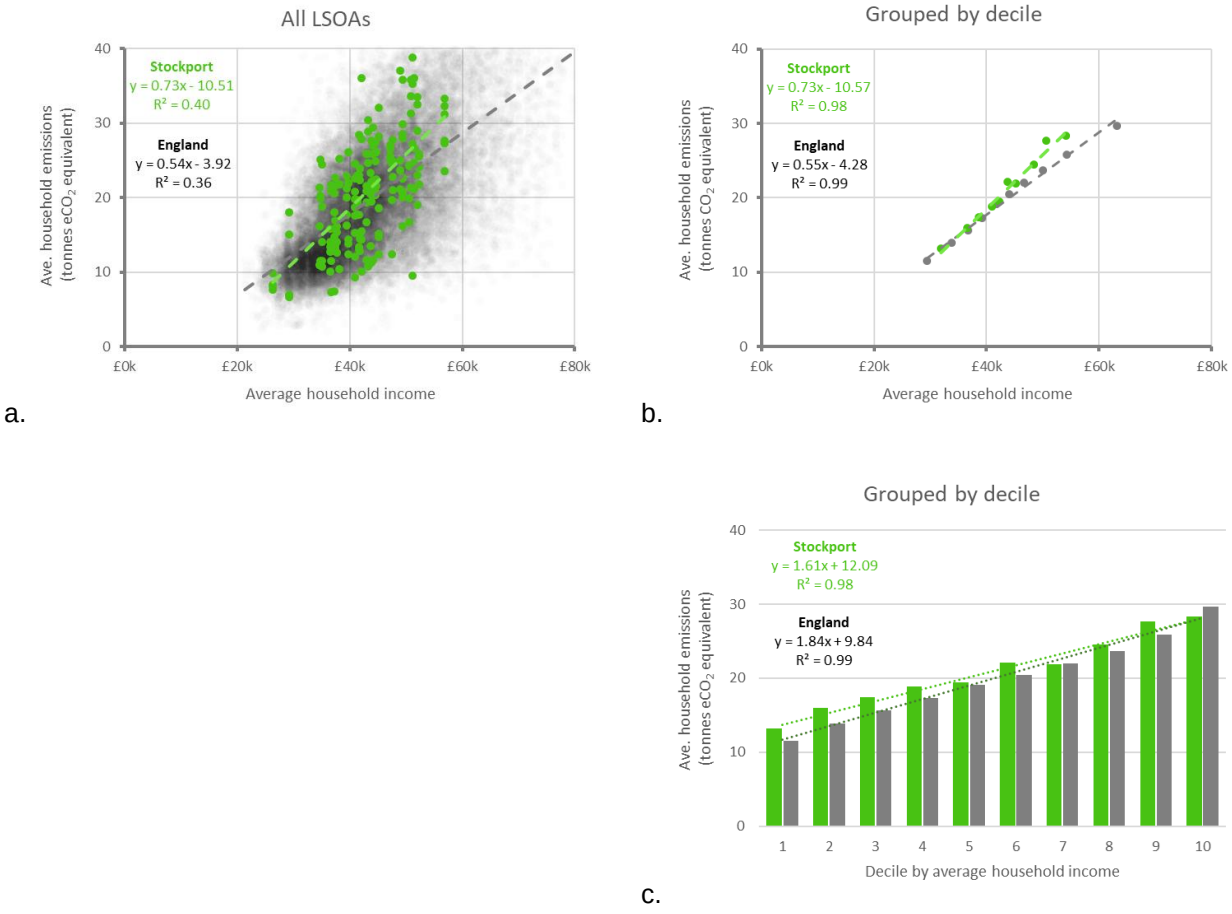

Figure A2.1. Correlation of average household emissions with average total household income across LSOAs in England (grey) and Stockport (green) with a) ungrouped data, b) data grouped by income decile, c) data grouped by income decile and plotted as equally spaced columns. The trendlines are lines of least square regression.

A2.4 Discussion and explanation

The differences in the strength of the correlations between ungrouped and grouped data are largely attributable to the process of averaging data within decile groups which effectively filters out any of the variability in the data that is not attributable to changes in income. The small differences in r^2 values between Figures A2.1b and A2.1c are because the average incomes for the decile groups are not evenly spaced (See Table A2.1)

Table A2.1 Average household incomes within income deciles and the differences between these averages for Stockport and England.

	Stockport		England	
Decile	Average income within decile	Difference between decile averages	Average income within decile	Difference between decile averages
1	£32.2k		£29.4k	
		£4.4k		£4.4k
2	£36.6k		£33.8k	
		£1.9k		£2.9k
3	£38.5k		£36.7k	
		£2.5k		£2.6k
4	£41.0k		£39.2k	
		£1.3k		£2.4k
5	£42.3k		£41.7k	
		£1.5k		£2.4k
6	£43.8k		£44.0k	
		£1.4k		£2.7k
7	£45.2k		£46.7k	
		£3.3k		£3.3k
8	£48.4k		£50.0k	
		£2.2k		£4.2k
9	£50.6k		£54.2k	
		£3.4k		£9.0k
10	£54.1k		£63.2k	
Average		£2.4k		£3.7k

Figure A2.4. Household emissions plotted against income for LSOAs across Stockport (green) and England (grey) with decile boundaries for England (upper graph) and Stockport (lower graph). The percentage of LSOAs in each decile are also plotted.

Although grouping the data by income decile leads to stronger apparent correlations it only has a very minor effect on the line of least squares regression when emissions are plotted against income. The difference in the gradients between Figures A2.1a & b and Figure A2.1c arises because the difference in average incomes between the deciles different in England than Stockport (See Table A2.1). Thus, on average, the difference in emissions per decile represents that corresponding to a £2.4k difference in income in Stockport and a £3.7k difference in income in England (over 50% greater). This difference is so large that emissions rise more steeply by income decile in England than they do in Stockport but more slowly be income itself.

As another illustration of how plotting data by decile can conceal differences between areas take emissions and income data for countries across Europe as digitised from Ivanova and Wood (2020, Figure 6a). Figure A2.4 (left) shows data as published in the paper with the two most extreme countries (Bulgaria and Denmark) highlighted. The gradient for Bulgaria is 7.3 times higher than for Denmark. Figure 2.4b (right) then represents the same data for these countries as decile plots. Here the gradient per income decile is 46% lower.

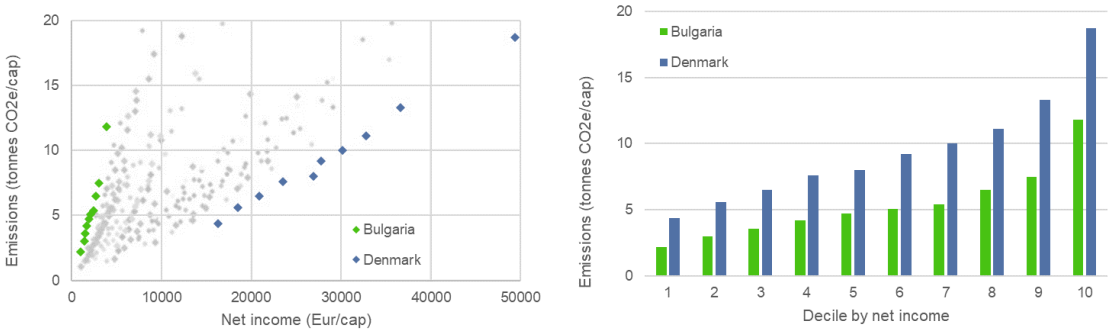

Figure A2.2. Comparison of plotting emissions data against income and against decile by income for the two countries in Europe with the most extreme gradients for this relationship (Ivanova and Wood, 2020, Figure 6a). Grey data is from other countries.

A2.5 Conclusions

Plotting emissions data by income decile is an excellent way of illustrating how emissions change across the income spectrum. It is particularly useful to support policymaking because each column represents that same number of people and thus it gives an immediate indication of what proportion of the population will be affected by any policy recommendation. On the other hand, decile plots are a very poor way of comparing the relationship between emissions and income between different regions or populations, because the plots are affected by the distribution of incomes as well as the relationship itself. Comparisons should always be made on the ungrouped data.

The analysis also reinforces that any grouping of data is likely to increase the strength of correlations. It is important to remember that this will also apply to data grouped by LSOA. Variability for both emissions and incomes across individual households will be greater than is apparent from plots of data for LSOA throughout the dissertation.