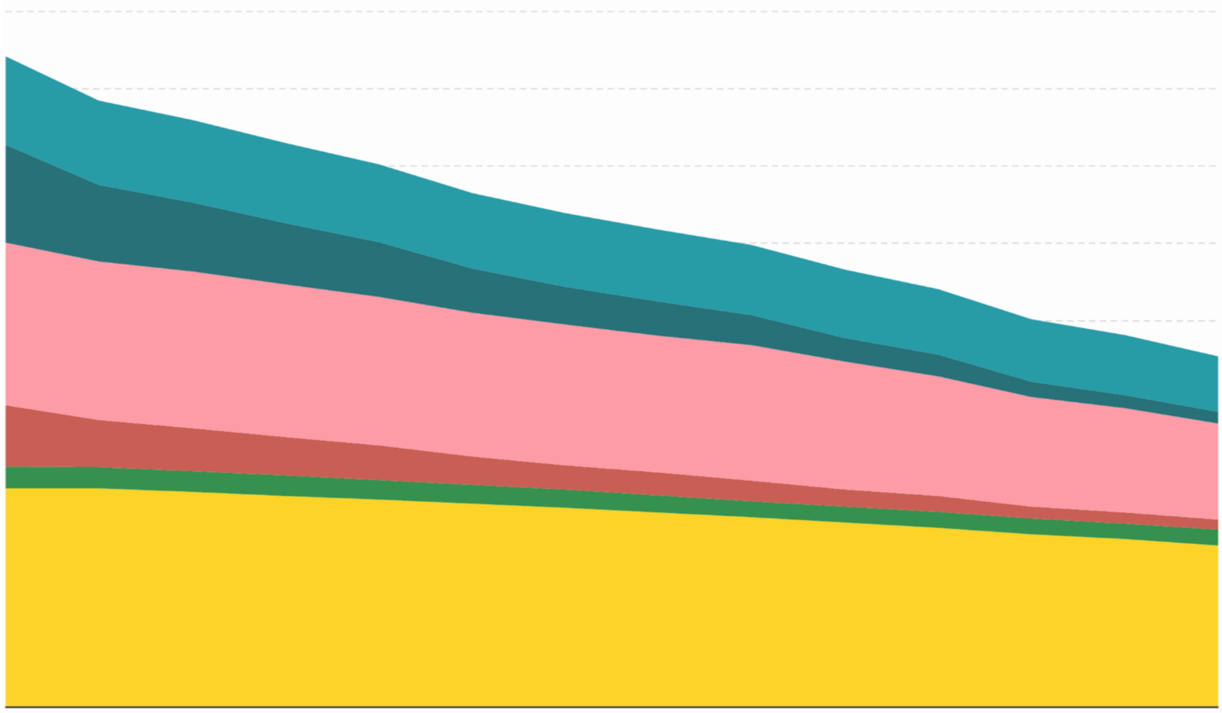
City of Bristol Carbon Neutrality

CO_2 emission baseline and gap analysis

Report to accompany baseline and trajectory datasets



Final

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1. Introduction

Regen was asked to develop an evidence base to help inform the City of Bristol's[1] mayoral response to the 13 November council motion that Bristol should achieve a citywide net zero carbon position by 2030.

This report is written to accompany the dataset, provided to Bristol City Council, which provides a baseline analysis of the current level and sources of carbon emissions in Bristol. This dataset is intended to support and provide an evidence base for the development of a comprehensive net zero carbon plan for Bristol.

The dataset contains baseline sources of energy demand and supply to the city and the associated carbon emissions broken down by sector and sub-sectors and by technology types including emissions emanated from energy use for power, heat and road transport[2].

This is consistent with Scope 1 & 2 emissions as defined by the Greenhouse Gas Protocol[3] but excludes land-use change. These direct emissions were chosen because they are the areas that Bristol Council and residents have more direct control. Indirect emissions emanating from the supply chain and source of goods and services imported into the City (Scope 3) have not been included.

Alongside the dataset Regen was also asked to produce a forward looking analysis of the likely trajectory of carbon emissions under the current policy environment. To do this, Regen developed two possible projections for the City of Bristol carbon emissions by 2030:

1. The **'Committed'** trajectory. This is a projection based on the historic emissions trajectory for the City of Bristol which assumes a continuation of existing investment in carbon mitigation policies and measures that have already been committed or budgeted to 2030. This has been aligned to a national trajectory for a 'Steady Progression' scenario within the framework of the National Grid Future Energy Scenario (FES)[4]. This outcome would be short of what would be needed to meet the UK's carbon reduction targets[5].

2. The **'Target 2050'** trajectory. This scenario assumes that Bristol delivers a broader and more ambitious set of policy and other measures to achieve the existing commitment to a net zero carbon city by 2050. In the scenario it is assumed that Bristol continues to proactively decarbonise its energy usage, building on a range of measures and future investments such as those identified in City Leap and the Joint Local Transport Plan. At a national level the UK would meet the commitments of the 4th and 5th carbon budgets and would be on track to meet its 2050 UK carbon targets of an 80% reduction in carbon emissions.

Neither of these trajectories however meet the goal of achieving a carbon neutral position for the city by 2030. They are instead intended to identify what the 'gap' is currently between Bristol's existing potential trajectories and achieving zero carbon, and to inform the development of a Bristol Carbon Neutral delivery plan.

[1] "City of Bristol" is used to refer to the whole city; council, businesses, consumers, institutions and stakeholders. Bristol City Council refers to the impacts and actions of the council and its estate.
[2] Cars, HGVs LGVs, Buses and Motorcycles. Not in scope: Rail, air and marine emissions
[3] http://ghgprotocol.org/
[4] http://fes.nationalgrid.com/fes-document/
[5] For example, see 5th Carbon Budget Committee on Climate Change

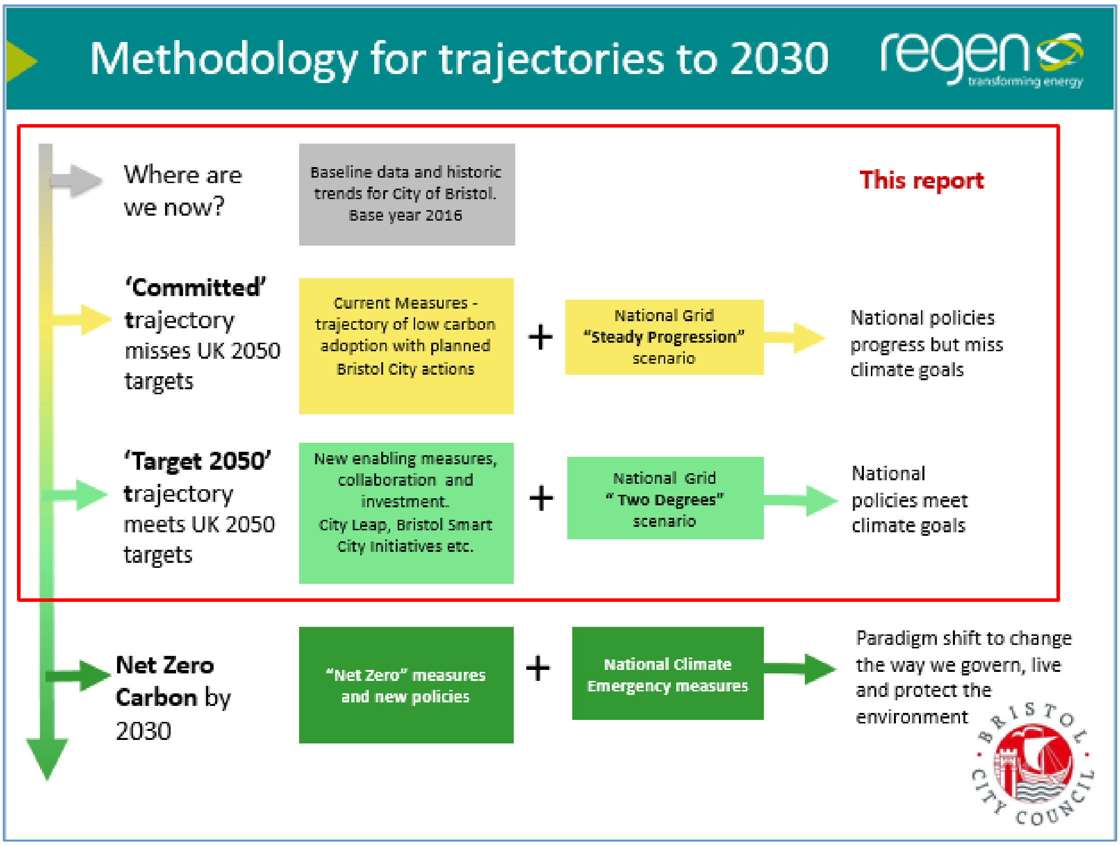


Figure 1-1: Summary of study methodology

1-1. Data sources and key documents

In order to complete the analysis, Regen has used data from a number of resources to develop the baseline energy use and carbon emission analysis. A full list can be found in appendix 11 and referenced within the dataset. The key data sources included:

- Regen databases
- Department for Business Energy and Industrial Strategy (BEIS) energy statistics
- Ofgem Feed-in Tariff registers
- Planning databases
- Local development plans
- National Grid FES 2018 tables
- Department for Transport (DfT) statistics
- Regen's Transport Model

The trajectories were informed by key documents and analysis already produced by the City of Bristol. These included:

- Bristol City Leap Prospectus[6] which includes details of heat networks, energy efficiency and renewable energy.
- Bristol One City Plan[7], which includes targets on local renewable generation, zero carbon new buildings and energy efficiency standards.
- Heat decarbonisation evidence base by Element Energy for Bristol City Council in 2019 was used for heat decarbonisation pathways (Element Energy study).[8]
- Joint Local Transport Plan Consultation launched in February 2019 which was used to inform the transport shift analysis[9].
- The Economics of Low Carbon Cities: A Mini-Stern Review for the City of Bristol[10]

The City Leap programme has the overall ambition of delivering up to £1bn of low-carbon, smart energy infrastructure investment in Bristol over the next 10 years that will enable the city region to become carbon neutral by 2050.

The City Leap prospectus was launched in 2018 with the objective of attracting ideas and investment into its low-carbon programmes. The project has already attracted 67 Expression of Interests across a range of electricity, heat and mobility interests.

The delivery plan for the City Leap investments are likely to involve delivering energy efficiency measures to over 40,000 dwellings in the City along

City Leap Programme at a glance

Potential investment opportunity	Estimated investment opportunity over ten years
Heat networks	£300m
Smart energy system	£125m
Domestic energy efficiency	£300m
Commercial energy efficiency	£100m
Renewable energy	£40m
Monitoring, dissemination and evaluation	£10m
Transport	Additional
Hydrogen	Additional
Marine energy	Additional
Total	**£875m**

[6] https://www.energyservicebristol.co.uk/prospectus/
[7] https://news.bristol.gov.uk/news/bristol-launches-first-ever-one-city-plan
[8] Element Energy. An evidence based strategy for delivering zero carbon heat in Bristol. A report for Bristol City Council (October 2018)
[9] https://travelwest.info/projects/joint-local-transport-plan
[10] http://bristol.ac.uk/cabot/media/documents/bristol-low-carbon-cities-report.pdf

with domestic solar rooftop PV and batteries to 11,000 dwellings.

In order to decarbonise heat there is anticipated to be around 2,500 heat pumps and 27 projects to deliver 521 MWth of heat energy through the planned Bristol Heat Networks.

In the commercial sector it is anticipated there will be delivery of around 25 MW of batteries and up to 60 MW of large-scale solar rooftop.

The project also plans an initial EV charging network of around 60 chargers (with 120 connection points) from which a further charger network can be developed.

2. Summary of analysis

Bristol's climate emergency and carbon neutrality commitment are important steps in the fight against climate change. Reducing carbon emissions in the City to net zero needs huge commitment, investment and change from both local and national government. It will also require the mobilisation and support of businesses, institutions, communities and individuals across the city.

The analysis found that the baseline carbon emissions for the City of Bristol were around 1,724 kt CO_2e in 2016, roughly split into thirds by the end-use sectors of domestic, non-domestic, and transport energy demand. This equates to circa 3.7 tonnes of CO_2e per person per year.[11]

Projecting the City of Bristol carbon reduction policies forward under the 'Committed' scenario, and the 'Target 2050' scenario, we see emissions fall in all three of the sectors. The overall reduction in emissions across these sectors by the 'Committed' and 'Target 2050' scenarios are shown in Table 2-1. These changes in emissions come from a combination of local progress and national policy changes, such as grid electricity decarbonisation.

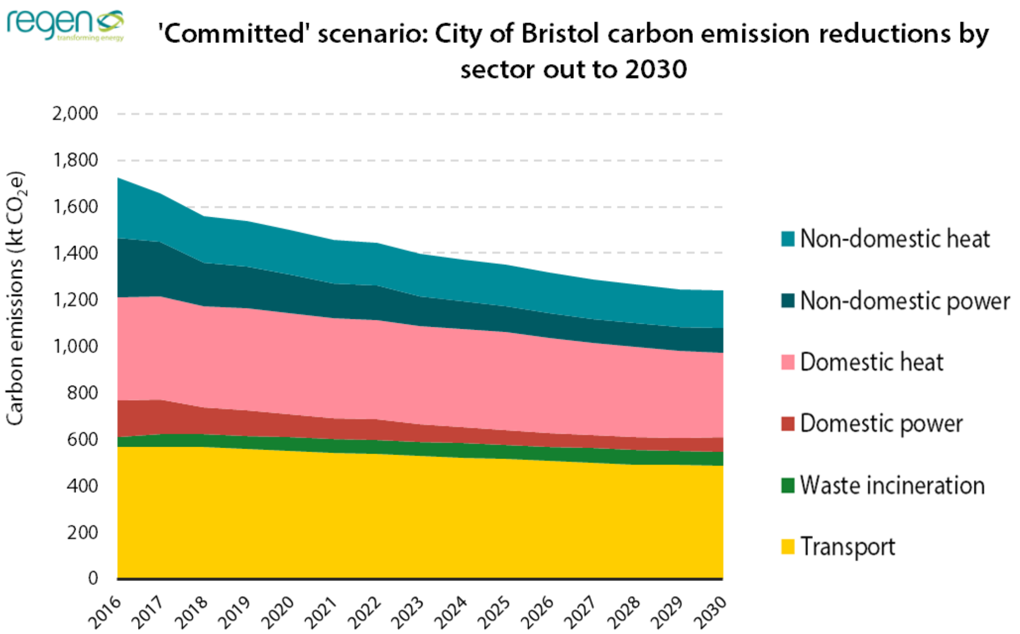
The more ambitious 'Target 2050' scenario delivers overall reductions of 46% with the 'Committed' projection due to reduce emissions by 28%. In both cases the largest reductions are seen in the non-domestic sector with the smallest reductions in transport. In a 'Target 2050' trajectory transport emissions reduce by 26% and in the 'Committed' trajectory it reduces by only 14%.

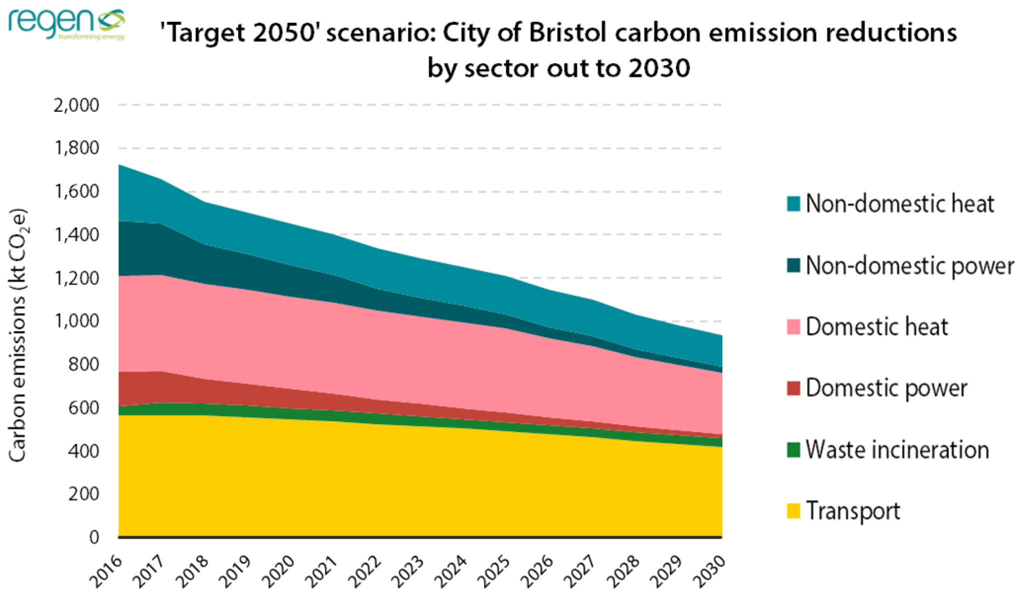
Table 2-1: Summary results and reductions by sector

	2016	2030	Reduction	% Reduction
	'Committed' scenario emissions (kt CO_2e)			
Domestic (Total)	603	423	180	30%
Heat	*444*	*362*	*81*	*18%*
Power	*160*	*61*	*98*	*62%*
Non-domestic (Total)	512	270	242	47%
Heat	*259*	*161*	98	38%
Power	*253*	*109*	144	57%
Waste incineration	43	61	- 18	-42%
Transport	566	486	80	14%
Total	1,724	1,241	483	28%
	2016	2030	Reduction	% Reduction
	'Target 2050' scenario emissions (kt CO_2e)			
Domestic (Total)	603	304	299	50%
Heat	*444*	*283*	*161*	*36%*
Power	*160*	*22*	*138*	*86%*
Non-domestic (Total)	512	172	340	66%
Heat	*259*	*147*	*111*	*43%*
Power	*253*	*25*	*229*	*90%*
Waste incineration	43	40	3	6%
Transport	566	419	147	26%
Total	1,724	936	788	46%

[11] Based on a population of circa 456k from ONS data 2016-based Population Projections for Local Authority by Age

Carbon emission summary graphs of the two scenarios out to 2030 by sector and demand type





A ‘Target 2050’ trajectory by 2030 would require considerable commitment and investment at both national and local level in order to achieve the scale of changes that are modelled. **Error! Reference source not found.** illustrates some of the actions required under this ‘Target 2050’ scenario to achieve some of the commitments already made by the City of Bristol.

Table 2-2: City of Bristol existing ideas and commitments and indicative actions that they would require

'Target 2050' Bristol Key commitments by 2030	Actions that this would require	Committed and planned activities
Energy generation:		
Achieve 20% of local renewable generation by 2027. *One City Plan*	This could involve installing solar rooftop PV • 30,000 domestic roofs at 3 kW per roof • 60 commercial sites c. 60 kW per roof • 30 large commercial sites with 2 MW systems It would also require doubling wind capacity at Bristol Port	City Leap plans to fit Domestic solar rooftop PV and batteries to 11,000 dwellings.
Example national actions: • Support for small and medium scale renewable generation to replace Feed-in-Tariff		
Built environment:		
Zero carbon new developments standard by 2025. *One City Plan*	This would lead to nearly **12,000 domestic dwellings** being built to a zero-carbon standard. This would avoid 24 GWh of heat demand and around 4.4kt CO_2 a year[12].	This is consistent with the One City Plan
75% of properties with an Energy Performance Certificate (EPC) at a level of C or above in 2031. *One City Plan*	This would require around **68,000 dwellings** insulated or fitted with other energy efficiency measures to improve performance and move EPC bands to above C rating.	The City Leap programme is looking to deliver energy efficiency measures to over 40,000 dwellings in the City.
Example national actions: • Energy performance certificates are accurate and methodology that reflects energy efficiency rather than heating technology • Targets for minimum EPC levels during property transactions		
A combination of heat pumps and heat networks supplying 32% of existing domestic dwellings by 2030. *Element Energy Study*	This would need around **43,000 existing dwellings** being installed with either hybrid or single heat pumps and **9,000 connected to the heat network.** The heat network delivers c. 350MWth by 2030.	The City Leap programme is currently anticipating fitting 2,500 heat pumps. The City Leap programme has 27 projects with the capacity to deliver 521MWth of heat from the heat network.
Example national actions: • Support or legislation for widespread roll-out of heat pump technology		
Smart systems Bristol *City Leap/BESST*	City Leap also promotes smart energy systems and smart meters	The BESST project is building on this to create clusters of smart

[12] Assuming the heat avoided was delivered by gas

	as an enabler of a low-carbon energy system.	energy businesses and homes to facilitate the delivery of innovative energy and transport service propositions.
Transport		
55,000 electric vehicles registered in the city. *FES Two Degrees*	The 26% reduction in carbon from transport would require 24% of vehicles in Bristol to be electric by 2030. This would increase electricity demand by c. 69GWh.	The City Leap is aiming to install 60 chargers with 120 connection points.
Example national actions: • Support to bring down the cost of electric vehicles and facilitate new models and choice • Development of a national charger network		

2-1. The zero carbon challenge

Bristol has already reduced carbon emissions 35% since 2005 and is likely to continue to see some significant reductions to 2030. The 'Committed' trajectory models how Bristol's existing commitments, if delivered, could reduce emissions a further 28% to around 1,241 kt CO_2e a year.

Moving Bristol City onto a 'Target 2050' trajectory is expected to deliver a larger 46% reduction to around 936 kt CO_2e. As Table 2-2 illustrates, delivering this will require a step change in activity including shifting a large number of journeys onto low-carbon modes, huge investment in decarbonised heat networks, low-carbon heating technologies and insulation of 68,000 properties.

To achieve zero carbon by 2030 will require change of another order of magnitude which would double the already challenging 'Target 2050' outcomes. This will require acceleration of action at an unprecedented scale, but also presents a huge opportunity. For Bristol this means delivering step changes in heating and powering key sectors, leap frogging incremental improvements to aim directly for zero carbon.

3. Baseline and historic trends

The City of Bristol is calculated to have emitted 1,724 kt CO_2e in 2016. The breakdown of carbon from the key sectors is outlined in Table 3-1**Error! Reference source not found.**.

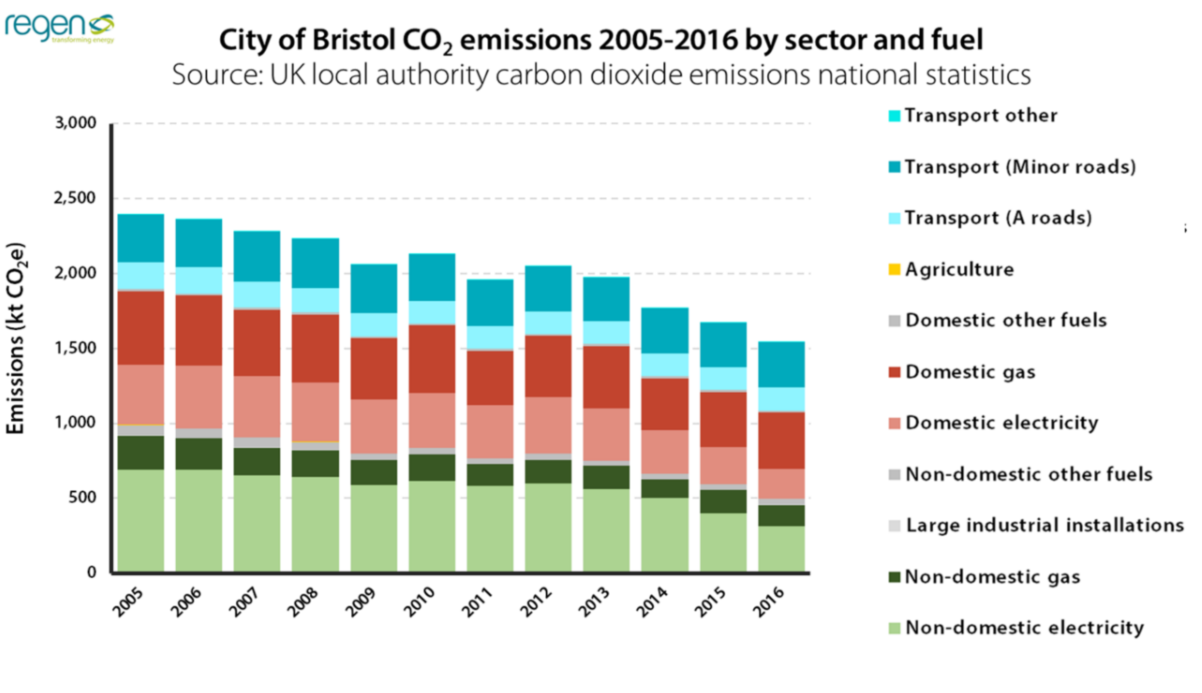
Table 3-1: Baseline emissions by sector

Sector	2016	Sector description
Domestic	603 kt CO_2e	This is the heat and electricity usage from domestic dwellings in the City of Bristol including social housing.
Non-domestic	512 kt CO_2e	The usage from commercial, industrial, retail and public sector properties.
Transport	566 kt CO_2e	Carbon from all vehicles including cars, LGVs, motorcycles, buses and HGVs.

Figure 3-1 provides a summary of the City of Bristol carbon emissions from 2005 to 2016. The trends show that emission have fallen 35% from nearly 2,500 kt CO_2e in 2005 to 1,724 kt CO_2e in 2016. The reduction is in line with national carbon emission reductions, both in terms of the scale and source of carbon savings.

As noted in the recent Committee on Climate Change progress report to parliament, the national reductions have mostly been a result of the reduction in carbon from electricity generation for domestic and commercial sectors, due to the increasing level of renewable generation and reduction in the use of coal.[13] Energy efficiency has also reduced overall demand for electricity and gas over the period by 20% and 30% respectively. However, efficiency in gas use has stalled in the last 5 years. Reductions in other sectors such as transport and heat have been much smaller.

Figure 3-1: City of Bristol historic kt CO_2e emissions



13 https://www.theccc.org.uk/wp-content/uploads/2018/06/CCC-2018-Progress-Report-to-Parliament.pdf. P.11

4. Transport and electric vehicles

4-1. Baseline Analysis

According to DfT statistics there were around **226,000** [14] **vehicles** registered in Bristol at the end of 2017, which equates to 0.6 % of the total GB vehicle fleet. Over 180,000 Bristol registered vehicles are cars.

DfT statistics from the National Road Traffic Survey[15] estimates annual mileage driven on Bristol's roads has increased 6% since 2010 to **1.46 billion journey miles** in 2017. This represents 0.45% of the total GB vehicle miles driven. Although vehicles registered and vehicle mileage are not directly correlated, and in a city, it is likely that although there are a high number of vehicles, they will tend to have lower annual mileage, the mileage figures for Bristol do seem especially low. This is discussed further in Appendix 13.

Road transport CO_2 emissions in Bristol fell by 6% from 2005 to 2010 but have remained largely static in the period 2010-2016[16] as improvements in vehicle efficiency and public transport have been offset by the rise in vehicle miles driven within the city[17].

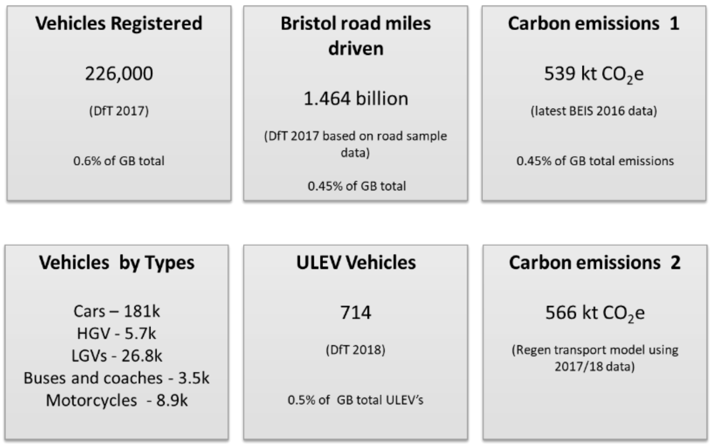


Figure 4-1: Baseline summary for City of Bristol

Data from the ONS and DfT suggest that from 2009 to 2017 the population of Bristol has increased by 10%. At the same time the vehicle mileage driven on Bristol roads has risen by 3%, while the number of bus passenger journeys has increased by 50%.

Table 4-2 Recent trends in population and transport use in Bristol

Bristol	2009/10	2017	Increase	Increase %	
Population	418,990	459,252	40,262	10%	People
Bus Passenger Journeys	28.1	42.3	14.2	50%	Millions
Vehicle Miles	1,424	1,464	40.0	3%	Million miles

[14] DfT Vehicle registrations by local authority – dataset 0135 end 2017.
[15] Dft Vehicle Mileage by Local Authority – dataset TRA 8901 end 2017.
[16] BEIS Local Authority CO2 emissions estimates 2005-2016 (kt CO2) - Full dataset
[17] Carbon emission data produced by BEIS using road usage sampling data

4-2. Electric and ultra-low emission vehicles (ULEVs)

As of end 2018 there were **710 ultra-low emission vehicles** (either electric or plug-in hybrids) registered in the Bristol City local authority[18]. This represents 0.5% of the GB ULEV registered vehicles, a little lower but broadly in line with the national average uptake of EVs.

4-3. Baseline carbon emissions

Carbon emissions from road transport in a city or region are difficult to establish accurately with the existing data available because:

- Methods using vehicles registered in Bristol do not account for the fact they will be used elsewhere, and non-Bristol registered vehicles commute into the city. Some fleet vehicles may be registered at head office locations outside or inside Bristol.
- Analysis using vehicle miles[19] as currently used by BEIS, does not differentiate between vehicle types and fuel usage, therefore electric vehicles are not considered. See section 13 which compares vehicle mileage figures for Bristol to other comparable cities.

The last baseline data for road transport emissions produced by BEIS for 2016, estimated Bristol city annual carbon emissions of **539 kt CO_2e** for all road types. Alternative options for calculating baseline transport carbon emissions are discussed in Appendix 12.

For the purpose of future modelling however this baseline has been recalibrated using the using the methodology of the Regen Road Transport Future Scenario Tool method. The model makes the following key assumptions:

- The vehicles registered within Bristol are representative of the mix of vehicles types using Bristol's roads taken from the DfT vehicle licence database for end 2018
- Vehicle mileage surveys for Bristol represent the mileage this mix of vehicles drives on Bristol's roads.

These assumptions allow the tool to assess how local changes may impact transport energy demand and carbon emissions and the impacts of increasing levels of electric vehicles and chargers on the electricity network. The tool also:

- Includes variables to consider vehicle fuel efficiency and the carbon intensity[20] of fuel types over time.
- Models domestic and commercial vehicles including cars, HGVs, LGVs, buses and coaches and motorcycles.

The tool estimates an annual carbon emission transport baseline of **566 kt CO_2e** which is slightly higher than the BEIS 2016 estimate of 539 kt CO_2e. The difference between this figure and the lower BEIS 2016 estimate is understandable given time differences in data sets and the basis of analysis.

4-4. Future trajectory analysis

In order to achieve a net zero or carbon neutral position it will be necessary to all but eliminate carbon emissions from transport sources. For understanding the trajectory for emissions to 2030, three main factors have been considered:

1. **The future growth in demand for transport.** The city population is set to increase by 2030 by 13% (The ONS[21]). If nothing were done to alleviate the impact of population growth and

[18] DfT Dataset VEH 0132 ULEV's by local authority area
[19] Extrapolated from National Road Traffic Survey sampling data
[20] Baseline Carbon intensity is based on 2018 UK Government GHG Conversion Factors for Company Reporting for fossil fuels, BEIS electricity carbon intensity and Regen's analysis of future hydrogen intensity

economic development the number of vehicles and road mileage driven within Bristol would increase. Based on the historic trend a 13% population growth could result in a 3.8% increase in vehicle miles although the Joint Transport Strategy has projected a higher potential journey increase for the region[22].

2. **Reducing journey miles by shifting modes of transport and changes in transport use.** It is expected however that the impacts of population and economic growth will be offset by changes in transport usage, increased use of public transport and a socio-economic shift away from reliance on private vehicle use. In many respects this shift is already evident with growth in bus journeys. JTS states that over the last 10 years, cycle trips have more than doubled with an increase of around 10% a year, bus journeys have increased by over a third and rail passengers have increased by more than half. There is also evidence that people are buying vehicles later and, particularly in urban environments, reliance on private cars may have peaked and may now be declining.
    - For the "Committed" scenario it is assumed that these factors offset each other producing a net 0% increase in vehicle miles.
    - For the "Target 2050" scenario it is assumed that measures to reduce vehicle miles take precedence resulting in a net 5% reduction in vehicle miles.
3. **Increasing numbers of Ultra Low Emission Vehicles being purchased,** and in particular electric vehicles[23] this is due to a combination of falling EV costs, greater choice of EVs and measures to address range and charger anxiety.

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[21] Office of National Statistics 2016-based Population Projections for Bristol Local Authority by Age

[22] The Joint Transport Strategy (JTS) notes that, without mitigation, car transport journeys could increase by 25% by 2036 P.13. https://s3-eu-west-1.amazonaws.com/travelwest/wp-content/uploads/2015/05/Full-Draft-JLTP4.pdf

[23] For a further description of what a high EV uptake outcome would look like see Regen Harnessing the EV Revolution 2018 https://www.regen.co.uk/wp-content/uploads/Harnessing_the_electric_vehicle_revolution_-_Regen_market_insight_series_-FINAL_2_pages-3.pdf

4-5. Trajectory scenario projections summary

		Baseline	"Commited" scenario 2030 based on FES 2018 Steady Progression	"Target 2050" scenario 2030 based on FES 2018 Two Degrees Scenario	"Carbon Neutral" illustration "Near" Net Zero Carbon based on Two Degrees
Carbon reduction 1 Shift in vehicle type and fuel usage	Electric Vehicles	710	14995	56408	223044
	Other ULEV Vehicles	70	628	1354	7250
	Petrol and Diesel Vehicles	225437	219653	173864	0
	All Vehicles Miles (Millions)	1,464	1508	1485	1424
	CO_2e Emissions 1 Tonnes	565,460	486296	427875	66244
	Carbon Reduction 1 From Baseline	0%	14%	24%	88%
Carbon reduction 2 Population and vehicle growth minus shift in mode of transport to public transport, active mobility and shared transport	Miles driven in cars	1,032	1066	1011	958
	% Miles by car	71%	71%	68%	67%
	CO_2e Emissions from cars	272,588	232725	175346	4590
	Net Reduction/increase in car miles %		0%	-5%	-25%
	Additional carbon increase/saving (tonnes)		0	-8767	-1147
Total carbon savings	CO_2e Emissions 1 + 2 Tonnes	565,460	486,296	419,108	65,096
	Total Carbon Reduction 1+ 2 Cumulative		14%	26%	89%

4-6. Transport emissions 'Committed' scenario

Bristol Road Transport – 2030 "Committed" scenario

Carbon emissions baseline

566 kt CO_2e

(Regen transport model using 2017/18 data)

Shift to ULEV

15k EVs plus 500 other ULEVs

CO_2 reduction of 14%

Based on a national "Steady Progression" scenario and limited city measures

Population and journey growth

Population growth of 13% is offset by changes in vehicle usage including public and active transport modes.

2030 outcome

Net CO2 reduction of 79 kt to 486 kt CO_2e

The 'Committed' or 'Steady Progression' is characterised by a slow uptake of ULEV and Electric Vehicles and limited measures nationally and within the city to support a shift to public and other active transport solutions.

Under this scenario it is projected that ULEV growth may reach only 15,000 EV vehicles by 2030 plus 500 other ULEV buses and HGVs. This modest shift to low emission vehicles would lead to a 14% reduction in carbon emissions.

Population growth, leading to a potential journey increase for car mileage of 10%, is offset by the measures currently being taken to increase the use of public transport and active mobility solutions. This includes, for example, improvements to rail links, extending Metrobus and cycle lanes.

4-7. Transport emissions ‘Target 2050’ trajectory

Bristol Road Transport – 2030 “Target 2050” scenario

Carbon emissions baseline	Shift to ULEV	Population and journey growth	2030 outcome
566 kt CO_2e (Regen transport model using 2017/18 data)	56 k EVs plus 1.5 k other ULEVs Based on a national “Two Degrees” scenario and Joint Transport Strategy and City Leap	Net reduction of 5% in car journeys and mileage	Net CO2 reduction of 147 kt to 419 kt CO_2e A 26% reduction

A ‘Target 2050’ outcome by 2030 would require the adoption and delivery of a number of transport initiatives, including those set out in the 2019 **Joint Transport Strategy**[24], that would initiate a step change in transport shift from cars to public transport and active travel. Key policies would include:

- Four ‘mass transit’ routes, potentially light rail from Bristol City Centre to the airport, Bath, North and East Fringes of the city and would be expected to displace car journeys on very congested routes. (see JTS p.44)
- City centre, levies or low emission zones. The report notes that workplace parking levies (see JTS p.58) could deliver a 2% reduction in trips. A “Clean Air Zone”, or congestion charging could have significant impact on uptake of electric vehicles.

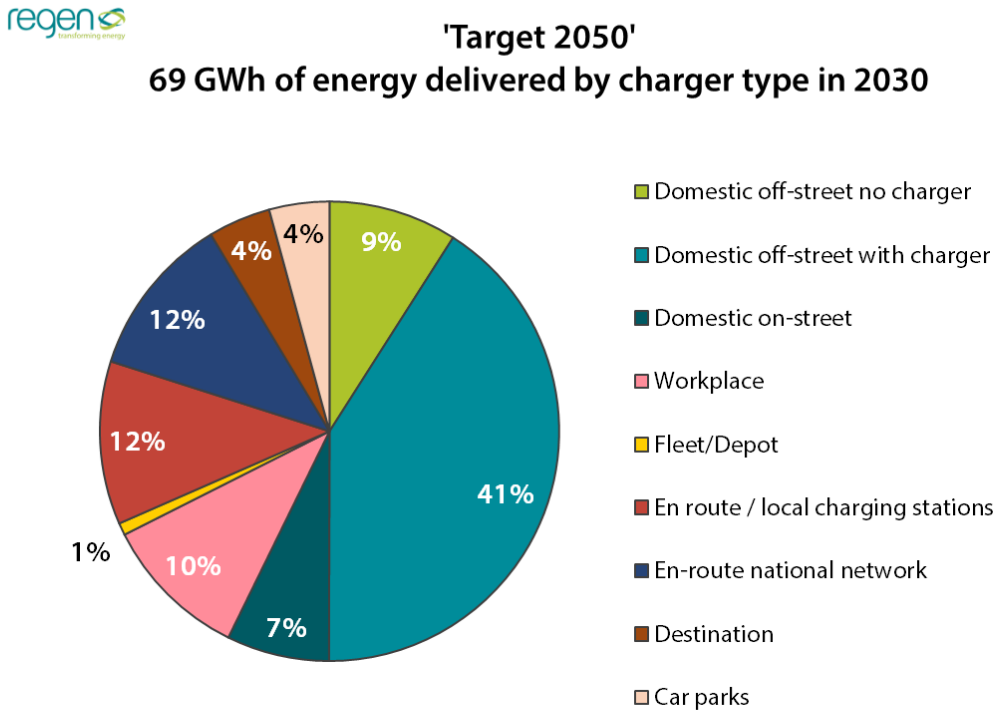
In addition to the measures set out in the JTS, the **Bristol City Leap**[25] proposed to spend £2m to support the deployment of at least 60 rapid and fast chargers (with 120 connections) as the first stage of a wider investment in charging infrastructure at destination, on-street and workplace locations. While it has not been possible to model the impacts of these investments in detail for this study, the ‘Target 2050’ scenario assumes:

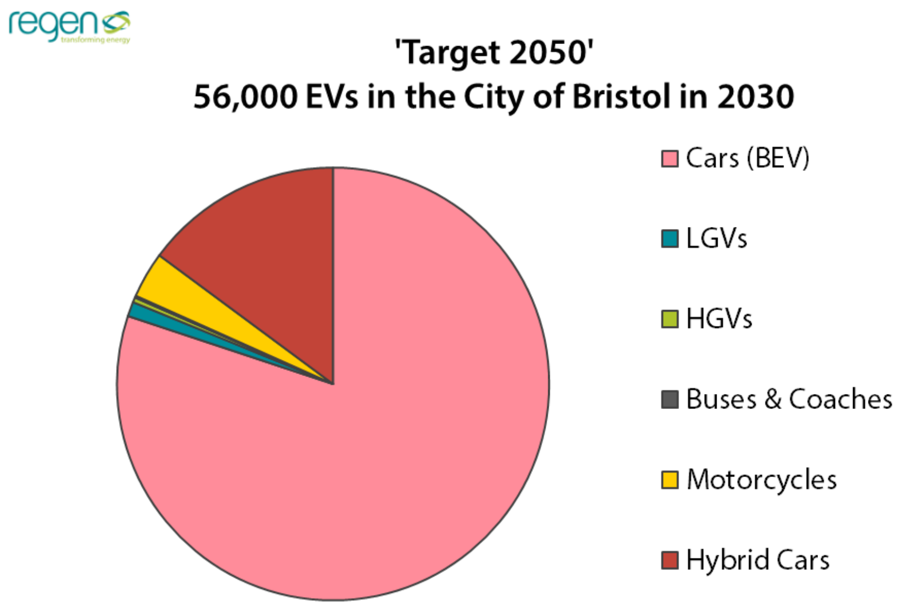
- A combination of national and city initiatives is sufficient to increase accelerate the uptake of EVs and ULEV to reach over 55,000 vehicles by 2030.
- Low emission zone initiatives, Metrobus and active travel initiatives in the city are sufficient to offset the growth in population with a net reduction of 5% of car vehicle mileage and journeys.

A ‘Target 2050’ scenario would achieve a net carbon reduction of 26% or 147 kt CO_2e. The electricity required to power this number of electric vehicles would be circa 69 GWh which could be provided by a variety of changes including home based, on-street, en-route and destination chargers. Over this period, improvements in appliances and building fabric energy efficiency contributes to a reduction in demand. However, with the electrification of heat, some of these gains are countered by increases in demand. In the National Grid FES 2018, both Steady Progression and Two Degrees see a decrease in energy demand out to 2030, followed by an increase to 2050.

[24] P.13. https://s3-eu-west-1.amazonaws.com/travelwest/wp-content/uploads/2015/05/Full-Draft-JLTP4.pdf
[25] Bristol City Leap see https://www.energyservicebristol.co.uk/prospectus/

Figure 4-3 Outputs from the Regen Road Transport Future Scenario Tool





5. Domestic and non-domestic buildings

The analysis and dataset include carbon emissions both from planned new build properties and existing properties within the City of Bristol buildings to 2030. As a result, this section covers the following four categories:

- Existing domestic dwellings
- New domestic dwellings
- Existing non-domestic properties
- New non-domestic properties

Baseline emissions from buildings (2016 kt CO_2e)	
Domestic (Total)	603
Heat	*444*
Power	*160*
Non-domestic (Total)	512
Heat	*259*
Power	*253*
Total	1,115

5-1. Domestic dwellings baseline

The existing domestic building stock in Bristol comprises just over 200,000 dwellings. Around 12% of Bristol's dwellings are social housing and 11% have been identified as being in fuel poverty[26].

It is estimated that dwellings currently emit 444 kt CO_2 a year as a result of energy used for heat and hot water, and 160 kt CO_2 from residual electricity demand to run appliances and lighting in the home.

The 2016 baseline of emissions from domestic heat and power is calculated through the split of heating technologies, power demand, and the associated carbon factors.

Calculations using EPCs

Around half of Bristol properties have an EPC. EPCs are produced when a property is sold, let or has applied for a renewable energy subsidy. Although not a perfect measure of energy performance and carbon emissions[27], the high number of homes with an EPC provides a useful dataset to analyse the state of the existing housing stock. Heating technologies are not evenly distributed by EPC band, with electric heating more prevalent in less efficient dwellings.

A comparison of 2011 EPC records and 2011 census data suggests that they provide a reasonably large sample of the domestic heating fuel type used which can be extrapolated to all dwellings. It has therefore been assumed that the EPCs are representative of the city's building stock and have been extrapolated to provide a picture of the total efficiency and heating technologies. Using this analysis, it is assumed that:

- 82% of the city's dwellings are heated by mains gas
- 17% are electrically heated
- 3,000 kWh[28] per property for electricity usage on appliances or lighting

[26] https://www.bristol-energy.co.uk/our-fuel-good-fund
[27] https://www.regen.co.uk/over-and-over/
[28] Estimate based on Bristol Energy average demand for Profile Class 1 dual fuel customers. Also, with reference to Ofgem TDC (Typical domestic consumption values)

The emissions from power are calculated using the electricity demand for uses other than for heat, i.e. appliance and lighting demand. This power demand was multiplied by the carbon intensity of the grid, using a slightly reduced factor accounting for local low-carbon generation.

Energy rating	Assumed annual kWh for heat[29]	Existing split	Implied numbers in band
Zero carbon	500	0%	0
EPC A	2,550	0.2%	323
EPC B	3,952	9.5%	19,104
EPC C	7,541	28.6%	57,328
EPC D	10,926	38.9%	77,906
EPC E	14,469	18.0%	36,060
EPC F	17,024	4.0%	8,062
EPC G	18,574	0.7%	1,501

Table 5-1: kt CO_2 trajectory from existing dwellings to 2030

5-2. New domestic dwellings

Bristol is expecting to have an additional 57,000 residents by 2030[30] and as a result is expecting to build over 20,000 new homes by 2030. There is expected to be around 1,500 new dwellings built each year[31].

Key to the carbon impact of these new properties is their energy demand which will be determined by how well they are insulated, as well as the technology that is used for heating. Analysis of the average EPCs submitted for new builds from 2015 and 2016 suggests that in that period, around half of new properties are heated by gas, and around half heated by electricity. Only 2% of new domestic properties appear to be heated by heat pump.

The following energy efficiency ratings have been registered in Bristol from new build dwellings built between 2013 and 2016:

Energy rating	Assumed annual kWh for heat[32]	New dwellings
Zero carbon	500	0%
EPC A	2,550	7%
EPC B	3,952	70%
EPC C and below	7,541	23%

5-3. Non-domestic properties baseline

According to ordinance survey data there are around 21,400[33] non-domestic properties in Bristol. There are a wide variety of property types within this category.

Figure 6-3 shows the Element Energy study breakdown of non-domestic heat demand. The study calculated a total demand of just over 1,000 GWh, of which 81% is currently delivered by gas, 12%

[29] Heat demand calculated from EPC stock data average demand per m^2 applied to average Bristol dwellings
[30] ONS Population growth by local authority 2016-based Population Projections for Local Authority by Age
[31] Regen analysis of local plans for Bristol
[32] Heat demand calculated from EPC stock data average demand per m^2 applied to average Bristol dwellings
[33] ONS business unit counts 2017

by electricity and the balance from other sources[34]. The largest demand comes from industrial, retail and transport sectors.

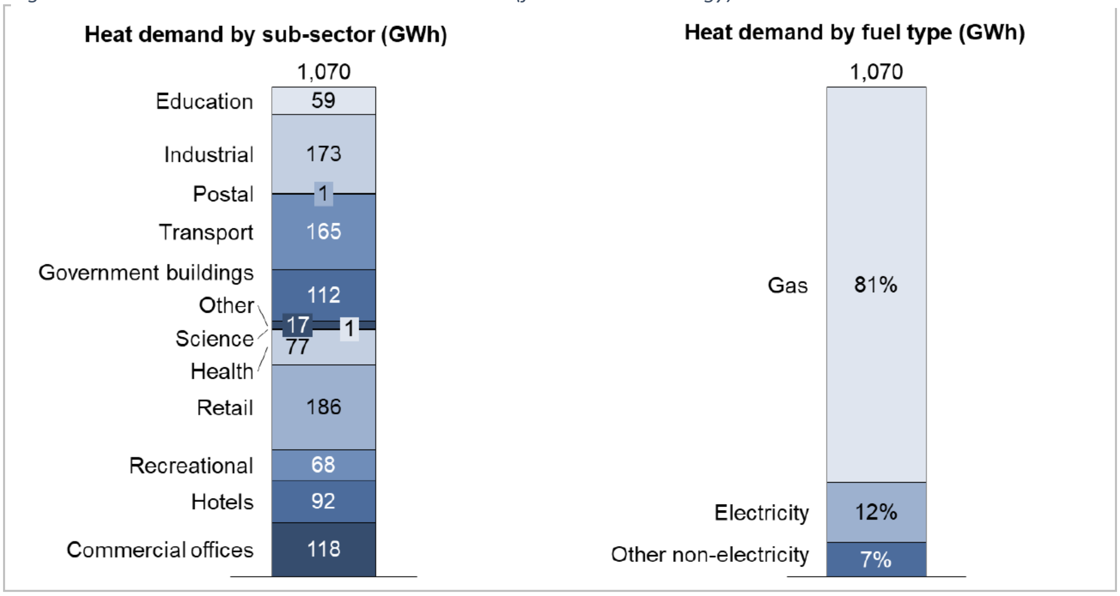
Based on this breakdown, the carbon emission baseline for the non-domestic sector is estimated to be **259 kt CO_2** for heat and **253 kt CO_2** for power.

The average non-domestic energy demand per m^2 for all properties is therefore much lower than the mean domestic energy consumption per m^2. An analysis of gas connection data from WWU suggest that there are over 4,639 non-domestic gas connections. The wide difference between the non-domestic gas connections and the number of properties is not atypical and can be explained by:

- A relatively large number of non-domestic properties which will be unheated (warehouses, industrial units etc.)
- Several properties may share one gas connection

Those non-domestic properties which do have a gas connection will, on average, have a high heat requirement. An analysis of EPC data for Bristol City, suggests that non-domestic properties heated by natural gas are on average 2.5 times larger than those heated by grid supplied electricity.

Figure 5-2 Heat demand in the non-domestic sector (from Element Energy)



[34] Element Energy (2019) – figure 4.2

5-4. New non-domestic properties

Bristol is expecting a large amount of non-domestic new development up to 2030. The biggest sites are expected to be around Avonmouth and Bristol Port, but there are also planned developments in the city centre.

A projection of circa 50,000 m^2 a year of new build commercial building is expected to be completed in Bristol to 2030, the majority being either office, industrial or warehousing. Currently 87% of new non-domestic properties are B rated and above, and 27% are A-rated.

For this analysis it is assumed that new non-domestic properties currently use around 100 kWh/m^2 for heating or cooling per year. The potential range is however large, as some properties will be unheated and others, such as hotels, may require significantly higher energy demand. 100 kWh/m^2 has therefore been used as a mid-range figure. [35]

[35] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770783/2nd_UK_Cost_Optimal_Report.pdf. P.110

6. Domestic and non-domestic future scenario projections key assumptions

The following stages have been used in order to develop trajectories for each of the sectors:

1. The heat demand needed for each sector is determined by the energy efficiency of the building stock as measured by Energy Performance Certificate bandings.
2. The type and proportion of heating technologies (both gas and electricity) used in buildings to deliver the required heat demand.
3. The carbon emissions from heating (including for hot water) are then calculated from the carbon factors associated with each heating technology.
4. In addition, the carbon emissions from electricity used in running appliances and lighting is also added to the total.

6-1. Heat trajectories

The future heat trajectories for both heat networks and heat pumps have been based on the Element Energy heat decarbonisation and evidence base developed for Bristol City Council (2018).

The Element Energy study considered a variety of potential decarbonisation scenarios for heat in the city using Low, Medium and High scenarios for the installation levels of various technologies and actions such as energy efficiency and new build regulation.

We were able to determine the proportion of heat from heat pumps and heat networks delivered by different sectors by using Element Energy's total GWh delivered along with information contained in Element Energy's report on the percentage of heat delivered to domestic, non-domestic, new and retrofit buildings in 2025. Through this we have been able to estimate the proportion of heat delivered by heat networks and heat networks to each key sector, each year to 2030.

More information on this approach and the results of the calculations can be found in Appendix section 15. How we have used these scenarios in the two trajectories is detailed in Table 6-1.

Table 6-1: Element Energy scenarios and how they have been used in the two trajectories

Sector	Element Energy scenarios used for 'Committed'	Element energy scenarios used for 'Target 2050'
Existing properties Domestic and non-domestic	Medium heat network Low heat pump	High heat network Medium heat pump
New properties Domestic and non-domestic	Medium heat network Medium heat pump	High heat network High heat pump

6-2. Heat Networks

Element Energy's medium heat network scenario informs the 'Committed' trajectory. This trajectory assumes the completion of schemes outlined in **the City Leap prospectus**. This includes Temple & Redcliffe, City Centre Phase 1 and 2, and construction of the Strategic

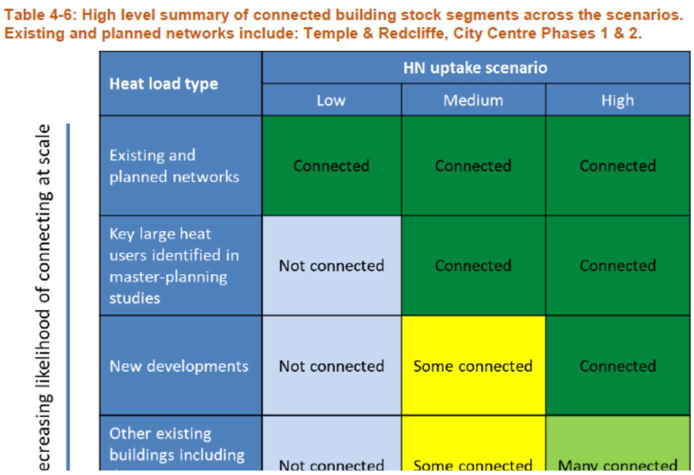


Table 4-6: High level summary of connected building stock segments across the scenarios. Existing and planned networks include: Temple & Redcliffe, City Centre Phases 1 & 2.

Heat load type	HN uptake scenario		
	Low	Medium	High
Existing and planned networks	Connected	Connected	Connected
Key large heat users identified in master-planning studies	Not connected	Connected	Connected
New developments	Not connected	Some connected	Connected
Other existing buildings including	Not connected	Some connected	Many connected

Figure 6-1: Heat network assumptions source: Element Energy Study

Heat, mainly to allow the supply of low carbon waste heat from Avonmouth to the city centre.[36]

'Target 2050' uses Element Energy's High Heat Network scenario. This assumes a similar deployment of schemes by 2030, but a larger share of existing buildings are connected. In both scenarios it is assumed that there is a higher rate of connection of non-domestic buildings due to the greater heat demands and economies of scale along with the ease of coordination and delivery.

Heat Network scenario projections to 2030				
Element Energy Scenario	**Carbon Reduction Scenario**	**Total heat delivered by Heat Networks (GWh)**	**Heat delivered to domestic properties (GWh)**	**Heat delivered to non-domestic properties (GWh)**
High	'Target 2050'	334	111	223
Medium	'Committed'	276	65	211

Table 6-2: Heat network scenario projections to 2030. Source Element Energy data and Regen projections

The carbon factor for heat networks can vary greatly and is dependent on the carbon factor of the input fuel type. If the heat network is not fuelled by low carbon, renewable resources, then it may have an unsustainably high carbon factor which increases, rather than decreases carbon emissions in the city. The carbon factor for heat networks in this analysis has also been taken from Element Energy's study which have been calculated from various planned sources for heat in the city.[37] This varies over the period and is 0.1066 kg CO_2 per kWh in 'Target 2050' scenario in 2030 reflecting that the source of the heat remains relatively high carbon during this period. A key challenge to meet a more ambitious decarbonisation target will be to ensure that heat networks are able to secure low carbon heat sources and to move away from the use of gas.

6-3. Heat pumps

A total sector heat demand estimate has then been used to determine the proportion of heat delivered by heat pumps each year to 2030 and from there a percentage of total heat has been calculated. The results of this calculation infer that for 'Committed' and 'Target 2050', 7% and 13% of existing dwellings respectively are heated by either a single or hybrid heat pump by 2030.

Heat pump scenario projections to 2030 (Heat pump and hybrid heat pump)				
Element Energy scenario	**Carbon reduction scenario**	**Total heat delivered by Heat Pumps (GWh)**	**Heat delivered to domestic properties (GWh)**	**Heat delivered to non-domestic properties (GWh)**
Medium	'Target 2050'	360	172	188
Low	'Committed'	145	93	52

Table 6-3: Heat Pump Growth Scenarios - Source Element Energy and Regen extrapolation to 2030

The carbon factor of heat pumps and hybrid heat pumps will vary over the period as the carbon intensity of the national electricity supply decarbonises. This is detailed in the dataset provided to Bristol City Council alongside this report.

The carbon factor for a heat pump is based on the grid electricity carbon factor with an assumption of a coefficient of performance of 3. As a result, the carbon factor is a third of the grid electricity carbon.

[36] Element Energy, 2018, p.10
[37] Element Energy Study. P.20

6-4. Domestic electricity non-heat electricity usage

The non-heat electricity usage from appliances and lighting is anticipated to be similar across new and existing homes. It is not an issue on which there is perfect clarity, as appliances and electric heating are not metered separately.

Electricity sales to those with dual fuel tariffs can give an indication of the underlying appliance demand, as the electricity use for these is assumed to be entirely appliance use. However, the appliance electricity consumption from those with electric heating is hard to specify. In the dataset, we have used figures based on a range of sources, including Ofgem publications[38], letters from network operators[39], suppliers, and BEIS statistics.

Our analysis suggests that homes with electric heating are using much less energy for heating their homes than those with gas. This is explained partly through the reduced average size of electrically heated homes (from EPC data for Bristol), as well as the relative cost per unit of electricity and the increased proportion of households with electric heating which are in fuel poverty.

This residual electrical demand is assumed to be the same across all heating types however, and decreases across the period in line with data from National Grid FES 2018, as appliance efficiency improves in line with EU directives. It is estimated to be 3,000 kWh/dwelling/year in 2016. The carbon emissions related to this energy use will be determined by the carbon factor of national electricity supply.

6-5. Non-domestic non-heat electricity usage

The electricity consumption of non-domestic buildings other than that which goes towards heat, isn’t well defined from EPC and national statistics. However, the heat component of electrically heated non-domestic units can be assessed through these statistics[40], and a proportional split applied.

This approach is limited in the sense that it does not allow for sub-sectorial differences in energy and electricity consumption, and it apportions the same residual electricity demand to all sectors. However, without specific metering data from across the sub-sectors in Bristol, this approach arrives at a similar final total figure for electricity appliance demand without additional assumptions.

Furthermore, it allows for a ‘proportional’ approach, meaning that this number keeps astride with changes to the numbers of units, including non-domestic new build and demolition rates. This proportion may become less correct with step-changes in appliance efficiency in non-domestic buildings, and if the building type mix in Bristol changes significantly between 2016 and 2030.

[38] Ofgem letter on TDCV (typical domestic consumption values) https://www.ofgem.gov.uk/system/files/docs/2017/08/tdcvs_2017_open_letter.pdf
[39] https://www.ofgem.gov.uk/system/files/docs/2017/08/wales_and_west_utilities.pdf
[40] BEIS energy consumption statistics: https://www.gov.uk/government/collections/total-final-energy-consumption-at-sub-national-level

7. Carbon reduction trajectories for domestic dwellings

7-1. Total existing and new domestic dwellings heat demand and carbon emissions

The carbon emissions from heating domestic dwellings was 444 kt CO_2e in 2016. The combined emissions for new and existing domestic dwellings in 2030 are expected to be 362 kt CO_2e (18% reduction) in a 'Committed' trajectory, and 283 kt CO_2e (36% reduction) in a 'Target 2050' scenario.

Table 7-1 summarises the dataset for domestic dwellings along with the proportion of heat demand met by different technology types out to 2030.

Table 7-1 Domestic heat results by heat demand and proportion[41,42]

	Total domestic heat demand by technology type ('Current') (GWh)						Carbon emissions from heat (kt CO_2e)
	2020		2025		2030		
Natural gas	1,925	92.9%	1,877	89.9%	1,604	79.3%	341.3
Electric heating	92	4.8%	95	2.0%	91	2.0%	9.6
Heat pump	16	1.0%	47	2.7%	71	7.1%	0.8
Heat networks	10	0.6%	19	3.7%	65	7.6%	9.3
Coal	7	0.4%	6	0.2%	-	0.0%	-
LPG	3	0.2%	3	0.1%	-	0.0%	-
Oil	3	0.1%	13	0.1%	22	0.0%	-
Biomass	2	0.1%	2	0.0%	-	0.0%	-
Hybrid heat pump	1	0.0%	1	1.3%	-	4.0%	1.2
Total:	2,060	GWh	2,062	GWh	1,854	GWh	362.2

	Total domestic heat demand by technology type ('On track') (GWh)						Carbon emissions from heat (kt CO_2e)
	2020		2025		2030		
Natural gas	1,896	93.0%	1,739	86.1%	1,223	62.7%	260.2
Electric heating	99	4.8%	89	2.0%	82	2.2%	3.4
Heat pump	12	0.9%	68	2.6%	111	13.3%	0.5
Heat networks	9	0.7%	18	6.6%	111	14.1%	16.0
Coal	7	0.4%	6	0.2%	-	0.0%	-
LPG	3	0.2%	3	0.1%	-	0.0%	-
Oil	2	0.1%	2	0.1%	-	0.0%	-
Biomass	1	0.1%	1	0.0%	-	0.0%	-
Hybrid heat pump	-	0.0%	25	2.3%	61	7.7%	2.6
Total:	2,030		1,950		1,588		282.8

Heat demand from existing domestic dwellings

The 'Committed' trajectory assumes a continuing trend of improvements to the energy efficiency of Bristol's existing domestic housing in Bristol. This trajectory assumes heat energy demand reduces by 13%, as a result of upgrades to around 32,000 dwellings.

The 'Target 2050' trajectory is more ambitious and meets the objective within the One City Plan to have 75% of properties in the city at an energy efficient EPC rating of level C or better by 2031[43]. This aspiration would imply upgrading 68,000 homes, currently in EPC bands G to D, to ratings of C and above. Achieving this will reduce the heat energy delivered by around 25% and save 97 kt CO_2 per year.

[41] Element Energy Study, data tables.
[42] EPC data for City of Bristol
[43] P.31 https://www.bristolonecity.com/wp-content/pdf/BD11190-One-CIty-Plan-web-version.pdf

To estimate the magnitude and types of measures that would be needed to achieve this level of energy efficiency, Regen analysed the 13,000 existing EPCs in Bristol which detail measures that move EPCs D, E, F and G to an EPC level C. These were then extrapolated to the 68,000 properties that would need upgrading in the 'Target 2050' trajectory.

Table 7-2: Types of measures and numbers needed to upgrade 68,000 properties to reach 'Target 2050'

Domestic energy efficiency measures	Estimation of installation numbers required
Replacement boiler	35,117
Solid wall insulation	34,885
Floor insulation	31,545
Heating controls	27,317
Double glazing	16,751
Loft or roof insulation	16,681
Cavity wall insulation	14,925
Hot water insulation	13,315
Draft proofing	9,092
Upgrade electric heating	5,742

Key policies to deliver energy efficiency

Both trajectories will require building on **Bristol's Warmer Homes initiative and Warm Up Bristol** which has successfully insulated 10,000 dwellings[44] as well as continuing programmes to improve the 34,000 social houses[45] of which 27,000 are currently owned by the city.

It is estimated that 8,000 social houses are below EPC rating C, of which 4,000 have solid walls. The Energy Savings Trust estimate that this would cost around £13,000 per property to upgrade which would imply a cost of over £50m[46].

The City Leap prospectus also highlights two key areas. Firstly, the **Fuel Poverty Programme,** which would focus on improving the 20,000 fuel poor properties in the City to an EPC standard C or above.

The second area is a focus on efficiency in private homes including an **affordable revolving loan fund** for householders which has already received £300,000 funding from Bristol City Council[47]. Assuming £60/tonne and a five year payback for energy efficiency[48], this on its own could deliver around 10 kt CO_2 savings by 2030. There is also a complementary consumer confidence programme to drive demand for energy efficiency in the 'able to pay' sector[49].

The City Leap investment programme could potentially lead to the installation of energy efficiency measures in 40,000 buildings across the city which is around two thirds of the level needed to achieve a 'Target 2050' scenario, assuming that the City leap upgrades will be on properties below a rating of C and upgrading to EPC level C and above.

[44] https://www.energyservicebristol.co.uk/wp-content/pdf/City_Leap_Prospectus%204-5-18.pdf (p.7)
[45] Element Energy, 2018, p.16
[46] https://www.energysavingtrust.org.uk/home-insulation/solid-wall (accessed 21.3.19)
[47] https://www.wessexresolutions.org.uk/?domain=www.wrcic.org.uk
[48] https://www.london.gov.uk/sites/default/files/carbon_offsett_funds_guidance_2018.pdf (p.6)
[49] https://www.energyservicebristol.co.uk/wp-content/pdf/City_Leap_Prospectus%204-5-18.pdf (p.16-17)

Table 7-3: Assumptions around heat energy and efficiency for existing dwellings in trajectories.

	Baseline	**'Committed' 2030**	**'Target 2050' 2030**
Change in kWh delivered		**-13%**	**-25%**
Properties moved to C and above		**32,695**	**68,485**
Zero carbon	0%	0%	0%
EPC A	0%	1%	4%
EPC B	10%	12%	20%
EPC C	29%	41%	48%
EPC D	39%	36%	24%
EPC E	18%	9%	3%
EPC F	4%	0%	0%
EPC G	1%	0%	0%

Heating technologies in existing domestic dwellings

Natural gas heats around 82% of domestic dwellings in Bristol but provides 93% of heat energy to this sector. These statistics suggest that gas heated properties have a significantly higher energy demand than electrically heated homes.

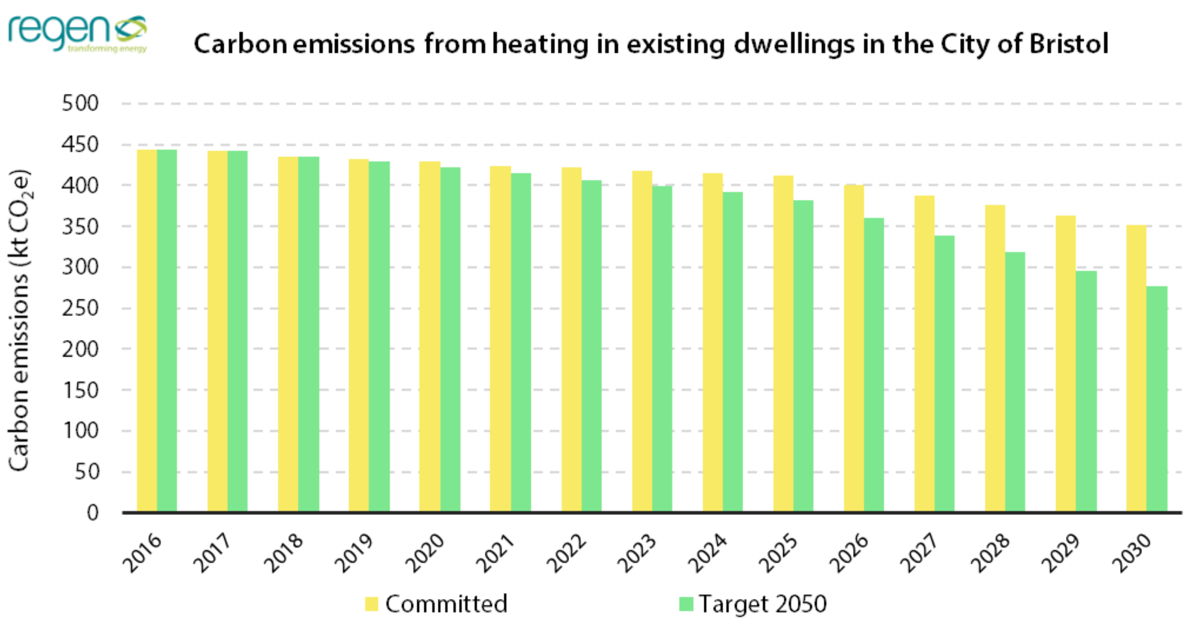
A further key policy for the City of Bristol is the development of heat networks with significant plans outlined in the City Leap Prospectus published in 2018[50]. An 'Target 2050' trajectory uses the high growth for heat networks from the Element Energy analysis which suggests that around 8% or 16,000 existing properties are connected to the heat network by 2030.

The roll out of heat pumps, both hybrid and single heat pumps will also make significant contributions to the decarbonisation of heat in Bristol. The medium heat pumps scenario from the Element Energy analysis projects that 12% of dwellings (around 24,000) would be heated by either single or hybrid heat pump by 2030.

City Leap is expected to support the installation of around 2,500 heat pumps. However, these trajectories suggest that the heat pump roll out would need to be significantly higher in the city in order to achieve the anticipated level of installations for this scenario. Achieving this level would therefore require UK wide incentives and regulations such as those used to achieve the switch to condensing boilers.

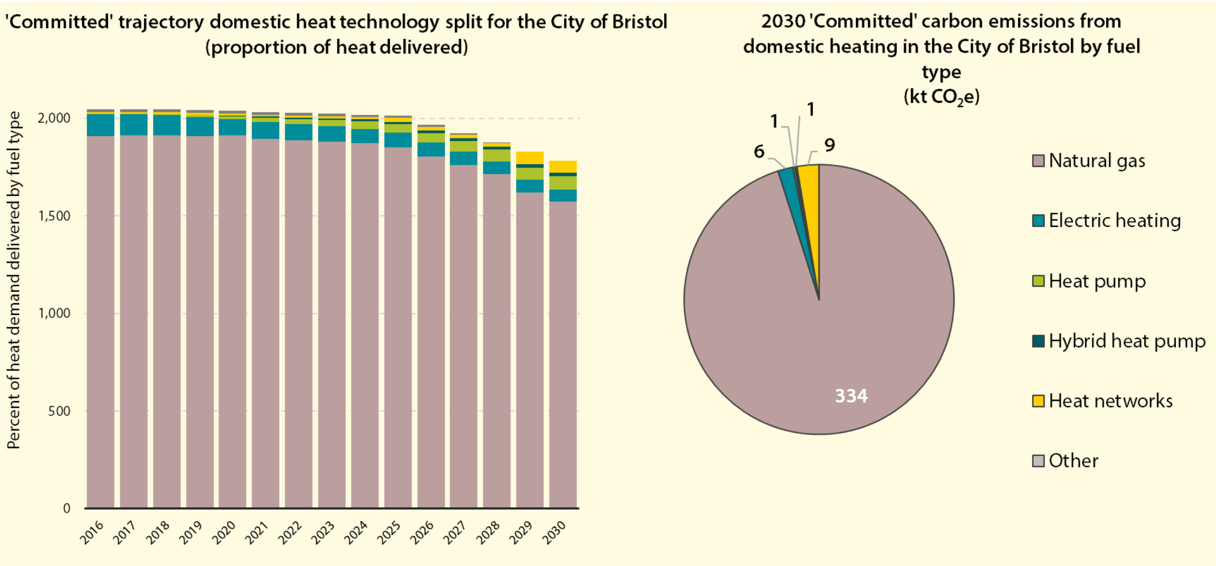
The study assumes that the installations of heat pumps and heat networks displace existing heating from natural gas as well as some electrically heated properties and therefore the proportion of properties heated by gas reduces towards 2030. To calculate the carbon emissions from gas the direct combustion carbon factor for natural gas has been used of 0.183 kg/CO_2e from BEIS [51]which is also consistent with Element Energy's study.

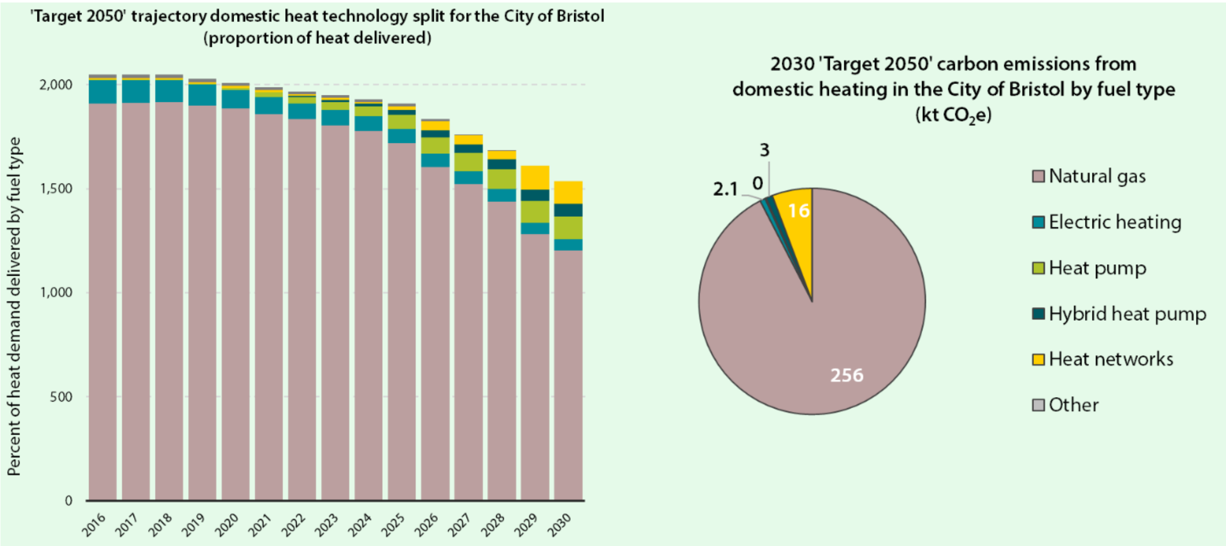
Figure 7-1: Carbon emission trends from heat energy in existing domestic dwellings over time 2030



[50] P.12-13 https://www.energyservicebristol.co.uk/wp-content/pdf/City_Leap_Prospectus%204-5-18.pdf
[51] https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

Figure 7-2: Changes in fuel type over time and 2030 carbon emissions from heat demand by technology types by scenario





7-2. New domestic dwellings

Heat demand in new dwellings

New build homes are already built to much higher energy efficiency standards than existing dwellings with nearly 80% built to EPC levels A and B.

In a 'Committed' trajectory the ratings of new homes are expected to continue to improve over time, removing all bands under EPC B by 2030, with 5% built as 'carbon zero' with a very low residual heat energy demand.

A 'Target 2050' trajectory follows Bristol's One City Plan which expects all new homes to be zero carbon by 2025. This trajectory puts 80% of new builds as zero carbon by 2025. This trajectory is also consistent with the UK government's announcement that no new properties would be heated by gas from 2025[52].

The assumptions used in this study are set out Table 7-4. This includes an estimated 500 kWh per year residual heat energy use for a 'zero carbon' property.

Table 7-4: Changes to energy ratings for new build domestic dwellings as modelled in the trajectories

Energy rating	Estimated kWh per year[53]	Baseline	'Committed' 2030	'Target 2050' 2030
Zero carbon	500	0.0%	5.0%	80.0%
EPC A	2,550	7.3%	20.0%	20.0%
EPC B	3,952	71.2%	75.0%	0.0%
EPC C	7,541	16.3%	0.0%	0.0%
EPC D	10,926	4.0%	0.0%	0.0%
EPC E	14,469	1.1%	0.0%	0.0%
EPC F	17,024	0.2%	0.0%	0.0%
EPC G	18,574	0.0%	0.0%	0.0%

Heating technologies in new dwellings

This analysis also uses Element Energy data for the level of heat networks and heat pumps installed in new domestic properties. These are outlined in Table 7-5**Error! Reference source not found.**. In the 'Committed' scenario 60% of new build properties built in 2030 would be heated by a heat network or heat pump, in an 'Target 2050' scenario this is 95%. The actions taken in the 'Committed' and 'Target 2050' trajectories are calculated as avoiding 8 and 13 kt CO_2 up to 2030 respectively.

Table 7-5: Assumptions for new build domestic dwellings heating technologies in 2030 by trajectory

Heating technology	Baseline (average 2015 & 2016)	'Committed' 2030	'Target 2050' 2030
Gas	50%	18%	0%
Electricity	48%	21%	5%
Heat pumps	2%	45%	34%
Heat network	0%	16%	61%

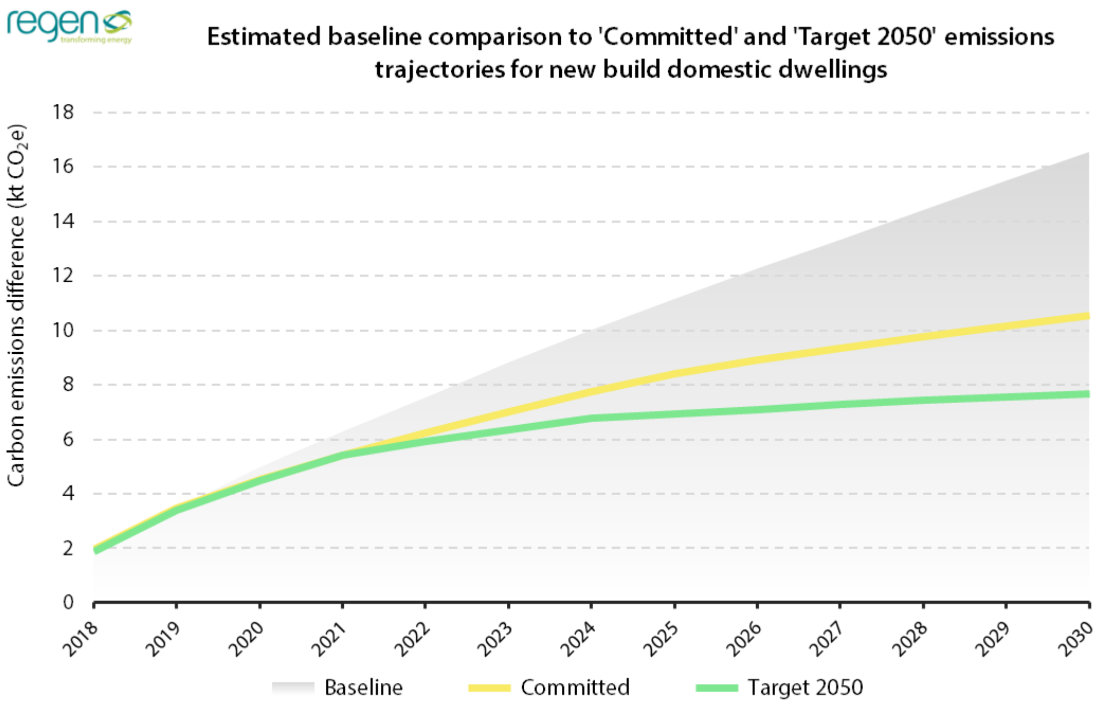
[52] https://www.independent.co.uk/news/uk/politics/gas-ban-new-homes-fossil-fuels-government-phillip-hammond-spring-statement-a8821941.html (accessed 21.03.19)
[53] From EPC data for Bristol and Regen analysis of energy trends

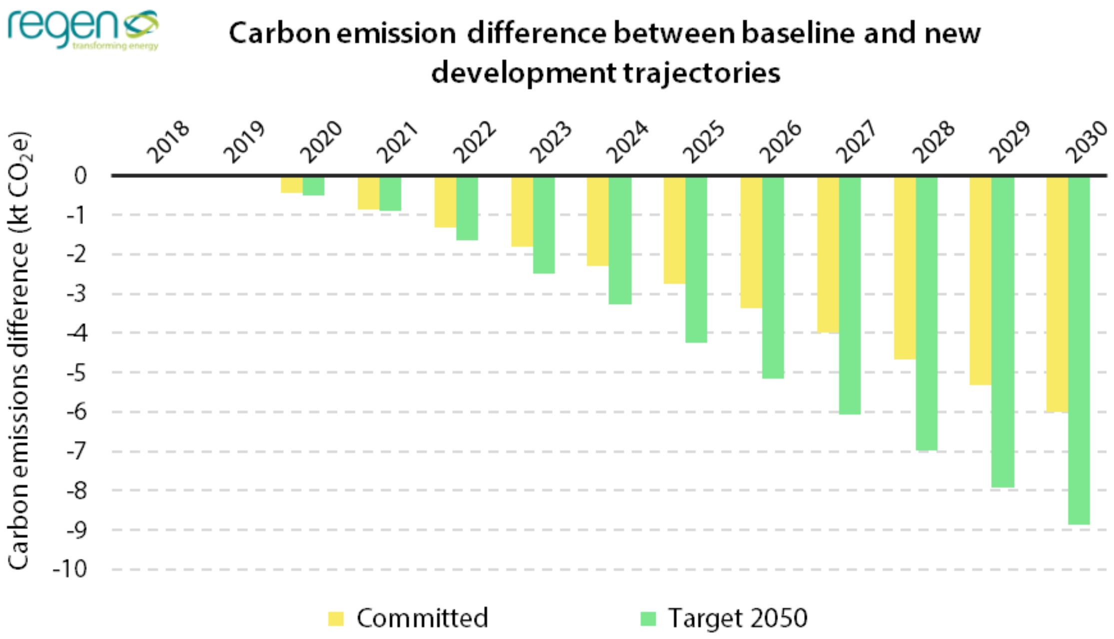
New domestic dwelling heat results

The results from the analysis show that there is significant potential to avoid new sources of carbon emissions through policies such as the zero carbon new homes standard by 2025.

Compared to the baseline emission for new builds in 2015 and 2016, the improved standards under a 'Committed' trajectory reduces carbon emission by around 6 kt CO_2 of carbon from new properties per year to 2030. Higher standards under a 'Target 2050' scenario would reduce emission by nearly 9 kt CO_2 per year. More could be avoided by bringing the zero carbon standard date forward to earlier in the 2020s.

Figure 7-6: kt CO_2 from new build dwellings to 2030





8. Carbon reduction trajectories for non-domestic properties

8-1. Total existing and new non-domestic heat demand and carbon emissions

The carbon emissions from heating non-domestic properties was 259 kt CO_2e in 2016. The combined emissions for new and existing non-domestic property in 2030 is expected to be 161 kt CO_2e (a 38% reduction) in a 'Committed' trajectory and 147 kt CO_2e (43% reduction) in a 'Target 2050' scenario.

Table 8-1 outlines how reductions in the non-domestic heat demand and carbon could reduce over time to 2030.

Table 8-1: Total emissions and heat demand delivery for new and retrofit non-domestic

	Total non-domestic heat demand by technology type ('Target 2050') (GWh)						Carbon emissions from heat (kt CO_2e)
	2020		**2025**		**2030**		
Natural gas	812	75.7%	681	68.0%	330	36.1%	58.5
Petroleum products	125	11.7%	125	12.5%	125	13.7%	35.7
Electric heating	116	10.8%	56	5.6%	40	4.4%	1.6
Manufactured fuels	7	0.7%	47	4.7%	222	24.4%	2.3
Heat networks	7	0.6%	7	0.7%	7	0.8%	26.4
Heat pump	5	0.5%	63	6.3%	123	13.5%	6.6
Coal	-	0.0%	-	0.0%	-	0.0%	-
Hybrid heat pump	-	0.0%	22	2.2%	65	7.1%	14.3
Total:	1,072	GWh	1,000	GWh	912	GWh	145.6

Heat demand in existing non-domestic properties

The 'Committed' trajectory assumes a continuing trend to improve the energy efficiency of non-domestic properties in Bristol that delivers around a 10% reduction in heat energy use by 2030. A 'Target 2050' trajectory assumes a higher 20% level over that period.

EPC data suggests that of the 21,000 non-domestic properties in Bristol, around 70% of non-domestic properties are below EPC level C. To estimate the magnitude and types of measures that would be needed to achieve this level of energy efficiency, Regen analysed the measures in the 4,405 existing EPCs covering the properties below EPC level C.

Table 8-2: Percentage of non-domestic properties and types of measures required

Efficiency measures	% of properties
Install heating controls	70%
Add renewable generation or heating	57%
Improve boiler efficiency	40%
Fitting or improving glazing	40%
Passive cooling	19%
Draft proofing	17%
Cavity wall insulation	10%
Loft insulation	9%

Heat technologies in non-domestic properties

Key to decarbonising non-domestic heat will be the roll out and take up of heat networks and heat pumps within the sector. The Element Energy study assumes that due to investment planning and economies of scale, there will be more existing non-domestic properties connecting to new sources of heat in the next decade than domestic dwellings.

Key policies to deliver trajectories

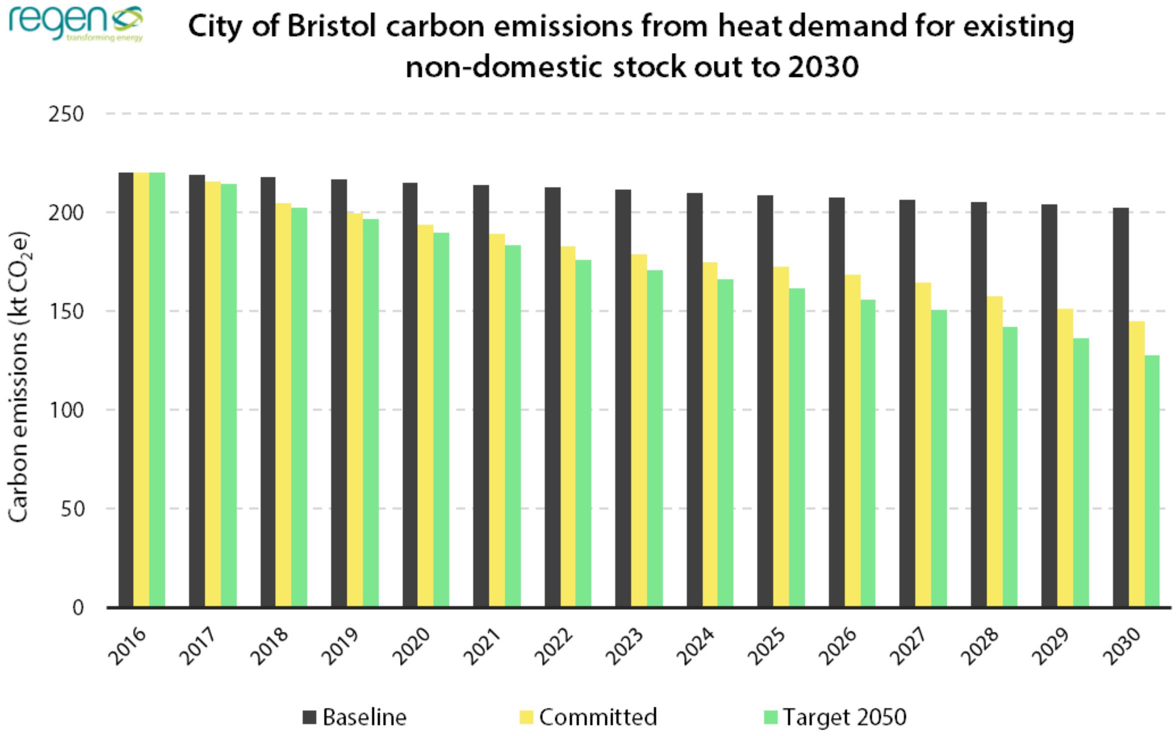
The potential reductions to the carbon from heat in non-domestic properties is expected to be delivered by:

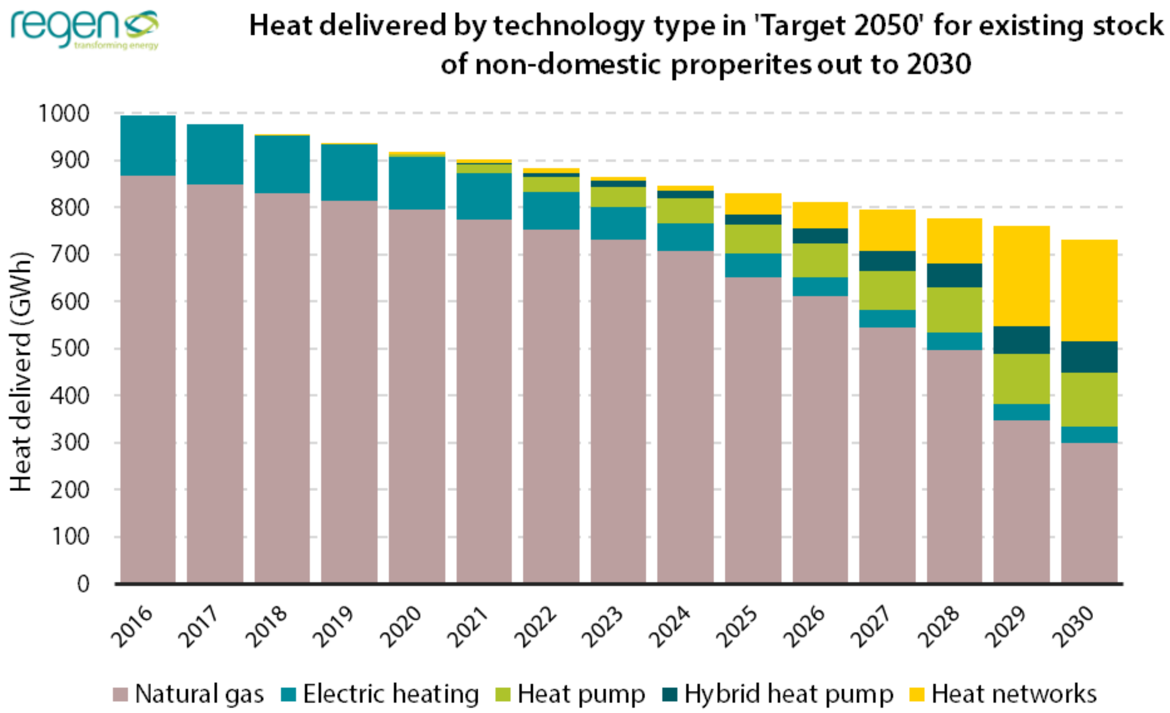
- **Energy efficiency improvements to existing properties.** The **City Leap prospectus** highlights the need for support for energy efficiency advice to small and medium sized enterprises and is looking for £100m to fund this to 2027.
- **Demolition rate of 0.6%.** Element Energy's analysis suggests that around 0.6% of non-domestic property is demolished each year. Replacement property will be built to higher energy efficiency standards.
- **Shift in heating technologies.** The shift towards both heat pump and heat network connections has been mapped using medium and high scenarios from Element Energy.

Table 8-3: Non-domestic existing stock changes in heat demand and type

	Baseline (existing non-domestic properties)		Non-domestic heat demand by technology type ('Committed' GWh)		Non-domestic heat demand by technology type ('Target 2050' GWh)	
	2016		**2030**		**2030**	
Natural gas	866	77%	518	54%	298	35%
Petroleum products	125	11%	125	13%	125	15%
Electric heating	128	11%	55	6%	34	4%
Heat networks	-	0%	202	21%	217	25%
Manufactured fuels	7	1%	7	1%	7	1%
Heat pump	-	0%	31	3%	117	14%
Coal	-	0%	-	0%	-	0%
Hybrid heat pump	-	0%	17	2%	65	8%
Total:	**1,126**		**955**		**863**	

Figure 8-4: Carbon emissions from existing non-domestic properties to 2030





8-2. New non-domestic buildings

Bristol is expecting a large amount of non-domestic new development up to 2030. The biggest sites are expected to be around Avonmouth and Bristol Port. Around 50,000 m^2 a year of new build commercial building is expected to be completed in Bristol each year to 2030, the majority being either office, industrial or warehousing.

Energy efficiency of new non-domestic buildings

The EPCs for non-domestic buildings provide both banding information and information directly about carbon emissions per m^2. Currently 87% of new non-domestic properties are B rated and above. 27% are A-rated with 0.7% A+ rated or zero carbon.

Energy rating	$kgCO_2/m^2$	New dwellings
Zero carbon (A+)	0	0.7%
EPC A	20.3	26.7%
EPC B	35.1	59.2%
EPC C	63.8	7.1%
EPC D	87.0	6.2%

The ratings do not however provide information about the energy usage per m^2 or the average energy use related to a particular band. As a result, for this study it is assumed that new non-domestic properties currently use around 100 kWh/m^2 for heating or cooling per year. The potential range is however large as some properties will be unheated and others, such as hotels, may require significantly higher energy demand. 100 kWh/m^2 was used as a middle of the range figure as the uses of the future new non-domestic developments in Bristol are not currently certain. [54]

The 'Committed' trajectory then assumes a reduction of around 5% in the energy use per m^2 a year over the period and the 'Target 2050' trajectory assumes a reduction of 10%. The 'Target 2050' trajectory has a very low residual heat demand by 2025 and is consistent with the **One City Plan**[55] which sets out policies for all new non-domestic properties to be zero carbon by 2025.

It is anticipated that a 'zero carbon' standard property would still have a small residual demand for heat energy. The Zero Carbon hub notes that this would be around 11 $kgCO_2/m^2$ for domestic properties after which an allowable solution or offsetting could be used.[56] Given the economies of scale for a non-domestic property a zero carbon building might be expected to have a residual carbon emissions below that of a domestic property.

Currently A-rated non-domestic properties have approximately 20 $kgCO_2/m^2$ for heat demand with B rated at 35 $kgCO_2$/m2. In 2030 the trajectories presented have approximate heat demand carbon of:

- Baseline: 26 $kgCO_2/m^2$
- 'Committed': 21 $kgCO_2/m^2$
- 'Target 2050': 16 $kgCO_2/m^2$

Heating technology for new non-domestic

Without information about the heating technologies currently used for new non-domestic properties, the baseline technologies are assumed to be the same as existing properties for this study. The levels of heat pumps and heat networks are however significantly higher than existing properties by 2030.

54 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770783/2nd_UK_Cost_Optimal_Report.pdf. P.110

55 https://news.bristol.gov.uk/news/bristol-launches-first-ever-one-city-plan

56 http://www.zerocarbonhub.org/sites/default/files/resources/reports/Zero_Carbon_Strategies_for_Tomorrows_New_Homes.pdf (p.5)

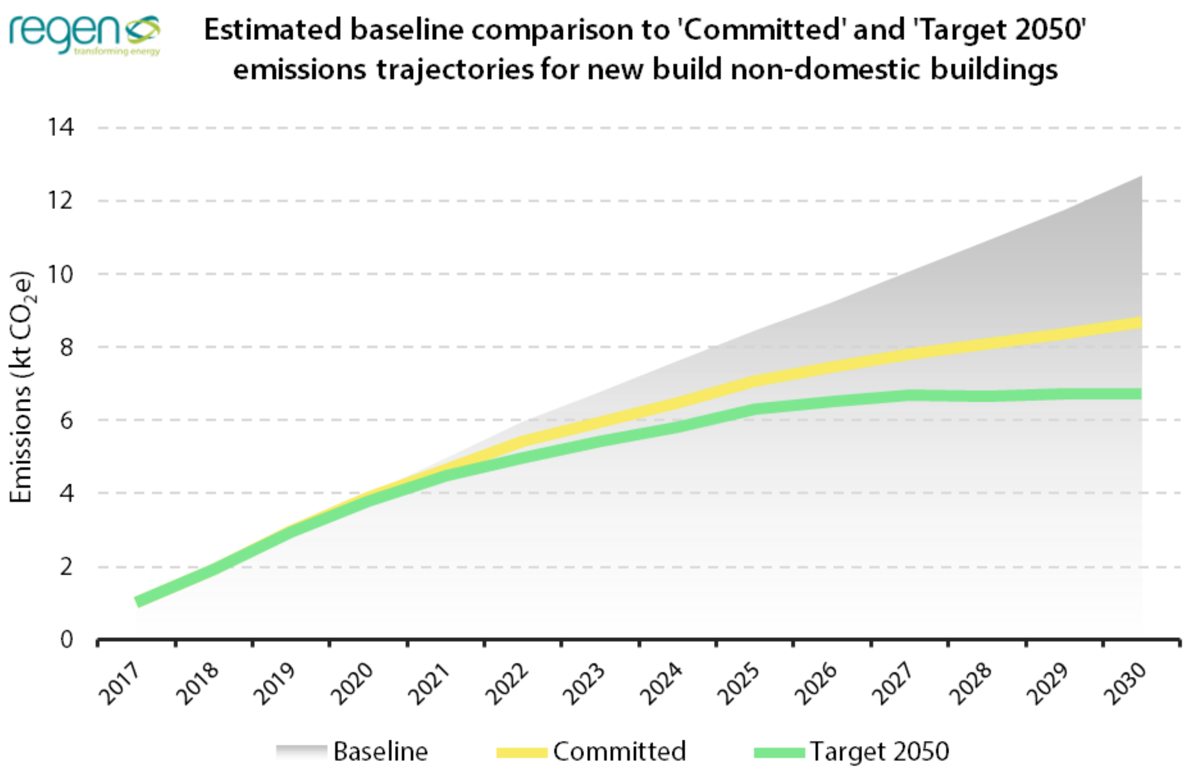
Table 8-5: Assumptions on heating technology for new non-domestic

New non-domestic property heating demand	Baseline	'Committed' 2030	'Target 2050' 2030
kWh/m^2	**100**	**57**	**31**
Natural gas	87%	27.2%	2.6%
Electricity	13%	4.8%	0.4%
Heat pump	0%	46%	44%
Heat network	0%	22%	53%

New non-domestic property results

As of 2030 in a 'Target 2050' trajectory, it would be expected that nearly all new properties would be heated by either a heat network or by heat pump. The remaining carbon emissions relate to the carbon factor of the heat network or grid electricity. Further reductions would require action from Bristol to ensure that the heat network sources and electricity are decarbonised.

Figure 8-6: kt CO_2 from non-domestic new developments to 2030



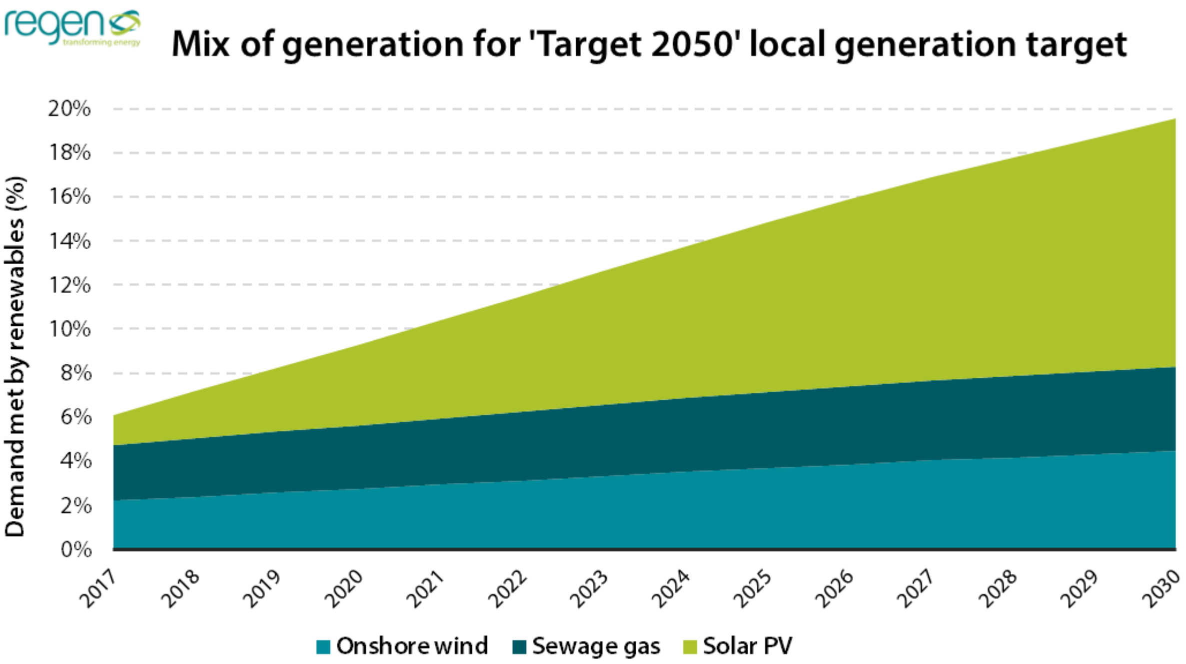
9. Electricity generation

9-1. Renewable electricity baseline

The 2016 baseline for renewable energy shows around 27 MW of rooftop solar PV installed in the City of Bristol, generating 25 GWh per year, onshore wind has 17 MW which produces 39 GWh.

The city is also estimated to generate around 45 GWh per year of sewage gas. This currently delivers

Figure 9-1: Changes in renewable energy generation to meet local generation targets



around 7% of the City of Bristol's electricity usage.

9-2. Opportunities to increase local generation and carbon reduction

Increasing the amount of renewable electricity generation is important to maximise the use of local resources and create and keep value within Bristol's economy. Small scale generation is also important to help engage people and businesses in a low-carbon future. This ambition is reflected in Bristol's One City Plan which sets out an objective to have the equivalent of 20% of Bristol City's electricity consumption generated by local renewable energy sources by 2027.

The opportunities to increase the amount of renewable electricity generated in the city will be limited by the level of resource available. In common with all cities, and under all scenarios, Bristol will continue to be a net importer of electricity.

The most likely opportunities to increase local generation will come from a modest increase in onshore wind (at sites in and around Avonmouth) and the deployment of rooftop, building integrated and smaller ground mounted solar PV. Electricity generation from sewage gas could potentially increase, along with population growth, for use in Combined Heat and Power plants. However, there will be competing opportunities to use biomethane for heat and transport and so this is not expected to growth significantly.

Without a detailed analysis of where each consumer (business and householder) is sourcing their energy and the degree to which it is "green" it is difficult to assign a carbon intensity to the electricity used within Bristol.

The carbon reduction calculation used in this report focuses on the geographic location of generation assets. It assumes that local generation is the equivalent of electricity consumed locally within Bristol, with the balance being imported from the national energy system. Carbon factors used therefore reflect the source of local generation and the national carbon intensity of electricity supply. This is clearly an approximation.

Electricity generation from the Seabank gas fired power station has not been included as a "local" source of generation on the basis that it connects to the transmission network and is more appropriately considered as part of the national energy system mix.

9-3. Committed and Target 2050 trajectories for electricity generation

	Baseline	'Committed' trajectory 2030	'Target 2050' trajectory 2030
Local renewable electricity (% of total)	**7.1%**	**14.5%**	**19.6%**
Total solar rooftop PV (MW)	26	144	214
- Domestic (MW)	12	66	98.5
- Estimated domestic installations	4,074	22,048	32,829
- Small commercial (MW)	5.6	30.6	45.5
- Small commercial installations	98	140.9	166.7
- Large commercial (MW)	8.7	47.2	70.2
- Large commercial installations	4	23.2	34.7
Onshore wind capacity (MW)	18	27	36
Sewage gas MWh	46,000	69,000	69,000

Table 9-2: Local renewable energy generation comparison between scenario

In a 'Committed' trajectory, the city increases renewable generation capacity by 2030 to deliver the equivalent of 14.5% of electricity consumption. This requires an additional 9 MW of onshore wind and an additional 118 MW of solar PV.[57]

Under a 'Target 2050' scenario, the City of Bristol would achieve the target of near 20% equivalent of electricity consumption. In order to achieve this figure City of Bristol would need to facilitate over 190 MW of new solar installations. This could consist of:

- Seven-fold increase in domestic solar rooftop PV from 12 MW to 98 MW which would involve new 3 kW installations in over 28,000 new or existing homes. Contributing to this would be the City Leap outline plan to install or finance 11,000 domestic solar installations.
- In addition, it would require around 60 commercial installations of around 50kW with 30 large scale installations at 2 MW. City Leap also has an outline plan to install or finance around 60 MW of larger roof or ground mounted solar.

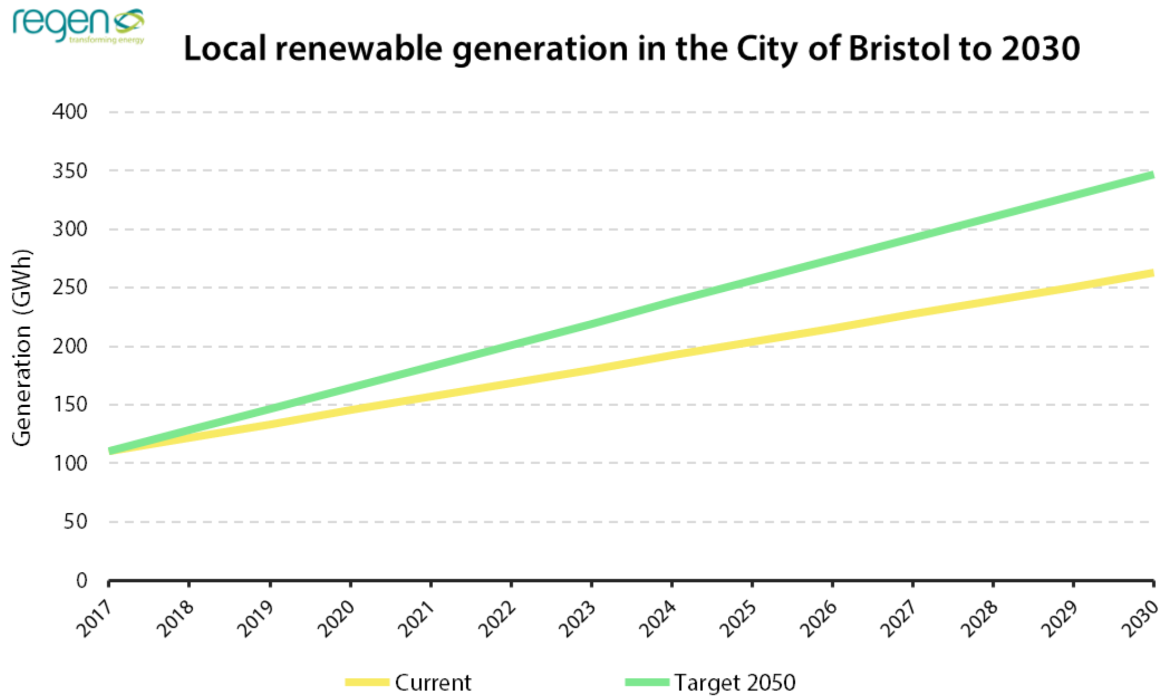
From a commercial perspective, and in the absence of further micro-generation subsidies, achieving a high growth outcome for solar PV will be extremely challenging. In terms of resource however deployment of over 200 MW of solar PV would remain below the technical feasibility for the City. The STEEP project housing stock assessment suggested there is solar PV potential on 128,000

[57] 15% goal and breakdown of technologies as discussed with BCC at workshop

properties across Bristol[58]. This would give a maximum potential of 384 MW on existing households assuming a 3 kW system. A further Lidar analysis conducted on behalf of Bristol City Council identified a potential 493 MW of rooftop PV capacity across all properties[59].

There would be a further 20 MW potential assuming a third of new build properties are suitable for 3kW systems. There is also some limited potential for hydro on the River Avon, for example Netham Weir.[60]

Figure 9-3: Generation from renewable electricity in Bristol by trajectory



[58] https://tools.smartsteep.eu/wiki/Bristol_-_Housing_Stock_Assessment, 2015
[59] LiDAR roof mapping – source Bristol City Council.
[60] https://consult.environment-agency.gov.uk/psc/bristol-community-energy-limited-28363/supporting_documents/Supporting%20Information%20Document.pdf

9-4. Baseline waste incineration

Another element of energy generation in the city is from direct waste incineration. The energy generated, and associated carbon emissions, from waste incineration is not calculated by the amount of waste incineration within the bounds of Bristol City. Rather, it is calculated by the total tonnage of waste sent to incineration from Bristol, wherever it may be treated.

This approach has been used as it is directly influenced by waste policy by Bristol City Council. This approach was used rather than assessing the total waste incinerated within the Bristol boundary as this would contain a high level of emissions that are outside of the Councils control and influence.

In 2016/17 total collected waste amounted to 185,000 kt, around 93% of this is sourced from household collections. Part of this waste is recycled, part of it is sent for incineration, and a diminishing remainder is landfilled. We have projected out two scenarios of waste collection and incineration, and from this calculated the total sent for incineration, and the associated carbon emissions.

9-5. 'Committed' and 'Target 2050' trajectories

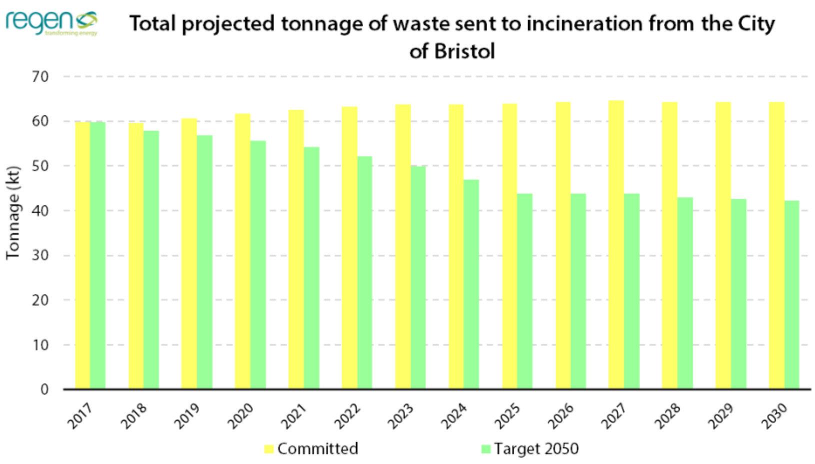
There is a range of reports on waste for Bristol city, primarily the 'Towards a Zero Waste Bristol: Waste and Resource Management Strategy' (2016)[61] and the Bristol One City Vision. The Zero waste Bristol strategy is taken as the 'Committed' trajectory, and the One City Vision informs the 'Target 2050' trajectory.

Carbon emissions from waste depend on the carbon content of the feedstock. In 2016 'Food' made up 39% of the residual waste from the City of Bristol, other significant feedstocks included garden waste, disposable nappies, and textiles. As the feedstock can range the carbon factors associated therefore range[62], but an agreed figure of 0.95 tonnes of CO_2 for 1 tonne of waste are used in this database.

The trajectories face antagonistic factors. There are increasing amounts of waste sent to landfill due to an increasing population and a reducing portion of non-recyclables sent to landfill. The trajectories show a decrease in incineration tonnage however, as there is a reducing amount of non-recyclable waste due to initiatives that focus on:

- Reducing the food component of domestic residual waste
- Reducing the amount of non-recyclable waste produced
- Increasing the amount of waste which is appropriately disposed of
- Reducing the total amount of waste produced in Bristol

Figure 9-4: Waste incineration trajectories for the City of Bristol



[61] https://www.bristol.gov.uk/documents/20182/33395/Towards+a+Zero+Waste+Bristol+-+Waste+and+Resource+Management+Strategy/102e90cb-f503-48c2-9c54-689683df6903
Accessed 21/03/2019.

[62] http://randd.defra.gov.uk/Document.aspx?Document=11918_WR1910Energyrecoveryforresidualwaste-Acarbonbasedmodellingapporach.pdf
Accessed 21/03/2019

10. Closing the 'gap' to achieving a zero carbon trajectory

This report sets out the baseline and likely future trajectories for the City of Bristol up to 2030 based on existing plans and potential opportunities which have already been identified, such as the City Leap.

The scope of this study did not include the development of a plan to achieve net zero carbon emissions for Bristol. However, an analysis of the 'gap' that exists between the existing trajectories and a zero carbon goal is outlined briefly in this section.

Clearly even a 'Target 2050' trajectory, which would itself be ambitious and challenging, would not achieve a net zero carbon outcome by 2030. If we assume that a near net zero carbon outcome would require 90% decarbonisation (the remaining 10% carbon, then being offset or otherwise mitigated) then the overall gap between an 'Target 2050' and net zero outcome would be c. 750 kt CO_2e per year.

This would require a paradigm shift in the way that energy is generated, used and managed across the city. This is not something that the council can deliver on its own. It would require the mobilisation and support of the whole city including institutions, businesses, community groups and individuals. It would also require a radical decarbonisation of the UK economy in which the city forms a part.

Outlined below is a high level sketch of the sorts of initiatives and measures that would be needed to facilitate this change.

10-1. Transport

It will be difficult to achieve absolute zero carbon emissions from transport, as even ULEV and EVs will have a residual carbon impact. A 90% reduction however, taking Bristol transport emissions down to around 65 kt CO_2e per year, would put the city and its consumers in a position to be able to offset, or otherwise mitigate their carbon footprint.

The 'Net Zero scenario' modelled example of what a 90% carbon reduction could look like:

- Petrol and diesel vehicles completely removed. This would require adoption of a stringent emission zone policy, combined with national policies, to prohibit the sale and use of fossil fuel vehicles.
- 95% of vehicles are electric, and remaining vehicles – mainly HGVs and some buses – would be running on sustainable biogas or potentially low carbon hydrogen.
- The electricity source would be near 100% renewable with an intensity of less than 20g CO_2 per kWh
- Hydrogen for transport, if used, would be manufactured via electrolysis (using low carbon electricity) or stream methane reformation with ultra-efficient post-combustion CCS
- A reduction in overall car use of 25% with a shift to public and shared transport solutions, walking and cycling which would now be mainly a contributor to quality of life

Bristol Road Transport – example "Net Zero" scenario

Carbon emissions baseline	Shift to ULEV	Population and journey growth	2030 outcome
565 kt CO_2e (Regen transport model using 2017/18 data)	Complete shift to electric and other ULEV vehicles using low carbon electricity, sustainable biogas and/or hydrogen (via electrolysis or SMR with CCS)	Radical steps to reduce vehicle numbers and usage by 25% including mass uptake of public and other mobility solutions	Net CO_2 reduction of 90% to around 65 kt CO_2e

10-2. Domestic and commercial emissions

A 'Target 2050' scenario means that a large number of commercial and domestic properties will require a combination of deep cuts to demand for heat energy though energy efficiency investment along with investments at local and national level to fully decarbonise the remaining heat energy demand.

A zero carbon definition could be reducing emissions to around 11kgCO_2/m^2. [63] After which a form of 'allowable solution' could then be used to offset the residual emissions. Achieving this would likely require:

- Energy efficiency upgrades for over 180,000 Bristol properties (90% of existing dwellings) to move them to a rating of EPC B or above. This is likely to involve relatively expensive measures, such as whole house retrofits and external insulation for solid wall properties.
- All properties would also need to be heated or cooled by a low-carbon heat source, a combination of heat pumps, heat networks and green gas.
- Crucially a zero carbon trajectory would require decarbonising the sources of Bristol's heat network. Under an 'Target 2050' trajectory by 2030 heat networks would still have an average carbon intensity of 0.1066 kg CO_2 per kWh heat delivered. A net zero outcome would require this to fall to less than 0.02 kg CO_2 per kWh. Heat networks could be decarbonised to this level using technologies such as large-scale water source heat pumps, CHP from combustion of biogas (assuming power is utilised) or hydrogen produced via stream methane reforming with CCS or electrolysis.[64]
- Further reductions could be made by bringing zero carbon new building standards ahead of 2025. Carbon from new builds in a 'Target 2050' trajectory contribute around 16kt CO_2 a year with most of this increase from properties built prior to 2025.
- With renewable energy generation opportunities limited by geography, it would be important to identify renewable energy projects through which to offset residual carbon emissions from properties in the city. For example, Bristol could facilitate and/or fund a large renewable energy project outside the city boundaries such as offshore wind in the Bristol Channel or tidal opportunities in the Severn.

At a national and regional level:

- Bringing grid electricity close to 100% renewable or low-carbon, with an intensity of less than 20g CO_2 per kWh.
- Supporting a wholesale shift to new heating sources during the 2020s e.g. by requiring heat pumps or hybrids to be fitted as replacements to boilers.
- Facilitating the shift towards electric and low-carbon vehicles by reducing purchase prices, increasing choice and improving the charging infrastructure.

[63] http://www.zerocarbonhub.org/sites/default/files/resources/reports/Zero_Carbon_Strategies_for_Tomorrows_New_Homes.pdf

[64] Regen analysis – ultra efficient hydrogen manufacture with post combustion CCS or very low carbon electrolysis. Heat Pump intensity with low carbon electricity.

10-3. Electricity generation and carbon reduction

Even in a 'zero carbon' scenario it will not be possible, or cost effective, for Bristol to generate an equivalent of its electricity consumption from renewable energy sources within the city geography. The 'Target 2050' scenario probably represents the nearly highest potential generation from renewable sources.

Getting electricity to a "net zero" position will therefore require a combination of:

- National action to produce low carbon electricity with an intensity of less than 20g CO_2 per kWh. Note the Committee on Climate Change target is between 50 and 100 g CO_2 per kWh depending on the scenario.

- Strategies to source energy – by individuals, institutions and businesses – from green energy sources outside the city. This could be via asset ownership, direct Power Purchase Agreement, or through the purchase of Renewable Energy Guarantees of Origin (REGO's).

As an approach, asset ownership and encouraging individuals, communities and institutions to invest in the generating assets supplying electricity would have the most direct impact for increasing renewable energy generation. This could be small scale (via community energy schemes) or large scale. An example of a large-scale investment would be via a pension fund or Innovative Finance ISA investment in an offshore wind farm. For example, Bristol could facilitate and/or fund a large renewable energy project outside the city boundaries, such as new offshore wind in the Bristol Channel.

Local and community ownership would also have the additional benefits of supporting energy value retention in the local economy and engaging people with energy.

Note on the Use of REGOs as a decarbonisation approach

The use of REGOs (or equivalent international certification) is a contentious issue.[65]
At the moment it is considered, by Ofgem and others, that paper trading in REGOs does not materially increase the revenue earned by renewable energy generators and does not therefore contribute to investment in new generation and decarbonisation.

The reason for this conclusion is that the current REGO price is so low (at 10-15 pence per MWh) that they have become almost valueless to the generator. At this low-price Bristol could "green up" its current 1.6 TWh of annual electricity demand for £160-240k, without making a material contribution to combat climate change.

The low price is a function of the high level of renewable energy generation (creating new REGOs) compared to the low level of demand for specific green energy products.

However, if the market for REGOs dramatically increased, because cities like Bristol and other regions that have declared a climate emergency, moved to commit to source green energy, the REGO price could then increase. In this scenario REGOs could become a contributory factor to increase renewable generation and support decarbonisation.

[65] See for Example "We need to talk about green energy" https://www.regen.co.uk/we-need-to-talk-about-green-energy-tariffs/

11. Appendix: Data sources

Key data and statistic sources:

- Regen databases
- BEIS energy statistics
- Ofgem Feed-in-tariff registers
- Planning databases
- Local development plans
- National Grid FES 2018 tables
- Department for Transport statistics

Data and statistic sources in full:

Baseline data:

- Regen database
- BEIS sub-national energy statistics
- UK CO_2 emissions statistics 2005 to 2016
- Department for transport vehicle tables (VEH01)
- Demographic data from ONS (MYE5)
- Census data 2011
- Energy performance certificate statistics (EPC)
- 2016-based population projections for Bristol local authority

Renewable energy projections sources:

- Regen databases
- Planning databases
- Bristol policy reports (see full list)
- Lidar assessment for rooftop solar PV potential in Bristol

Transport projections sources:

- Department for transport vehicle tables (VEH01)
- National Road Traffic Survey
- FES 2018
- BEIS local authority carbon dioxide emissions national statistics

Heat demand projections sources:

- Census data 2011 (table QS415EW, among others)
- EPC data for Bristol local authority
- FES 2018 tables
- English housing survey
- BEIS sub-national gas consumption statistics
- Local plan trajectories
- UK business count data

Useful sources for CO_2 emissions:

- UK Conversions factors for company reporting
- DEFRA, Greenhouse gas reporting: conversion factors 2018
- SAP assessment methodology
- IPCC emission factor database
- BEIS regional carbon dioxide emissions national statistics

12. Appendix: Alternative transport baselines

There are several ways in which transport baseline carbon emissions for Bristol City could be measured. None are wholly accurate, however, so in the future, as Bristol wishes to measure the impact of initiatives taken within the city both to reduce road transport mileage and to encourage the use of low emission vehicles a more sophisticated approach will be needed.

Table 12-1 shows 4 potential methods of calculating baseline emission. Each has its limitations. A recommendation for future carbon neutrality planning is for the council to agree and develop a transport carbon emission methodology which could be adopted by the "core cities".

Table 12-1 Four methods of calculating CO_2 emission baseline

Measure/Basis	Baseline Measure CO_2e	Strengths and weaknesses
A) BEIS – Based on Vehicle Road Mileage	**539 kt (2016)**	The BEIS measure simply makes an apportionment of GB CO_2 emission, by road type, to regions based on the results of the Road Traffic Survey. Since Bristol road mileage is surveyed at 1.46 billion miles, 0.45% of national road mileage, the cities emissions are therefore 0.45% of the national emissions. This measure is simple to apply and is consistent however: • It will only be as good as the road traffic sampling • It does not easily differentiate between vehicle types and fuel usage • As the number of ULEVs grows it will be difficult to differentiate the impact of initiatives to increase ULEV uptake • It probably underestimates the actual emissions in a city environment
B) Vehicles Registered by vehicle type at average annual national mileage	**808 kt**	If vehicles registered by vehicle type was used as a basis, and it was assumed that the annual mileage driven by Bristol registered vehicles was the same as the national average mileage, then the 226k vehicles registered in Bristol would drive just over 2 billion miles, and therefore have a much higher carbon footprint of 808 kt CO_2e This measure focuses only on the vehicles registered and is probably too high since: • City based vehicles will tend to drive less miles per year • The number of vehicles registered in Bristol is probably higher than the numbers actually based in the city as there may be vehicle fleets registered at head offices in the city which are kept elsewhere.
C) Regen – Vehicle mix and mileage	**566 kt**	The Regen model baseline takes the vehicles registered as a good indication of the mix of vehicle types in the city, but then dials back the average mileage per vehicle to match the vehicle mileage estimate from the road traffic survey. Although still not wholly accurate this has the advantage that: • Future changes in vehicle type and fuel usage can be

		assessed • Future changes in mileage driven and the switch to other modes of transport can also be assessed.
D) Fuel Consumption and vehicle mileage and CO_2 emissions	**592 kt**	As a cross check a fourth approach would be to use the fuel consumption statistics (Dft Dataset ENV0101) by vehicle type, mileage by Vehicle Type and CO_2 by Vehicle Type (DfT ENV0202) to create a benchmark of CO_2 by fuel usage and vehicle miles. Applying this to the vehicle types and mileage in Bristol produced a slightly higher figure of 592 kt CO_2e Note this method of calculation using existing data does not currently differentiate between ULEV and non-ULEV vehicles and so only provides a cross check.

13. Appendix: Low vehicle miles in Bristol

A question which may be worth addressing in a future transport study is whether the survey of vehicle miles driven in Bristol is creating an estimate that is incorrect.

There is no conclusion evidence to suggest that this is the case, but Bristol does seem to have a comparatively low number of miles driven compared to the number of vehicles registered and to the population. The ratio of miles driven to vehicle registrations is circa 70%.

A very brief comparison of other regional cities suggests that the mileage figures for Bristol are very low and it would be worth investigating the underlying cause.

Table 13-1 Comparison of Bristol transport and population data with selected cities

City Comparison	Vehicles Registered	Miles (millions)	Miles per vehicle registered	Local Authority Population	Vehicles registered per person	Miles per person
Bristol	226,485	1,464	6,464	460,000	0.49	3,183
Oxford	56,369	628	11,134	155,000	0.36	4,049
Cardiff	159,018	1,815	11,414	362,000	0.44	5,014
Leeds	439,067	4,186	9,534	781,000	0.56	5,360
Exeter	83,567	809	9,676	127,000	0.66	6,367
Edinburgh City	195,709	1,885	9,632	513,000	0.38	3,674

As well as potential data issues there are several valid reasons why vehicle mileage in Bristol may be low:

I. Vehicles based in urban areas will naturally tend to have a lower annual mileage as they make shorter and less frequent journeys. This doesn't however explain the city comparison.
II. There may be a higher than average number of vehicles registered in the city that are not in fact based in the city, owing to the number of fleet vehicle registrations at head offices.
III. It could be that Bristol registered vehicles are driving more miles outside the city than non-Bristol registered vehicles are driving within the city. Although this would be unusual and cities, if anything, tend to have more "imported" miles from commuters coming in.
IV. It could be that Bristol residents although still retaining a relatively high number of vehicles are also using them less frequently in favour of other transport modes.
V. Bristol roads may be so congested that vehicles are being chronically underutilised

14. Appendix: heat network and heat pump calculations

Source	Scenario	Output	Technology	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
EE	Medium HP	Heat demand (GWh / yr)	Heat pump	0	0	0	14	26	39	52	66	80	107	133	157	181	205
EE	Medium HP	Heat demand (GWh / yr)	Hybrid heat pump	-	-	-	-	7	14	21	27	68	83	98	113	127	140
EE	Medium HP Total	Heat demand (GWh / yr)	TOTAL heat pump	0	0	0	14	33	53	73	93	148	190	231	270	308	345
EE	Medium HN	Heat demand (GWh / yr)	Heat network	-	11	11	11	11	11	11	11	86	86	86	86	229	229
	Scenario	Output	Technology	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
EE	High HPs	Heat demand (GWh / yr)	Heat pump	0	0	0	16	53	89	123	157	189	248	306	362	419	487
EE	High HPs	Heat demand (GWh / yr)	Hybrid heat pump	-	-	-	-	20	39	57	75	92	120	146	171	196	220
EE	High HPs Total	Heat demand (GWh / yr)	TOTAL heat pump	0	0	0	16	72	127	181	232	282	368	452	533	615	707
EE	High HNs	Heat demand (GWh / yr)	Heat network	-	11	11	11	11	11	11	11	144	144	144	144	355	355
EE	Total Heat demand (HH	Heat demand (GWh / yr)		2,989	2,917	2,887	2,856	2,834	2,813	2,792	2,772	2,752	2,733	2,715	2,697	2,680	2,663
Regen	Non domestic heat der	Heat demand (GWh / yr)	30%	906	885	876	866	859	853	847	841	835	829	823	818	813	808
Regen	Domestic heat demand	Heat demand (GWh / yr)	70%	2,082	2,033	2,012	1,990	1,975	1,960	1,945	1,931	1,918	1,904	1,892	1,879	1,867	1,856

	Medium HN	**% of total heat demand supplied in 2025**	
EE	Retrofit non-domestic	5%	
EE	New non-domestic	23%	
EE	Retrofit domestic	1%	
EE	New domestic	19%	
	High HN	**% of total heat demand supplied in 2025**	
EE	Retrofit non-domestic	5%	
EE	New non-domestic	59%	
EE	Retrofit domestic	1%	
EE	New domestic	66%	
	Medium HP Total	**% of total heat demand to sector supplied in 2025**	
EE	Domestic	6%	
EE	Non domestic	4%	
Regen	Retrofit non-domestic	3%	
Regen	New non-domestic	20%	
Regen	Retrofit domestic	5%	
Regen	New domestic	30%	
	High HP Total	**% of total heat demand supplied in 2025**	
EE	Domestic	9%	
EE	Non domestic	13%	
Regen	Retrofit non-domestic	35%	
Regen	New non-domestic	41%	This has been calculated assuming 100% of heat is between HP and HN. The remainder is assumed to be retrofit.
Regen	Retrofit domestic	9%	
Regen	New domestic	34%	This has been calculated assuming 100% of heat is between HP and HN. The remainder is assumed to be retrofit.

NOTE: In the absence of detailed data from Element Energy, the 2025 numbers and % calculated from their report have been used to project forward to 2030 and back to 2018 assuming the same magnitudes as 2025.