ClairCity: Citizen-led air pollution reduction in cities

D7.4 Final City Policy Package – First City (Bristol)

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Document Details

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Executive Summary

ClairCity aims to contribute to citizen-inclusive air quality and carbon policy making in middle-sized European cities. It does so by investigating citizens' current behaviours, their preferred future behaviours and their preferred future policy measures in six European cities. The project also examines the possible future impacts of citizens' policy preferences and implementation possibilities for these measures in the light of the existing institutional contexts in each city. With this aim, ClairCity has carried out in all six cities an extensive citizen, stakeholder and policy maker engagement process (Chapter 1).

This report summarises the main policy results for the first of the six cities, Bristol (UK). The other ClairCity cities are Amsterdam (NL), Ljubljana (SL), Sosnowiec (PL), CIRA/ Aveiro (PT) and Liguria / Genoa (IT).

Citizen-inclusive policy making according to ClairCity (Chapter 2)

- Tailor local policies based on detailed knowledge of behavioural practices of citizens;
- Engage with citizens via a diversity of methods, paying in particular attention to hearing the voice of hard-to-reach groups;
- Ask citizens for their preferred future behaviours and barriers to behavioural changes. Address the perceived barriers of citizens by concrete measures or get into a dialogue with citizens about their perceptions;
- Ask citizens for their preferred future policies for the city, examine potential impacts of these policies and discuss with stakeholders and policy makers their implementation possibilities;
- Examine and address potential implementation barriers for preferred citizen policy measures beyond citizen perceptions;
- Experiment, and exchange experiences with other cities that are also aiming to implement citizen-inclusive policies;
- Do not confuse citizen-inclusive policies with populist policies and take full responsibility for democratically implementing popular or unpopular measures considered appropriate, after having been optimally informed about citizens' views and behaviours.

Wideranging policy measures are required to further improve air quality and reduce carbon emissions in Bristol (Chapter 3).

- Emissions and concentrations of air pollutants in Bristol are still exceeding legal limits and WHO guideline values. Despite a downward trend in emissions and concentrations of air pollutants in recent years, there are currently still widespread measured breaches of legal NO_2 limit values in Bristol;
- Carbon emissions in the city are declining largely due to a decarbonisation of the national electricity generation mix. However, substantial further emission reductions are required as a contribution to national and international carbon emission reduction targets. In

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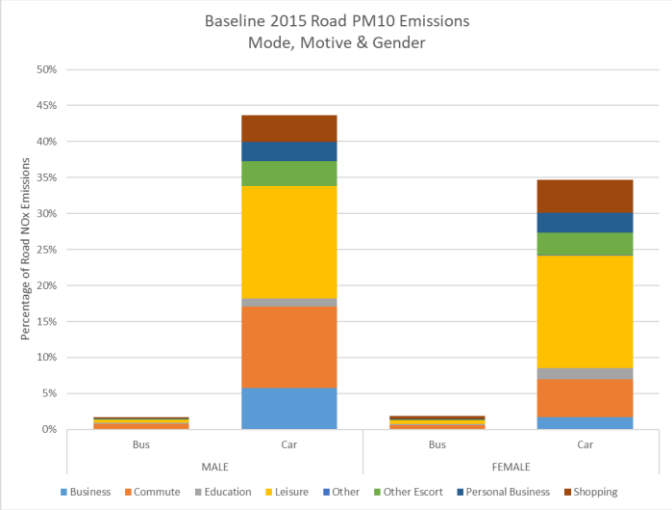
adition, the Mayor has now announced a ‘climate emergency’ for the city and has published a dedicated action plan to make the city carbon neutral by 2030.

Current behavioural practices of citizens substantially contribute to air pollution and carbon emissions in the city (Chapter 3 and 4).

- Transport and heating are the main citizen activities contributing to air pollution and carbon emissions in Bristol. Private cars contribute for 45% to NOx and for 40% to PM emissions in the city. Residential heating contributes for 8% to NOx emissions and for 48% to PM emissions – out of which 28% arise from residential wood burning. About half of the Bristol CO_2 emissions arise from residential energy use and some 15% from transport.
- Leisure transport by citizens generates far more NO_2 emissions (26% of total transport emissions) than commuting (16%) and men overall generate more NO_2 emissions than women (Figure 0-1);

Figure 0-1 Relative importance of trip motive in transport emissions split by gender (source: ClairCity modelling)



- Citizens with higher incomes generally generate more transport emissions than citizens with lower incomes. People earning <£25k generate 13% of the NO_x emissions by car compared to 19% for people earning £25-50 and and 22% >£50k. People earning <£25k are also those most making greater use of cheaper travel options such as the bus and active travel options but least use of the train;
- More women than men currently use a private car as their only means of transport, which is the most polluting travelling option. This holds for commuting (50% vs 38%) and leisure transport (38 vs 31%). Only for shopping, slightly more men (33%) than women (29%) presently only use a car;
- A substantially lower proportion of less -Black or Minority Ethnic (BME) respondents currently only use a car as their only means of transport than white respondents. This holds for commuting, leisure and shopping transport (21/31, 22/27, 27/32 % respectively);

- Lower educated respondents travel somewhat more by car only than higher educated respondents. This is most pronounced for leisure transport (32/24%);
- For current heating behaviour, differences between gender, ethnicity and education level are small.

Many Bristol citizens would be willing to change their own transport and heating behaviours as a contribution to ambitious air quality and carbon policies in Bristol (Chapter 4.1).

- There were in total more than 1,400 citizens with a wide variety of economic and ethnic backgrounds involved in the ClairCity engagement process in Bristol, out of which some 730 participated in the Delphi process asking them for their current behavioural practices as well as their preferred future behaviours and policies for the city;
- For commuting, 75% of the respondents want to use public transport or change to active transport in the future, compared to the 54% who use public and active transport now;
- The main stated reason for not being able to change now is the current unattractiveness of public transport;
- For shopping and leisure, 66% want to use public or active transport in the future, compared to 38% now;
- Electric vehicles are not yet a popular choice for the future (mentioned by only 4% of respondents);
- Home delivery is not seen as an important replacement for shopping (only mentioned by 9% of the respondents);
- For home heating, a massive change towards renewables is envisaged by the respondents: from 2% now to 62% in the future;
- 8% of the respondents want to continue using solid fuels in the future. These respondents state either to be not a home owner or to want to use a mix of fuels in the future, of which solids are one. Air quality was not mentioned as a reason not to continue with solid fuel;
- Costs and physical limitations of the building (assumed not to be suited for renewables) were mentioned as main reasons not to switch away from solid fuel;
- Irrespective of gender, ethnicity and education, all groups of respondents envisage to use more public transport and to cycle more, but to walk less in the future;
- More women than men presently use a car, while their preferences for change are similar;
- BME respondents generally own fewer cars at present, but a higher percentage than white respondents want to continue using a car in the future;
- Higher educated respondents are using less often a car at present and more often want to change to public or active transport in the future than lower educated respondents;
- For heating behaviours, differences between gender, ethnicity and education are less pronounced, although more BME respondents than non-BME respondents are currently using gas (86 versus 76%) and fewer want to change to renewables (b 52 versus 63%).

Many Bristol citizens support more ambitious air quality and carbon policies in the city (Chapter 4.2).

- Asked for their preferred policy measures in the city, many citizens in Bristol support ambitious policy measures that mainly focus on transport - but energy, general awareness and infrastructural measures are also part of the set of most desired policies;

- The favourite citizen policy measures are ‘banning / phasing out most polluting vehicles (not just charge)’; ‘making buses greener and cleaner’; ‘making public transport cheaper’, and ‘creating good alternatives to car use – walking and cycling’. 13 other policy measures were also highly valued by Bristol citizens;
- These measures are very much in line with existing or announced policies, but citizens ask for either a faster implementation or more ambitious targets in the execution of the measures compared to current policies;

Table 0-1: Overall preferred policy measures of Bristol citizens from ClairCity engagement process

Measures	Clean Air Zone	Active transport	Public transport	Cleaner transport	Energy measures	Other measures
Mentioned in all three main ClairCity engagement activities *)						
1. Ban/phase out most polluting vehicles (not just charge)	x			x		
2. Make buses greener and cleaner	x		x			
3. Cheaper public transport			x			
4. Create good alternatives to car use – walking and cycling		x				
Mentioned in two out of three main ClairCity engagement activities						
1. Reduce vehicle road space – increase public transport space			x			
2. Improve walking environment in Bristol		x				
3. Charge older/ more polluting vehicles entering the city	x			x		
4. Promote electric vehicles				x		
5. Awareness raising to promote active and public transport		x	x			
6. Make it easier for employees to work from home						x
7. Make property developers consider air pollution and climate change						x
8. Building housing close to major employment zones						x
9. More local shops and facilities in neighbourhoods						x
10. Organisations to provide more flexible working hours for employees						x
11. Improve energy efficiency for housing (rented/existing/new)					x	
12. Increase generation of solar wind and power					x	
13. Spread economic opportunities across different areas of the city						x

*) main ClairCity engagement activities: Delphi process (3 rounds citizen engagement in questionnaires, interviews, workshop), Mutual Learning Workshop (expert workshop), Skylines game (mobile phone game for citizens)

Policy makers confirm overall implementability of the preferred policy measures of Bristol citizens (Chapter 4.3).

- In a workshop attended by 18 City Council and regional policy makers from various departments, policy makers discussed implementation possibilities of the citizen measures;
- All main measures were considered implementable, although views on possible implementation speeds differed;
- Policy makers suggested how the measures could be implemented by involving national, regional and local government as well as business and citizens. For the city, concrete suggestions regarding financing were made (parking permits, workplace parking levy, congestion levies), regarding infrastructural measures (reallocation of road space,

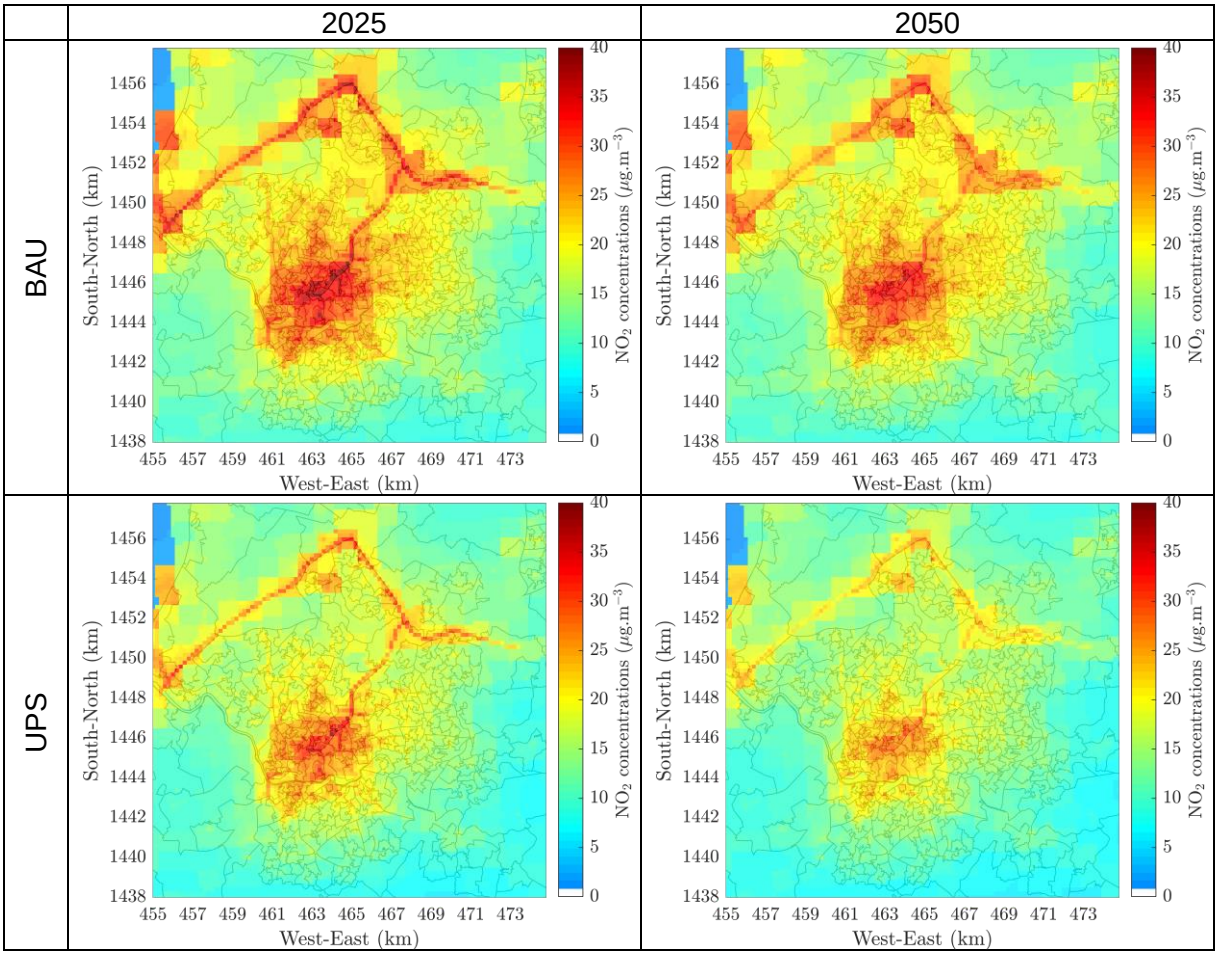
charging points for electric taxis) as well as regarding behavioural measures (bike training, City Council walking/cycling group).

- On a regional level, better integrated planning was considered most important and for the national level funding and a focus on health-based awareness policies. Business was encouraged to contribute to policies by bike to work schemes and cleaner business fleets. Citizens' ownership of problems and solutions was suggested to be promoted through e.g. education and mobilising local community groups;
- Based on the outcomes of the policy workshop, a 'Unified Policy Scenario' (UPS) was constructed that quantified the preferred measures of citizens where possible.

If implemented, the citizen measures could result in substantial and cost-effective emission reductions, air quality improvements and health improvements for citizens compared to a business-as-usual scenario taking 2015 as a baseline (Chapter 5).

- The impacts of the UPS were compared to a business-as-usual scenario (BAU) that takes into account policy measures in Bristol that were implemented or planned in 2015. Modelling results show that the UPS scenario would lead to a faster compliance with legal NO_2 limit values than the BAU scenario (UPS complies already in 2025, BAU not) (Figure 0-2);

Figure 0-2 Modelled NO_2 concentrations in Bristol in the BAU and UPS scenario, 2025 and 2050 (10^{-6} g/m^3)



- For large particulate matter (PM_{10}), current levels are compliant with legal limit values. However, neither the UPS scenario nor the BAU scenario would result in compliance with the WHO guideline values. Nevertheless, the UPS scenario would reduce concentrations more than the BAU scenario;
- For small particulate matter ($PM_{2.5}$), both scenarios would result in compliance with legal limit values, but even in the UPS scenario there would still be significant exceedances of WHO guideline values in 2050;
- Also, the UPS scenario would significantly improve human health compared to the current situation and to the BAU scenario. It is estimated that the number of premature deaths would be reduced by about 50% in the UPS scenario compared to the BAU scenario;
- The UPS scenario would lead to substantially lower carbon emissions than the BAU scenario, in particular after 2035. It would also, contrary to the BAU scenario, lead to near-zero carbon emissions in 2050;
- A qualitative assessment of the measures in the UPS scenario suggests that cost-effective execution of the measures could be achieved – depending on the exact way of implementation -, as measures with an assumed net cost to citizens and government could be compensated by others assumed to have a net benefit (e.g. congestion levy, parking permits, working place parking levy).

Mutual learning from other ClairCity cities could contribute to a successful implementation of citizen-inclusive air quality and carbon policies in Bristol (Chapter 6).

- Several factors in Bristol were identified as relevant for a successful implementation of citizen-inclusive policies: 1) A focus of current policies on ethnical and income equality; 2) A traditionally relatively strong dependence on project-based finance from a national level that was recently somewhat mitigated by the installation of a regional development fund; 3) a limited number of local measurements in particular for PM concentrations and 4) a mainly NGO-focused citizen engagement culture with a focus on energy and heating rather than on transport.
- It is also important to note that while the transposition of EU laws has previously strongly driven UK air quality policies, this driver will cease with Brexit. A preferential tax treatment to diesel vehicles on a national level is further hindering succesful execution of local air quality policies;
- National carbon policies in the United Kingdom, on the other hand, seem to be relatively well developed in relation to EU targets, with a climate law and institutional mechanisms already implemented for a number of years. Nevertheless, national policies for energy efficient housing (nearly zero emissions requirements) have been blocked in recent years or have failed with no replacement (Green Deal) – with a Bristol housing stock that is relatively poorly insulated;
- Compared to other ClairCity cities, Bristol seems advanced in developing an integrated regional/city public transport system, has a relatively developed cycling culture, is discussing finance instruments like a working place parking levy and congestion charging that are not found in other ClairCity cities, and has made significant progress in preparing a clean air zone for the city. These experiences could be useful for the other ClairCity cities for planning and implemenation of their future air quality and carbon policies;
- Bristol in turn could profit from exchanges with several other ClairCity cities that have sometimes more developed renewables, energy efficiency and district heating policies, or that are more advanced in transport policies such as the introduction of clean air and pedestrian zones, parking permit and electrical vehicle policies or the stimulation of active transport (cycling and walking).

Experiment, learn and cooperate with other cities for tailoring solutions to the cities' specific conditions (Chapter 6).

Comparing policies in all ClairCity cities showed that there is a standard set of air quality and carbon policy measures that is applied in all cities. It consists for transport of stimulating active, public and cleaner transport while simutaneously discouraging the use of private cars. For energy, promoting district heating, an energy efficient building stock and renewable energy use are key measures. Simultaneous application of this full set of measures is considered essential to succesfully support citizens to change their behaviour in the desired way. Yet, within this set there are many variations and degrees of implementation that widely vary between cities. All cities are currently in a stage of experimentation in which learning from best practices and also from failures could strongly contribute to successful citizen-inclusive policies in the future.

The ClairCity Bristol Action Plan

For citizen-inclusive city air quality and carbon policies

1. Leisure and shopping transport in Bristol causes even more air pollution than transport for commuting. **Alongside measures directed at reducing emission from commuting, actions to reduce emissions from journeys associated with leisure activity should be developed. For example, developing good active and public transport options in the locations and at the times that leisure related trips take place.** This could be combined with intensified cooperation with retailers, shopping malls, sports clubs, theatres and cinemas so that they promote active and public transport to reach their venues.

2. Women and people with lower educational attainment are more likely to use a car as their only means of transport. Black and Minority Ethnic (BME) Groups currently travel by car less than non-BME groups, but in the future want to travel by car more than other Bristolians. **Enable a whole city transport plan which means that people do not feel that a car is their only way to get to shift work or caring responsibility appointments. Promote alternatives to private car use (including car sharing), address car use as a status symbol and make public transport more attractive and feasible.**

3. Citizens want to cycle more, but walk less in the future. **Facilitate safer and more comfortable cycling through infrastructural measures (e.g. cycle lanes and paths, cycling traffic lights, bike parking facilities and integration with public transport (e.g. train-bike rent system). Promote walking by stressing its health benefits and facilitate walking by infrastructural measures.**

4. Many citizens want to change to renewables for home heating in the future. **Promote expansion of national support for rooftop solar PV, increase rooftop solar on public buildings and support local citizen cooperatives for renewables generation. Raise awareness about the mixed effects of biomass regarding climate and air quality.**

5. Many citizens support the air quality and carbon policies in the city that are already in place, but ask for more ambition and speed in their implementation. Faster and more ambitious implementation would also have significant benefits in terms of emissions, concentrations and health of citizens. Policy makers generally consider the citizen

policy preferences as feasible. **Communicate citizen support and health benefits of existing and planned policies, make the year-by-year planned implementation of long-term policy ambitions as explicit as possible in communications, and examine where the implementation of planned policies can be accelerated.**

6. Finance is a key institutional condition that determines the possibilities for implementing citizen-inclusive policies. Policies in Bristol are sometimes hindered by discontinuity of national funding. **Costs of infrastructural measures could partly be covered by generating local funding through e.g. parking fees and permits, congestion levies or workplace parking levies. Communicate the need for such financial instruments and examine possibilities to reward behavioural change (e.g. bike parkings offering discounts at local shops).**

7. Possibilities to implement citizen-inclusive policies are further determined by political conditions, the influence of regional and national policies and other factors. **Maintain the existing equal-opportunities framing in Bristol policies, and support this with an even stronger health framing of air quality policies that could appeal to all citizens. Aim for more public measurement stations and support 'citizen-science' air quality measurements, as these could contribute to awareness and add local evidence to national modelling results. Maintain good relationships with NGOs as an important intermediary to hear citizens' views.**

8. Many cities struggle with similar implementation issues for citizen-inclusive air quality and carbon policies as Bristol. **Maintain a regular and long-term exchange of experiences and experiments with a diverse and international network of cities. Examine in particular low-cost and little-effort opportunities for regular exchange beyond project funding, such as video-conferencing and informal networks between policy makers.**

9. The following actions were proposed by Bristol policy makers to **implement the suggested citizen measures:**

City:

- Integrated infrastructure planning together with the West England Central Authority, including multimodal hubs
- Renewables and energy efficiency targets and implementation (via Bristol Energy as a municipality owned social enterprise), using the generated energy as much as possible locally
- Parking permits, workplace levy and congestion fees to fund city council measures
- Electric taxi charging points to be installed
- Reallocation of road space in favour of public transport, walking and cycling, could also include closing the city centre for cars and extending resident parking space by closing roads
- Segregation of cycle lanes, loan bikes, free bike training, subsidies for electric bikes, BCC cycle/walking group and general promotion of active travel on foot or by bike

Region / WECA:

- Integrated regional transport planning stimulating P&R, train and bus, regional bike and (tourist) walking routes (including lighting)

- Integrated spatial energy planning (e.g. for renewables and district heating)
- Tendering for bus companies' licenses

National government and Europe:
- Promote health as a driver for transport policy
- Consistent long-term policies away from car use, including subsidising bus travel for under-18s and a higher fuel duty, scrappage schemes and mobility credits
- Reintroduce feed-in tariffs, spatial planning to favour wind farms
- Cross-border grid connectivity and learning from best practices
- Funding for rail electrification and for CAZ schemes

Business:
- Contribute to funding through work place parking levy, subsidising sustainable staff travel
- Promotion of alternative travel for staff through e.g. car clubs, better on-site facilities (showers, lockers and bike racks), restricting on-site car parking, cycle to work schemes, active travel champions
- Voice for change e.g. cycle business charter, flexible working hours, route planning
- Cleaner fleets, micro-freight consolidation, go-low pilot, incentivise EV fleet cf. Uber in London
- Invest in commercial PV on rooftops

Civil society and citizens:
- Need for ownership of problem and solutions – communication is key, voting, empowered & educated citizens, believe they can make a difference
- Lobby local councils and government for improvements, mobilise in local community groups
- Messaging and consultation re banning cars, encouage safe culture, discourage anti-social behaviour on public transport
- Invest in green investment banks

1 The ClairCity project

This chapter provides the context for the ClairCity project (section 1.1) and introduces its objectives (section 1.2). It also gives a reading guide for this report (section 1.3).

1.1 Introduction

In 2015, the Paris climate agreement set the goal to reduce global greenhouse gas emissions to a level keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius[1]. A similar binding agreement for global air quality is lacking, but in 2005 the World Health Organisation formulated guidelines for ambient air quality aiming to improve health and reduce premature death caused by air pollution throughout the world. In 2016, 91% of the world population was living in places where the WHO air quality guidelines levels were not met.[2] Many countries and the European Union have set national air quality targets that are often not as ambitious as the WHO guideline values, but still set a legally binding framework for emission and concentration reductions of air pollutants.

Cities are main contributors to the emissions of greenhouse gases and air pollutants. Recognizing their responsibilities, on top of their legal obligations many cities have set stricter voluntary local goals for emission reductions of greenhouse gases and air pollutants. Improving air quality and reducing carbon emissions as a contribution to the global, national and local targets and ambitions set therefore will be a huge challenge for cities all over the world in the years to come.

Citizens living in these cities do not only cause an important part of these emissions through their daily behaviours, they also can, and have to, contribute to solutions for reducing emissions not only by changing their own behaviour, but also by providing democratic support for policy measures to be implemented that will affect their daily lives. ‘Citizen-inclusive policy making’ is therefore a crucial prerequisite for future air quality and carbon policies in cities to be successful in reducing emissions and reaching targets set on the local, national and global scales.

[1] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[2] https://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

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1.2 Project objectives

Main objective of the **ClairCity Project**[3] is to contribute to successful, citizen-inclusive[4] air quality and carbon policy making in cities worldwide.

'Citizen-inclusive policy making' in the ClairCity project is defined as

1. Tailoring city air quality and carbon policy measures based on a detailed knowledge of current behavioural practices of citizens;
2. Asking citizens for their preferences regarding own future behavioural changes and taking these preferences into account in policy making;
3. Asking citizens for their preferences regarding future air quality and carbon policy measures in their city and also taking these into account in policy making.

It has to be noted that 'citizen-inclusive policy making' within the ClairCity project is seen as competely distinct from 'populistic' policy making. While the latter within the project is seen as an uncritical adoption of the majority voice of citizens on singular policy topics, 'citizen-inclusive policies' to ClairCity means establishing city policies that are as much as possible informed by a detailed and constantly refreshed knowledge of citizens' opinions and behaviours, with the final responsibility for taking – popular and unpopular – policy measures remaining at all times with the democratically elected bodies.

ClairCity aims to contribute to citizen-inclusive policy making by a detailed examination and cross-case comparison of six middle-sized cities throughout Europe. In each of these cities, a comprehensive citizen engagement process is set up consisting of a mix of proven and innovative methods. This carefully designed suite of activities aims to examine current behavioural practices of citizens as well as preferred future behaviours and policy preferences. By carrying out these activities, ClairCity also contributes to awareness of citizens of air quality and carbon policy issues.

The six pilot cities and regions examined in the ClairCity project are:
- Bristol (United Kingdom),
- Amsterdam (Netherlands),
- Ljubljana (Slovenia),
- Sosnowiec (Poland),
- Aveiro / CIRA Region (Portugal) and
- Genua/ Liguria Region (Italy).

[3] The ClairCity project ('Citizen Led Air pollution Reduction in the City') is funded under the EU Horizon2020 programme, grant agreement nr 689289. It started in May 2016 and runs until May 2020. ClairCity website: www.claircity.eu.
[4] The initial subtitle of ClairCity to promote 'citizen-led' policies throughout the project evolved into 'citizen-inclusive' policies, in order to take into account the important role of citizens and stakeholders for informing and co-creating policies, as well as the final responsibility of democratically elected policy makers for deciding on the implementation of these policies.

1.3 This report

This report is the ClairCity "**City Policy Package Report**" for Bristol, the first city for which the ClairCity engagement process has been completed[5]. It provides a summary of the lessons learned for local air quality and carbon policy making in Bristol. The primary target group of this report are Bristol policy makers and politicians. The report can also be of interest to politicians and policy makers in other cities, to national and regional policy makers, to EU policy makers, and not least to stakeholders and citizens in Bristol and elsewhere interested in improving air quality and reducing carbon emissions in their city.

Chapter 2 of this report discusses the ClairCity citizen engagement methods that were applied and tested in the city. Chapter 3 analyses the current air quality and carbon situation in Bristol and looks into current behaviours of citizens that contribute to air pollution and carbon emissions. Chapter 4 examines what behavioural changes Bristol citizens envisage for themselves in the future and what preferences they have for policy measures. It also shows what reflections Bristol policy makers have on the views of citizens. Chapter 5 quantifies potential consequences of the citizens' preferences in terms of emissions and concentrations of air pollutants and of carbon dioxide, in terms of health and in terms of costs of measures. Chapter 6 discusses specific institutional conditions and barriers for citizen-inclusive policies found in Bristol as well as mutual learning possibilities in order to remove these barriers. Chapter 7 finally gives the main conclusions and policy recommendations that follow from the ClairCity citizen engagement and analysis in Bristol.

[5] In the ClairCity project, this report is deliverable D7.4.

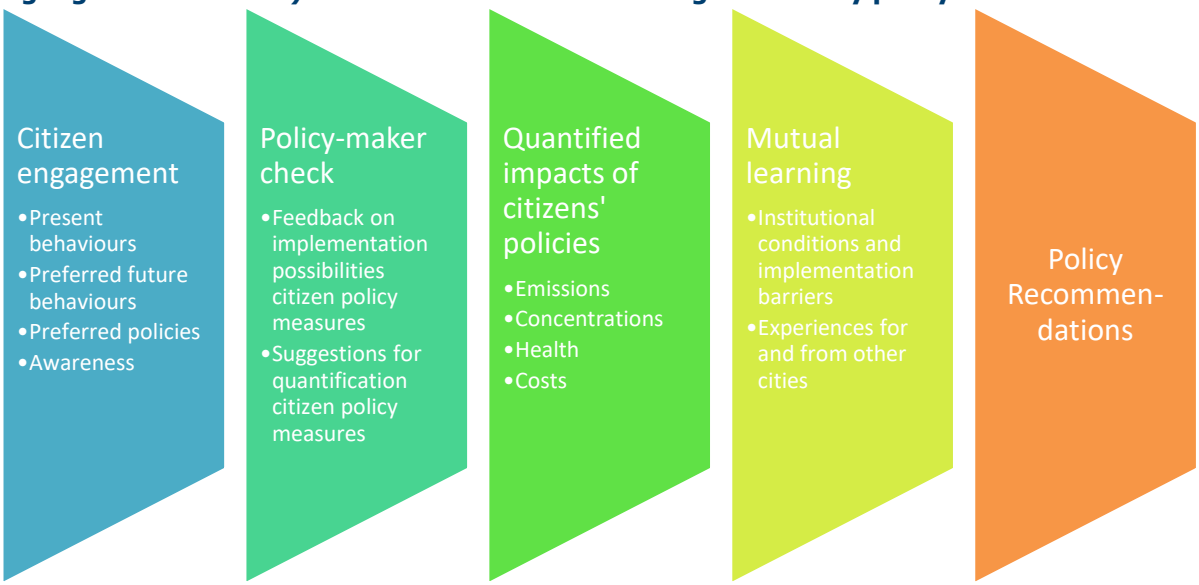
2 ClairCity citizen engagement in Bristol

This chapter gives an outline of the ClairCity method of preparing the policy recommendations (section 2.1) and of the citizen engagement activities in Bristol (section 2.2). A more detailed overview of the ClairCity project and the positioning of this 'Bristol Policy Package' can be found in Annex A. Details of the different ClairCity engagement methods applied in Bristol are given in Annex B.

2.1 The ClairCity method and positioning of the Policy Package

Figure 2-1 shows the five-step process in which the policy recommendations for city policy makers in Bristol were prepared.

Figure 2-1: ClairCity process including key phases and activities (Policy Package highlighted in red box) and chain of evidence leading to ClairCity policy recommendations



First, in the ClairCity engagement process citizens were consulted in order to examine their present behavioural practices, their preferences for future behaviours and their preferences for future policies. The process by itself contributed to citizen awareness of air quality and carbon issues and policies in the city and also included some activities specifically directed at awareness building.

Second, in a workshop with local and regional policy makers involved in air quality and carbon related policies feedback was obtained on implementation possibilities of the citizen policy preferences. In the workshop, the policy measures that evolved from the engagement process were also more worked out and partly quantified.

Third, from the more detailed citizen policy measures a 'Unified Policy Scenario' was constructed, of which the impacts were modelled regarding emissions and concentrations of air pollutants and greenhouse gases, health and costs to citizens and city. These impacts

were compared to a business-as-usual scenario with city policy measures implemented and specified in the base year 2015.

Fourth, the specific institutional conditions and barriers for implementation of the citizen measures in Bristol were examined, consisting in particular of political framing, financial conditions, multilevel policies and other conditions. These were compared with the experiences in the other ClairCity cities to examine what lessons could be learned from and for Bristol regarding promising ways for implementation of the citizen measures.

Fifth and finally, detailed policy recommendations for Bristol were prepared taking all the steps in the ClairCity process into account.

2.2 Citizen engagement in Bristol

Central in the ClairCity project stands the engagement process that was specifically designed for the project and rolled out in all six cities. It consists of a suite of existing and proven methods as well as of experimental and innovative methods (Table 2-1).

Table 2-1: ClairCity's citizen engagement activities

		Citizens, general	Citizens, specific target groups[1)]	Other stake-holders[2)]
Policy related	Mutual Learning Workshop	X		X
	Delphi Process	X	X	X
	Skylines Game	X		
Aware-ness related	Secondary schools activities		X	
	Elderly film competition		X	
	ClairCity City Day	X		X
	GreenAnts App	X		

1) Elderly, pupils secondary school
2) NGOs, business, knowledge institutes

Three engagement activities served as key sources to inform the policy workshop and policy recommendations: the Mutual Learning Workshop, the Skylines game for mobile phones and the Delphi-process. In the Mutual Learning Workshop, citizens and other stakeholders (business, NGOs, knowledge institutions) could discuss in the beginning of the engagement process potential policies for the city[6]. In the Skylines game, citizens could decide on policies for their city as if they were the mayor of the city[7]. The Delphi process consisted of a three step funneling process, starting with general questionnaires about citizens behaviours and preferences, and ending with 'Stakeholder Dialogue Workshops' to discuss outcomes of the process with stakeholders and to build various citizen scenarios as an input for the policy workshops[8].

[6] See ClairCity Report D4.16 Mutual Learning Workshop
[7] See ClairCity Report D4.10 Game User Manual and Data Report
[8] See ClairCity Report D4.4 Delphi Evaluation Report

In addition, several awareness building activities were carried out in the city to reach specific target groups and to further inform the policy recommendations. These were a film competition for the elderly, classroom discussions with secondary school pupils, a City Day to present ClairCity, and an app for the mobile phone that tracks citizens' personal transport behaviour and shows its consequences in terms of concentrations of air pollutants.

In total, during the period 2017 – 2019 over 1,400 Bristol citizens were reached by the various ClairCity citizen engagement methods (Table 2-2). While this sample is not fully representative of the Bristol population as a whole, it gives an indication of support for policy measures and intentions for behavioural change that can be used by policy makers to inform future policies. Specific efforts were also made to include minority groups, resulting in a sample that includes 13% Black and Minority Ethnic citizens, as measured in the first round Delphi survey, compared to an overall 15% share of minority groups in Bristol as a whole.

Table 2-2: Number of participants in ClairCity citizen engagement methods in Bristol

Citizen engagement activity	# of participants engaged
Delphi Process	Approx. 800
Skylines Game	> 600 **)
Mutual Learning Workshop	34
Stakeholder Dialogue Workshop (in Delphi process)	21
Policy Workshop*)	18

*) the number of participants of the policy workshop is also included here, despite not being formally part of the citizen and stakeholder engagement process

**) Game is still being played and data analysis therefore sitill has to be completed.

3 Current air quality and carbon situation in Bristol

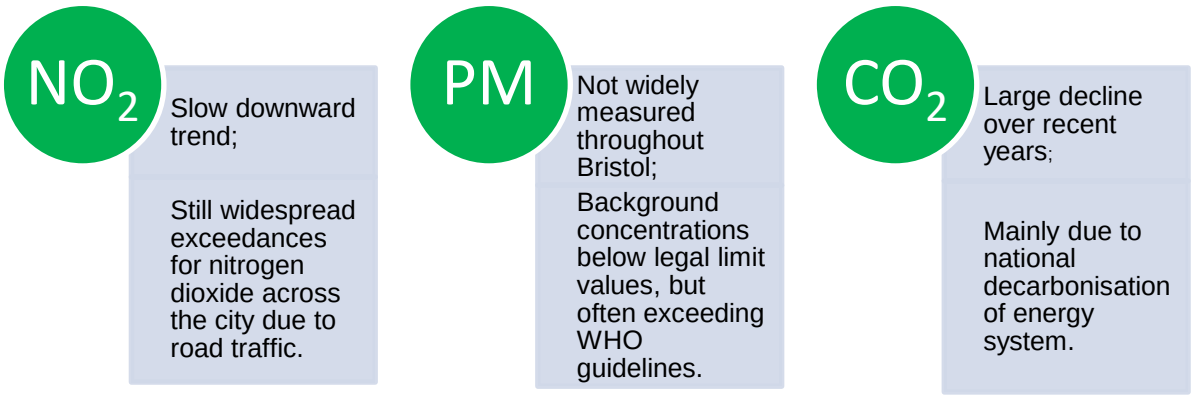
In order to establish a baseline against which the impacts of citizen desires for the future of their city can be compared, this chapter identifies the existing air quality and carbon concentrations and emissions in Bristol (section 3.1), current city air quality and carbon policies (section 3.2) and current stated behaviours of citizens that took part in the engagement process (section 3.3).

3.1 Current concentrations and emissions

An analysis of Bristol policy documents[9] shows that concentrations of air pollutants and carbon emissions are declining (Figure 3-1):

- In spite of a downward trend, exceedances of NO_2 legal limit values and air quality objectives, mainly caused by road traffic, still constitute a widespread problem in Bristol;
- No particulate matter ($PM_{10}/_{2.5}$) legal exceedances are currently found in Bristol, although the number of monitoring sites in Bristol is limited. However, non-binding WHO guideline values are often exceeded;
- CO_2 emissions have declined substantially over recent years, largely due to the national decarbonisation of the energy system.

Figure 3-1: Main features of the current Bristol air quality and carbon situation

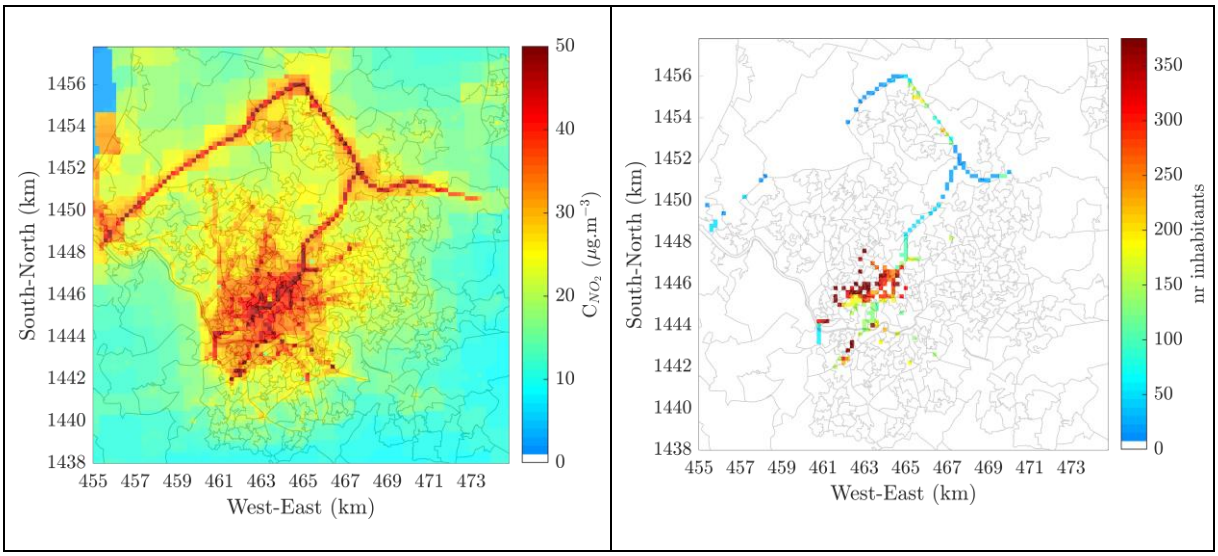


ClairCity modelling used to assess impacts of implementing citizens' views was calibrated to the local emissions and concentrations data (See also Annex C). Figure 3-2 a) shows the exceedances of NO_2 limit values in the current situation, with a clear visible correlation to the street pattern in Bristol. The simulation results indicate a maximum concentration of 91 $\mu g.m^{-3}$ within the urban area close to the M32 motorway (although relevant exposure may not exist at this location). This is substantially higher than the current EU annual legal limit value for NO_2 annual concentrations (40 $\mu g.m^{-3}$). According to the modelling, the legal NO_2 limit value is exceeded in 231 grid cells of 200 x 200 metres in Bristol[10] (Figure 3-2 b), corresponding to 5% of the total population within the urban area potentially exposed to those concentrations.

[9] See the ClairCity Bristol Policy Baseline report (D6.2).
[10] A 'cell' refers to the 200 m x 200m modelling domain that was utilsed by ClairCity

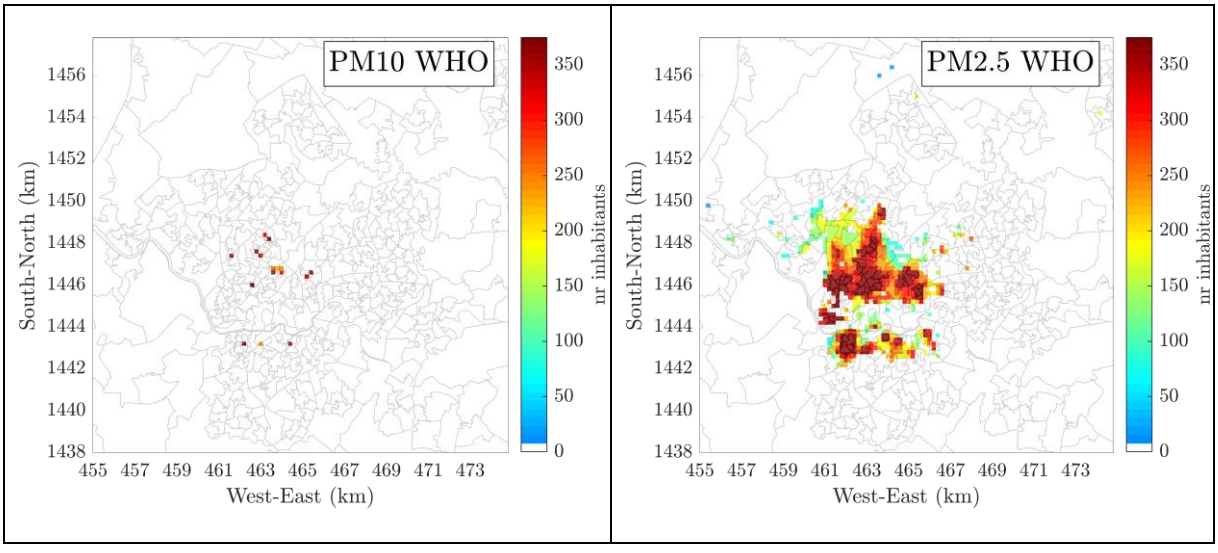
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689289

Figure 3-2: NO_2 contour maps for Bristol in current situation (reference year 2015): a) annual average of NO_2 concentrations and b) number of inhabitants within the cells exceeding the EU annual limit value of 40 µg.m^{-3}.



The ClairCity modelling also indicates that, while Bristol complies with the legal limit values for PM concentrations, it does not comply with the more stringent guidelines of the World Health Organisation (WHO)[11]. Figure 3-3 a) shows 16 cells exceeding the WHO guideline value, which represents 1% of the population. For $PM_{2.5}$, no less than 655 cells are exceeding the standard, denoting that some 25% of the population are potentially exposed to those elevated concentrations (Figure 3-3 b).

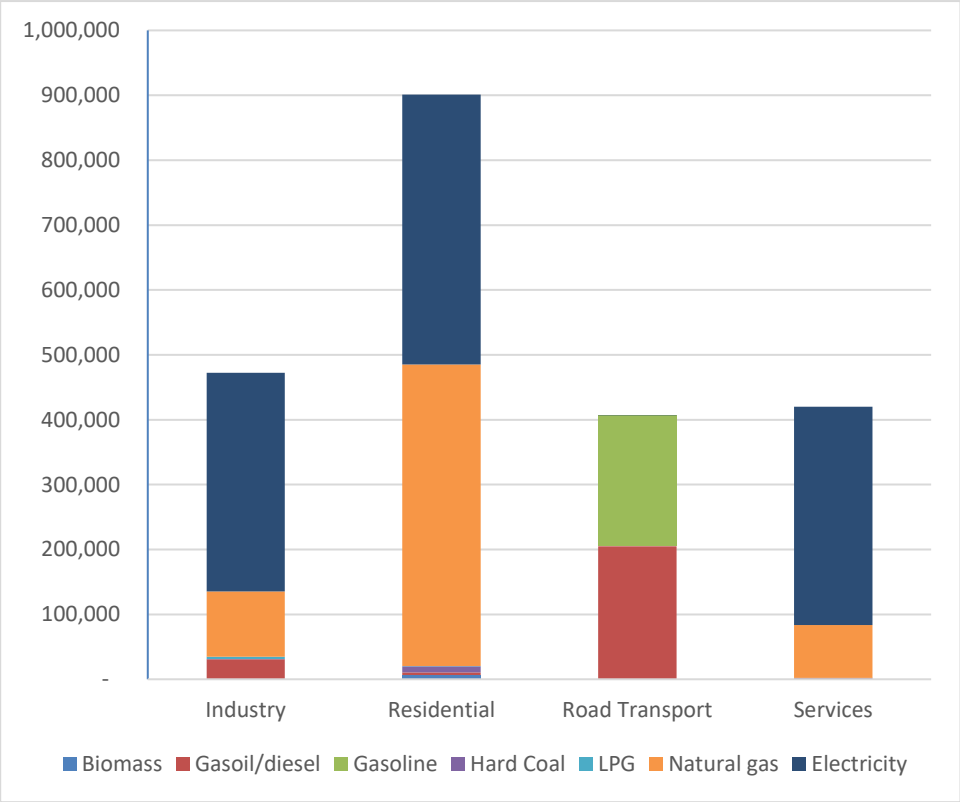
Figure 3-3: Number of inhabitants within the cells exceeding the WHO air quality guideline values: a) of 20 µg.m^{-3} for PM_{10} concentrations, and b) of 10 µg.m^{-3} for $PM_{2.5}$ concentrations.



[11] Based on the latest scientific evidence available, WHO has established limit values for PM10 and PM2.5 that are substantially below current EU and British legal limit values. These values are 20 µg.m-3 for PM10 (compared to a legal limit value of 40 µg.m-3) and 10 µg.m-3 for PM2.5 (legal limit value 25 µg.m-3 annual mean). See https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

In Figure 3-4 the Bristol Carbon Footprint for the year 2015,expressed as tonnes CO_2 equivalent on Life Cycle, is reported by fuel and sector. The indicator takes into consideration the overall life cycle of the energy carrier; this approach includes not only the emissions of the final combustion, but also all emissions of the supply chain; it includes emissions from exploitation, transport and processing (e.g. refinery) steps in addition to the final combustion; this hence includes also emissions that take place outside the location where the fuel is used. The figure shows that the residential sector causes by far the largest part of the (lifecycle adjusted) greenhouse gas emissions in Bristol.

Figure 3-4: Bristol Carbon Footprint in 2015, expressed as tonnes CO_2-eq on Life Cycle by fuel and sector (Gg CO_2 eq)



3.2 Existing air quality and carbon policies

Air quality and greenhouse gas emissions have played an important role in Bristol policy making a long time. Recent measures in Bristol include for instance modernising the bus fleet together with the operators, modernising the council vehicle fleet, a MetroWest project that improves rail connections in the region, investments in walking and cycling infrastructure and improved bus services through fast MetroBus connections[12].

However, due to the legal air quality exceedances in Bristol, the City Council has been directed by the Minister to produce a Clean Air Plan to achieve compliance with air quality

[12] https://www.cleanairforbristol.org/what-we-are-doing/what-is-bristol-city-council-doing-about-it/

limit values in the shortest possible time. Central to the plan is a proposed Clean Air Zone in the city. While several variants of the Clean Air Zone (CAZ) were disregarded as having disproportionate impacts on low – income households, in November 2019 Bristol City Council approved a compliance plan which includes a central area diesel car ban between 7am and 3pm combined with a larger charging Clean Air Zone for older polluting commercial vehicles. [13]. . This option includes coaches, taxis, heavy and light goods vehicles, but does not apply to private cars.

Regarding climate change, in November 2018 the Mayor adopted a Climate Emergency Action Plan[14]. The action plan states the ambition for Bristol to become climate neutral by 2030. Concrete actions stated in the plan include reducing the Council's own emissions to carbon neutrality by 2025, allocating £100,000 funding to a public engagement programme, creating an Environmental Sustainability Board with representatives from relevant city organisations and initiating the 'City Leap Energy Partnership', a large council-led energy investment programme.

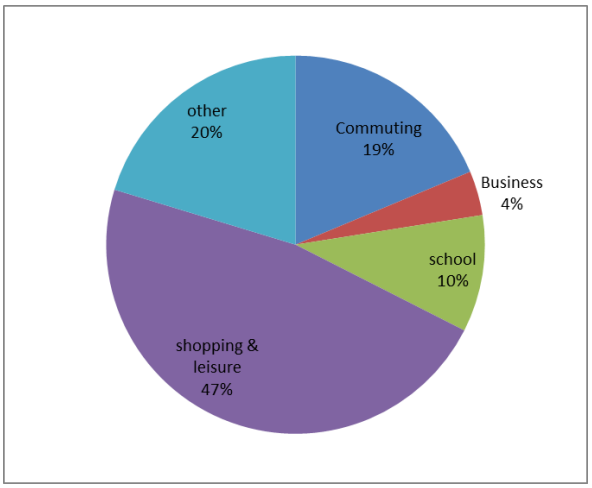
3.3 Concentrations and emissions relating to citizen behaviour

Road transport is the local pollution source of primary concern in Bristol. To better understand the impact that citizens are having on emissions of NO_2 and km travelled from road transport, in ClairCity the road transport emissions, attributable to citizens, were apportioned by a number of categories, including trip purpose, gender and income (See also Annex C).

3.3.1 Road transport emissions by trip purpose / daily activity

Transport emissions grouped by the underlying reason for travel are shown in Figure 3-5.

Figure 3-5 relative importance of trip motive in transport emissions (source: ClairCity modelling)



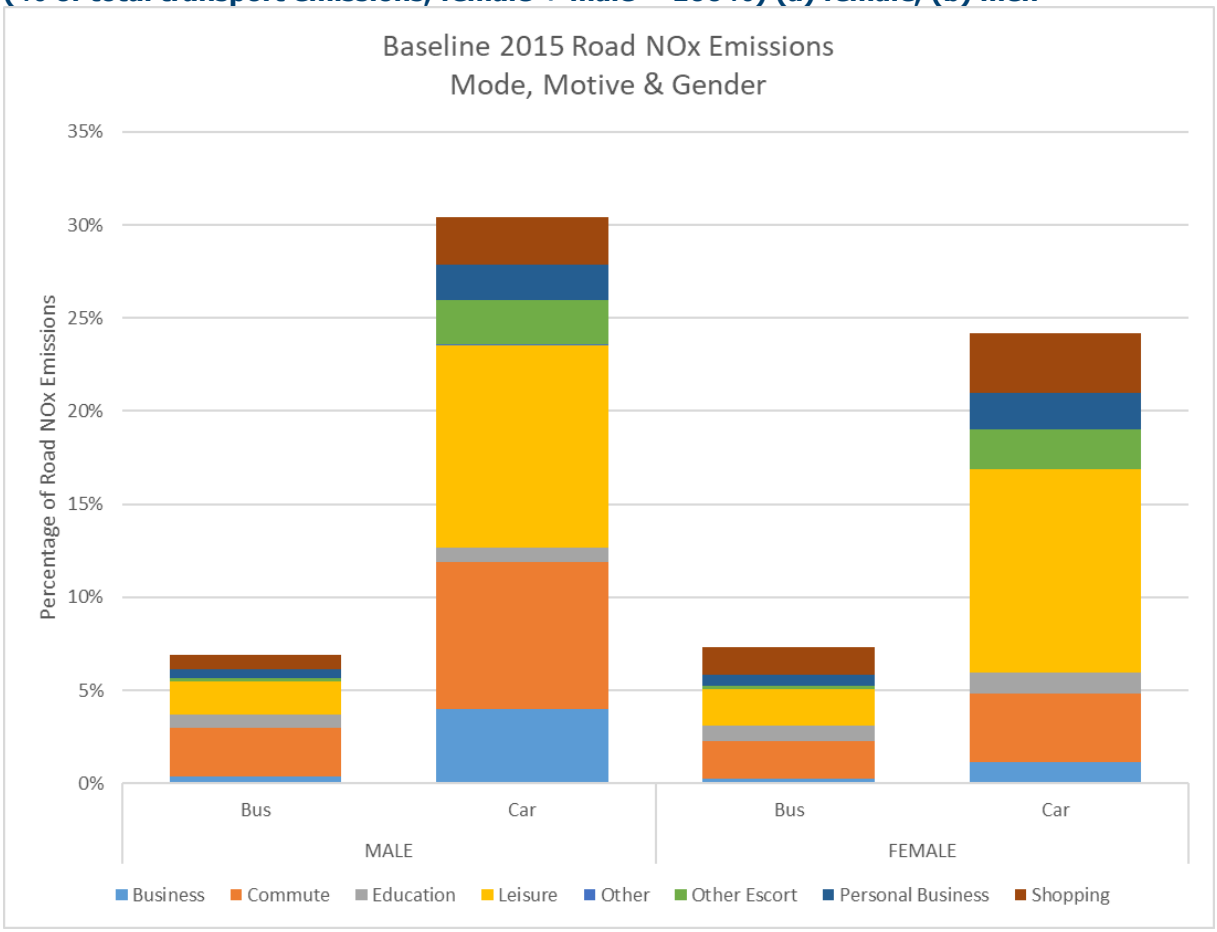
[13] https://bristol.citizenspace.com/growth-regeneration/traffic-clean-air-zone/
[14] https://www.bristol.gov.uk/policies-plans-strategies/council-action-on-climate-change

Most activities and consequence emissions are related to shopping & leasure activities. Commuting accounts for about 19%. The data indicates that while commuting has a substantial influence, it is actually shopping and leisure as a dominant activity that has the highest impact on NOx emissions.

3.3.2 Road transport emissions by gender

The annual road transport NOx emissions data for Bristol is presented in Figure 3-6 as percentages and apportioned by gender. Females overall travel less by car. They particularly generate less emissions for commuting by car compared to males (3.7% female, 7.9% male) and for business purposes (1.2% female, 4% male). Additionally, females walk and cycle less than males – there may be a number of reasons for this such as the need for more travel flexibility, family responsibilities, road safety concerns etc.

Figure 3-6 Total NOx emissions based on transport behaviour activities of Bristol citizens (% of total transport emissions, female + male = 100%) (a) female, (b) men

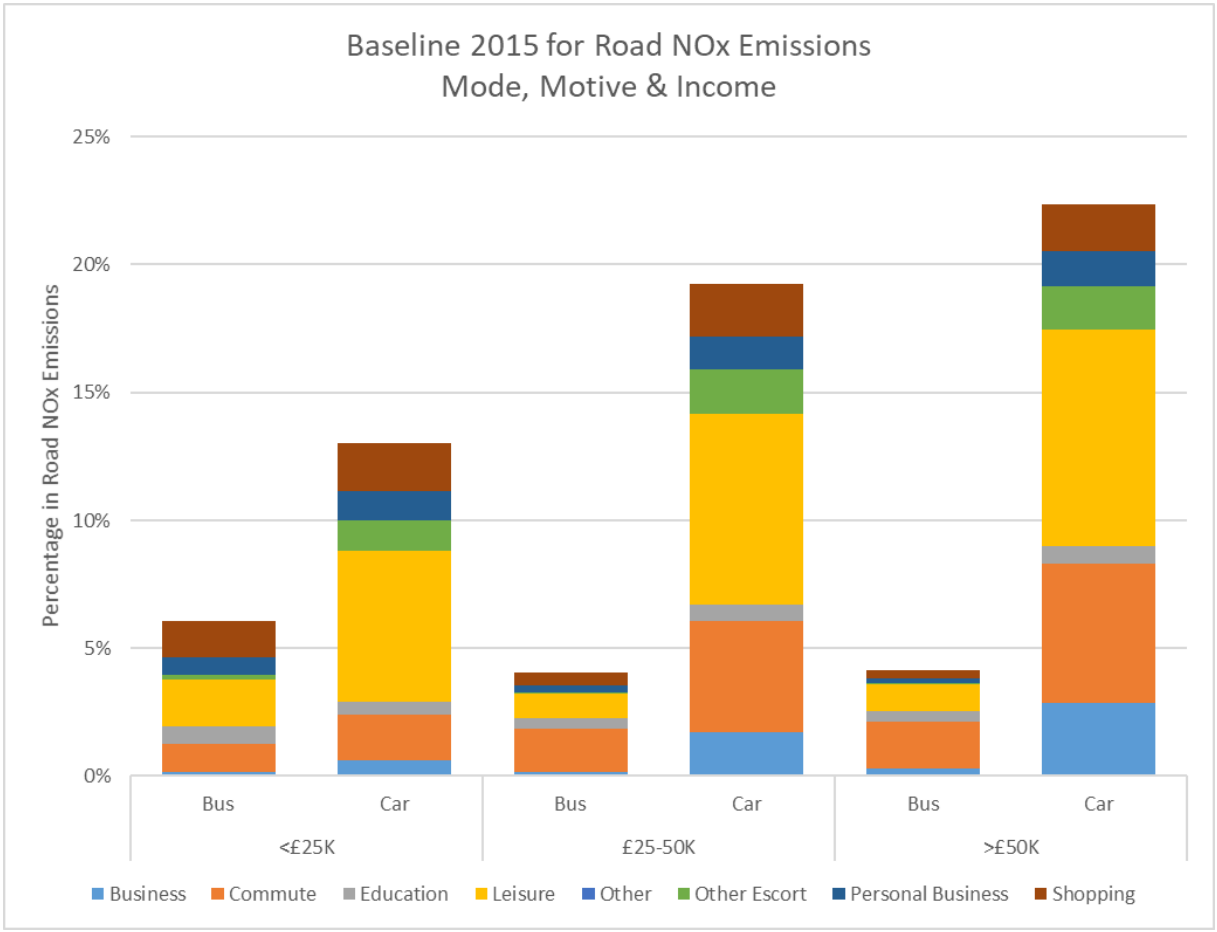


3.3.3 Road transport emissions by income

The annual road transport NOx emissions and km travelled data for Bristol is presented in Figure 3-7 as percentages and apportioned by income (e.g. <£25k, £25-50k and >£50k). The data shows that there is an impact of income on the generation of NOx emissions: citizens

with higher incomes as a group relatively also generate more emissions[15]. This is also supported by other studies (e.g. Barnes et al., 2019). For example, people earning <£25k generate 13% of the NOx emissions by car compared to 19.3% and 22.4% for people earning £25-50 and >£50k respectively. It is also noticable that people earning <£25k are also those most making greater use of the cheaper travel option such as the bus and active travel options but least use of the train.

Figure 3-7 Total NOx emissions of Bristol citizens' transport behaviour split out by income (%)



[15] ClairCity data have not been analysed if this also holds per person for the higher income group compared to the lower income groups

4 Citizens' views on cleaner air and carbon policies in Bristol

After having outlined the existing air quality and carbon situation in Bristol as well as the main current citizen behavioural practices related to that behaviour, this chapter analyses preferred future behaviours (section 4.1) and future policy preferences (section 4.2) of the Bristol citizens that were involved in the engagement process. Section 4.3 gives the reflections of Bristol policy makers on the citizen policy preferences.

4.1 Views of citizens on their own transport and heating behaviours in the future

In the Delphi process, Bristol citizens were asked to what extent they wanted to change their own transport and heating behaviour in the future. Below the results are given of the sample of 500 citizens interviewed.

4.1.1 Commuting behaviour

Almost three-quarters of the respondents wanted to travel to work in the future either by public transport or active travel (walking, cycling) (Figure 4-1). This is a substantial change compared to their stated present modes of transport for commuting, where only 54% rely soley on public transport or active travel[16].

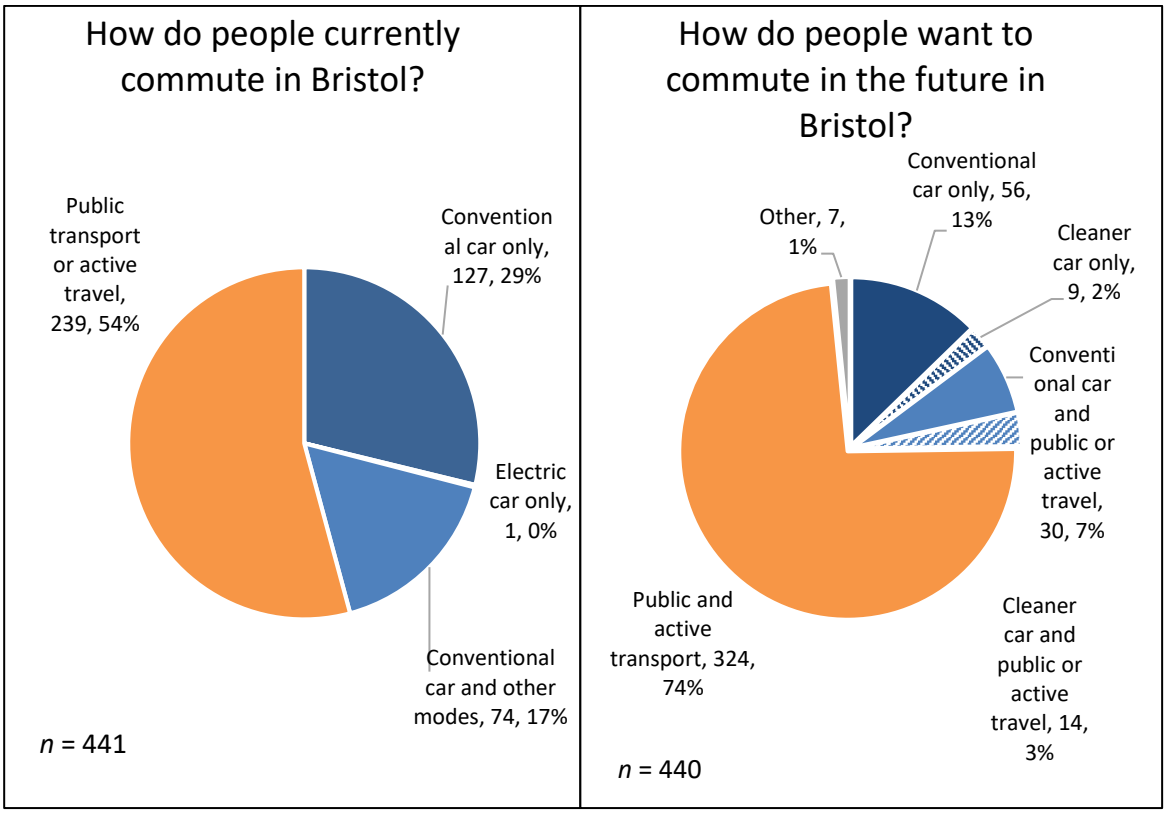
This increase in interest in less polluting transport came from those who soley rely on a car for their commute, as well as from those who already used a mix of transport modes. 20% of the respondents who currently only commuted by car (85 respondents in total) stated they would like to use at least some public transport, active travel or "cleaner" vehicle. Asked for reasons why they presently felt unable to change, the most commonly stated reason was a negative attitude about public transport (mentioned by 52% of this group), next to 'time/distance' (mentioned by 15%), 'convenience' (9% of this group), 'cost' and 'safety' (both mentioned by 7% of this group).

> *"[There is] not enough public transport (train and bus) in terms of frequency and diversity. Current public transport are too expensive and I am living too far away from work to be able to cycle. I do want to change! Unfortunately it's too challenging at the moment." [Female, BME, degree or above qualification, Bristol]*

[16] See D4.4 ClairCity Delphi Evaluation Bristol Report

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689289

Figure 4-1: Proportions of present and future car use of commuters in Bristol



N.B. “Cleaner car” refers to electric or hybrid vehicles. “Conventional car” to petrol or diesel. Where respondents did not mention a fuel type they were assumed to be conventional.

Table 4-1 divides commuting behaviour of respondents into a group that feels ‘entrenched’ in current polluting behaviour, a group that currently has a low polluting choice and wants to ‘stay positive’, and two groups that are either ‘looking for positive change’ or ‘getting worse’. Clearly, many respondents already show positive behaviour and want to continue doing so in the future, while only a very limited group is getting worse.

Table 4-1 Matrix of modal change desires for commuting trips in Bristol

	High polluting choice in future (conventional car only)	Low polluting choice in future (car and walk; walk and bus, online deliveries, EV etc)
High polluting choice in present (conventional car only)	31 Entrenched	85 Looking for positive change
Low polluting choice in present (car and walk; walk and bus, online deliveries, EV etc)	22 Getting worse	279 Staying positive

4.1.2 Shopping and leisure behaviour

Figure 4-2 shows current and desired future shopping transport behaviour of Bristol citizens. Figure 4-3 shows the same for leisure. Regarding shopping, currently approximately 38% of our respondents do not use cars for their shopping or leisure at all and 66% would like to stop using any type of car altogether for shopping and leisure – there is latent demand for public and active travel alternatives. Electric vehicles are not particularly popular – people are more interested in switching to public transport or active travel options. Only 4% of

respondents mentioned EVs for these types of journeys in the future. Only 9% of respondents included home delivery in their future choices – most people are still imagining that they will travel to the shops rather than groceries coming directly to them.

> *"Have you tried going to the countryside with two kids but without a car? :-(No cycle lanes, no acceptable buses at most places.." [Male, white, degree or above qualification, Bristol]*

> *"Young family, need to do multiple journeys within a set time. Need to carry goods and people [Female, BME, degree or above qualification, Bristol]*

Figure 4-2: Current and future transport choices for shopping in Bristol

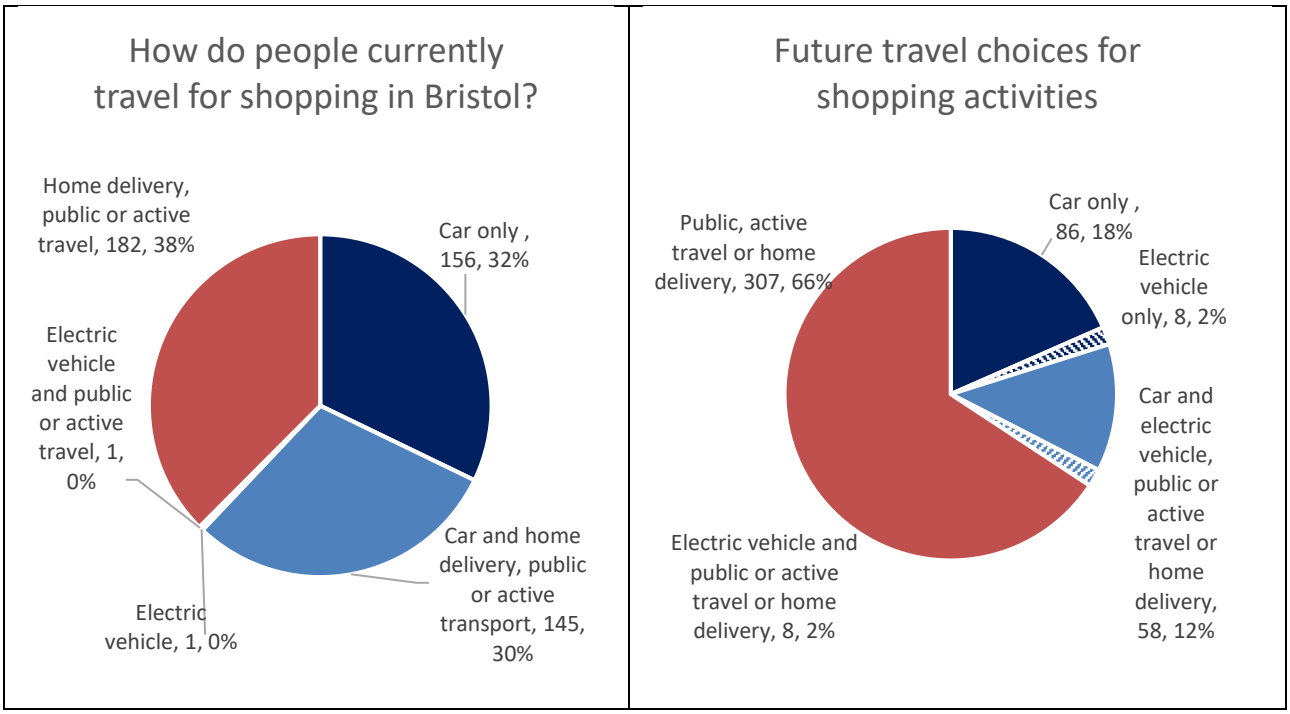
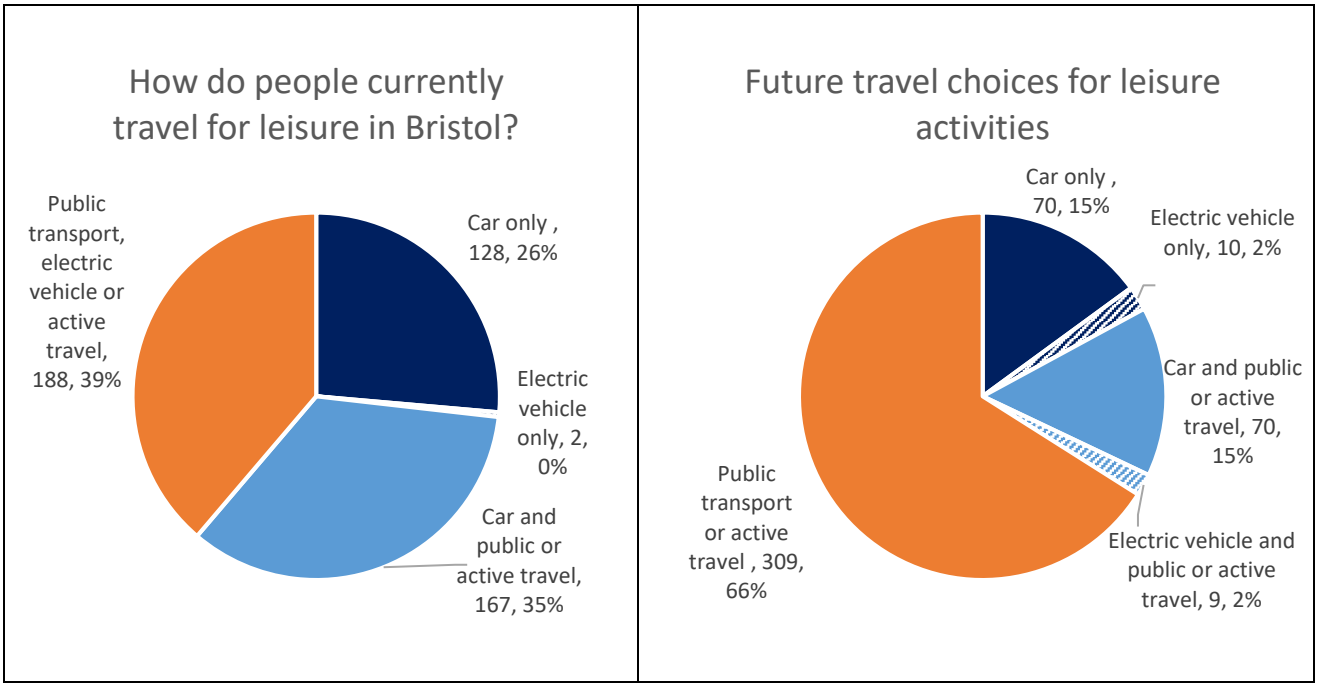


Figure 4-3: Current and future transport choices for leisure in Bristol



Tables 4-2 and 4-3 show that the number of people that want to change their transport behaviour for shopping or leisure in the future by getting out of the car is far larger than the number of people intending to increase their car use.

Table 4-2: Matrix of modal change desires for shopping trips in Bristol

	High polluting choice in future (conventional car only)	Low polluting choice in future (car and walk; walk and bus, online deliveries, EV etc)
High polluting choice in present (conventional car only)	56 Entrenched	89 Looking for positive change
Low polluting choice in present (car and walk; walk and bus, online deliveries, EV etc)	29 Getting worse	281 Staying positive

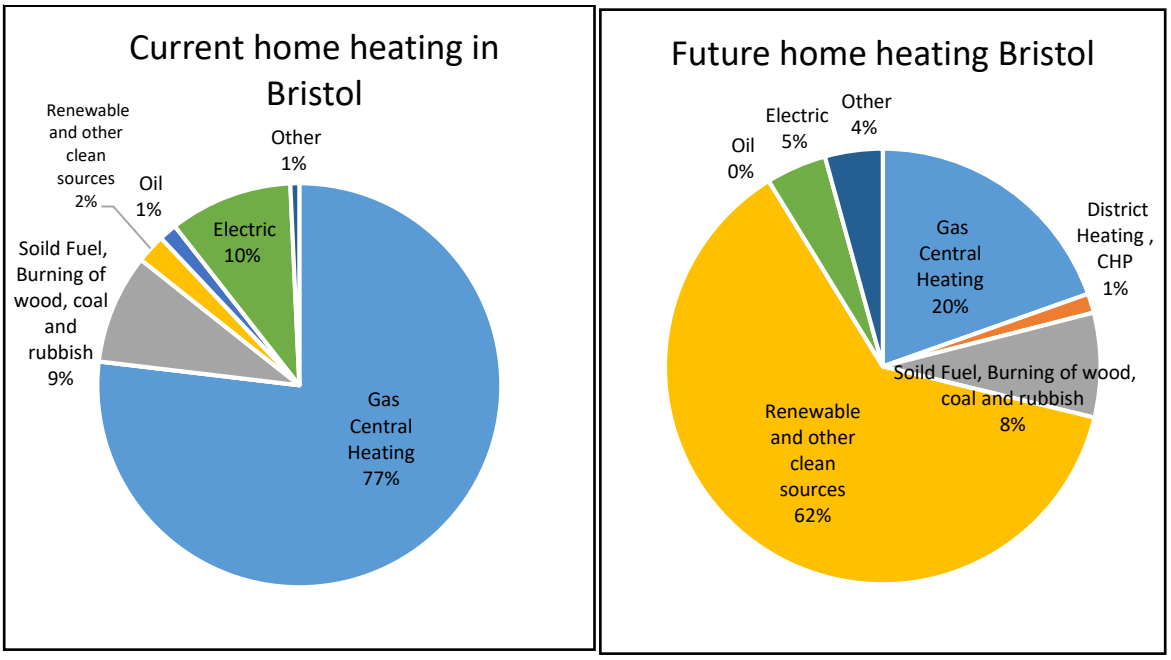
Table 4-3: Matrix of modal change desires for leisure trips in Bristol

	High polluting choice in future (conventional car only)	Low polluting choice in future (car and walk; walk and bus, EV etc)
High polluting choice in present (conventional car only)	47 Entrenched	71 Looking for positive change
Low polluting choice in present (car and walk; walk and bus, EV etc)	21 Getting worse	321 Staying positive

4.1.3 Home Heating behaviour

Figure 4-4 shows current and desired future home heating behaviour of Bristol citizens. 484 people responded to this question. Nearly three quarters of respondents (76%) use gas to heat their homes in Bristol, with a further 10% relying on electric heaters. Respondents were able to indicate more than one form of heating, so the total number of responses is higher than the total number of respondents. There was a significant demand for renewable heating in the future, with some respondents specifying type of energy (e.g. solar, wind) others suggesting more generic responses e.g. “green” or “renewable” sources.

Figure 4-4: Current and future choices for home heating in Bristol



There were 17 respondents who wanted to continue using solid fuel in the future, labelled as "entrenched." However, 15 of these wanted to combine solid fuel with other means, indicating less of a reliance on solid fuels. Similarly, of those in the "getting worse" category, 65% (13 people) were looking for a mix of either gas or renewables with solid fuel in the future. Exploring the "getting worse" data set, nearly half said that the reason they had not moved to solid fuel was due to cost, with not being a homeowner or the chimney/fireplace not being suitable also appearing for around 25%. None mentioned any concerns about the air quality impact of moving to solid fuel burning.

Table 4-4: Matrix of modal change desires for home heating in Bristol

	Solid fuel in the future	Not solid fuel in the future
Solid fuel in the present	17 Entrenched	28 Looking for positive change
Not solid fuel in the present	20 Getting worse	377 Staying positive

Understanding the motivations for those who are "looking for positive change" is useful for identifying potential low-hanging fruit to move people away from solid fuel use. In our Bristol data, 28 people wanted to move away from solid fuel. In their responses, cost was the most significant factor with more than half of respondents mentioning it.

Comments relating to problems in converting buildings were the next largest group, for example "old building" or "roof not facing the best way." The physical infrastructure of a relatively old housing stock in Bristol seems relevant in the renewables category implying a focus on self-generation rather than mains electricity. People are assuming their heating infrastructure would be part of the fabric of their house or building, like solar panels on their roof, rather than electric heating that could run from renewables located elsewhere.

> *Can't afford to change. Single mum, low income [Female, degree or above qualification, Bristol]*

> *Can't afford the costs of installing solar panels & can't afford to change our gas central heating to electric heating. [Female, white, Secondary education, Bristol]*

4.1.4 Demographic analysis

Within ClairCity, a detailed analysis was made of the demographic characteristics for transport and heating behaviour of the respondents in Bristol. This analysis can be found in the ClairCity 'People's report'[17]. The most prominent findings of this analysis are:

- More women than men presently use a car for commuting, leisure and shopping, while their preferences for change are similar. Less women than men cycle or want to cycle in the future;

[17] Seeing people in the data": understanding citizen behaviour for better air quality, carbon and public health management in cities

- Irrespective of gender, ethnicity and education, all groups of respondents envisage to use more public transport and to cycle more, but to walk less in the future;

- BME respondents generally use fewer cars at present and a higher share than white respondents want to continue using a car in the future;

- Higher educated respondents are using less cars at present and more often want to change to public or active transport in the future than lower educated respondents;

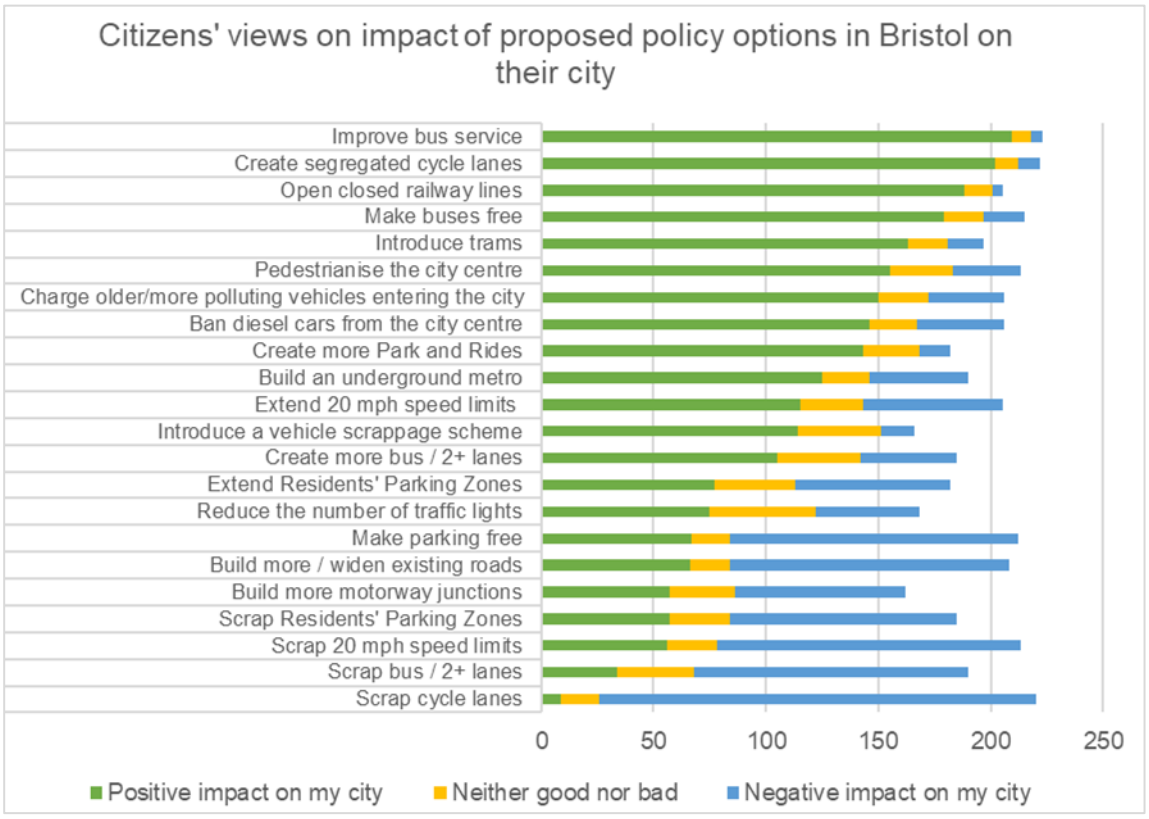
- For heating behaviours, differences between gender, ethnicity and education are less pronounced, although some more BME respondents are currently using gas and less want to change to renewables (but still a large majority)

4.2 Views of citizens on future policies in Bristol

In the ClairCity engagement process, Bristol citizens were also asked for their views of the impact of policy options generated by the Round 1 Delphi respondents on air quality and carbon policies in Bristol. Figure 4-5 summarises the outcomes of this engagement round. The outcomes suggest that further improving public transport, cycling and walking options are high on the priority list of preferred policies of citizens for their city.

More controversial are 20 mph speed limits and residents' parking zones, for which proponents for expansion as well as reduction are found – although the support for the former is somewhat higher than for the latter. There is also large public support for reducing costs of public transport ('make buses free'), which would need to be alligned with higher costs arising from improving public transport services. .

Figure 4-5: Citizens' views on the impact that proposed policy options in Bristol would have on their city



These findings were confirmed by the other parts of the engagement process (Skylines game, Mutual Learning Workshop). Overall analysis of the results of these three engagement activities led to four preferred measures of citizens (identified through the Delphi citizen engagement, Skylines game and Mutual Learning Workshop), and 13 further measures that were also prominent, i.e. identified through two out of the three engagement processes above (Figure 4-5).

The table shows that most of the preferred measures relate to transport, with a fairly even division of measures relating to the clean air zone, active transport, public transport and cleaner transport. Two energy measures were mentioned frequently: improving energy efficiency of housing and increasing local solar and wind generation. Of the ‘other’ measures, two relate to business (flexible working hours, work from home) and four to spatial planning (property developers considering air quality and climate change, housing in employment zones, local shops, spread of economic opportunities throughout the city).

Table 4-5: Overall preferred policy measures of Bristol citizens from ClairCity engagement process

Measures	Clean Air Zone	Active transport	Public transport	Cleaner transport	Energy measures	Other measures
Mentioned in all three main ClairCity engagement activities *)						
5. Ban/phase out most polluting vehicles (not just charge)	x			x		
6. Make buses greener and cleaner	x		x			
7. Cheaper public transport			x			
8. Create good alternatives to car use – walking and cycling		x				
Mentioned in two out of three main ClairCity engagement activities						
14. Reduce vehicle road space – increase public transport space			x			
15. Improve walking environment in Bristol		x				
16. Charge older/ more polluting vehicles entering the city	x			x		
17. Promote electric vehicles				x		
18. Awareness raising to promote active and public transport		x	x			
19. Make it easier for employees to work from home						x
20. Make property developers consider air pollution and climate change						x
21. Building housing close to major employment zones						x
22. More local shops and facilities in neighbourhoods						x
23. Organisations to provide more flexible working hours for employees						x
24. Improve energy efficiency for housing (rented/existing/new)					x	
25. Increase generation of solar wind and power					x	
26. Spread economic opportunities across different areas of the city						x

*) main ClairCity engagement activities: Delphi process (3 rounds citizen engagement in questionnaires, interviews, workshop), Mutual Learning Workshop (expert workshop), Skylines game (mobile phone game for citizens)

4.3 Reflections from Bristol policy makers

In a 'Stakeholder Dialogue Workshop', citizens and stakeholders produced three provisional scenarios from the preferred measures. These scenarios were discussed with Bristol policy makers in a policy workshop held in October 2018. The workshop was attended by 18 City Council and regional policy makers from various departments[18]. Table 4-5 shows the reflections of the policy makers, divided into three table groups, on the four main citizen measures. For reference the table also shows the existing policies in place at the time of the workshop (2018). The comments show whether policy makers consider the citizen ideas realistic or not, and include suggestions by policy makers to make these more implementable.

The results of the workshop suggest that overall, the main measures preferred by citizens are supported by policy makers. Citizens in general propose a quicker and more ambitious implementation of measures than foreseen in actual policies. In their reflections given in the workshop, policy makers overall also endorse higher ambition levels of measures, but sometimes are in doubt if a more rapid implementation of measures as suggested by citizens would be possible.

[18] This workshop was held on 8 November 2018 at Bristol City Hall.

In more detail, the policy makers that participated in the workshop support a ban of the most polluting diesel vehicles in the city, with a full ban considered unrealistic at short term, but feasible by 2030. Reducing emissions of the bus fleet is considered to be already on the way, with perhaps a possibility to accelerate developments up to 2023. Also, policy makers state that the flat fare for buses introduced in 2018 already has reduced public transport prices. Further price reductions, if possible, would have to be cross-financed, possibly by a work place parking levy or congestion charging. Regarding further improving the active travel infrastructure, policy makers were inconclusive as to whether a further acceleration of planned cycling infrastructure developments would be possible.

Table 4-6: Reflection of Bristol policy makers on preferred citizen measures derived fromn the Stakeholder Dialogue Workshop (Policy Workshop reflecting the existing policies as of October 2018).

Main Measures	Existing Bristol policies (as of 2018)	Table 1*)	Table 2	Table3
M1: Ban most polluting vehicles	• Four classes of Clean Air Zone (charging zone) considered, Euro-4 petrol and Euro-6 diesel not to be charged, nor electric and hydrogen vehicles • A "small area" diesel ban is considered and the impacts are quantified as part of a feasibility study.	• Banning most polluting vehicles by 2020 • 2023 ban all diesel cars from city centre • Full city-wide ban on diesel cars by 2030	• Rather ban vehicles than charging, as infrastructure would be needed for latter • Unrealistic timing for banning vehicles by 2018	
M2: Buses cleaner & greener	• Joint bus strategy to be developed together with bus companies and WECA • All Clean Air Zone options include measures for buses	• Buses cleaner by 2023 instead of 2027	• Buses cleaner nearly achieved, e.g. Euro 6 by 2021	• 80% bus fleet to be Euro 6 or better by 2023
M3: Cheaper public transport	• £2 flat fare introduced as of Nov 2018 • Overall budget neutral: Rides < 3 miles have become more expensive, > 3 miles cheaper Promoted by Mayor because of social justice considerations (poor live further from city centre)		• There is already a flat fare introduced as of Nov 2018	• Free park and ride buses at regional level • 50% reduction in ticket cost to be funded by work place parking levy or congestion charging
M4: Good alternatives to car use (walking & cycling)	• Bristol walking/cycle strategy under development, with many supportive measures but no quantitative goals regarding modal share. Also Bristol Transport Strategy to support this.	• Good alternatives to car use by 2025 • 65% sustainable travel (active + buses) by 2030	• Cycle infrastructure by 2030 is realistic	• Double miles of cycling network by 2025

*) Participating policy makers in the workshop were divided into three 'table groups'

In the policy workshop, there were also suggestions made to implement the citizen measures, with action points on a city, regional and national level as well as for business and citizens (Box 4-1). Proposed concrete measures for the city concern financing of policies (parking permits, workplace parking levy, congestion levies), infrastructural measures (reallocation of road space, charging points for electric taxis) as well as behavioural

measures (bike training, BCC walking/cycling group). Expansion of integrated planning on a regional level (spatial, infrastructure, transport) was also considered to be important, as well as wider policies and funding on a national level based on health. Business was further considered to be an important actor to contribute to change through measures such as bike to work schemes and cleaner business fleets. Finally, citizens' ownership of problems and solutions was considered key and to be promoted through e.g. education and mobilising local community groups.

Box 4-6 Suggested actions to implement citizen measures from the policy workshop

City:

- Integrated infrastructure planning together with WECA, including multimodal hubs
- Renewables and energy efficiency targets and implementation (via Bristol Energy as a municipality owned social enterprise?), using the generated energy as much as possible locally
- Parking permits, workplace levy and congestion fees to fund city council measures
- Electric taxi charging points to be installed
- Reallocation of road space in favour of public transport, walking and cycling, could also include closing the city centre for cars and extending resident parking space by closing roads
- Segregation of cycle lanes, loan bikes, free bike training, subsidies for electric bikes, BCC cycle/walking group and general promotion of active travel on foot or by bike

Region / WECA:

- Integrated regional transport planning stimulating P&R, train and bus, regional bike and (tourist) walking routes (including lighting)
- Integrated spatial energy planning (e.g. for renewables and district heating)
- Tendering for bus companies' licenses

National government and Europe:

- Promote health as a driver for transport policy
- Consistent long-term policies away from car use, including subsidising bus travel for under-18s and a higher fuel duty, scrappage schemes and mobility credits
- Reintroduce feed-in tariffs, spatial planning to favour wind farms
- Cross-border grid connectivity and learning from best practices
- Funding for rail electrification and for CAZ schemes

Business:

- Contribute to funding through work place parking levy, subsidising sustainable staff travel
- Promotion of alternative travel for staff through e.g. car clubs, better on-site facilities (showers, lockers and bike racks), restricting on-site car parking, cycle to work schemes, active travel champions
- Voice for change e.g. cycle business charter, flexible working hours, route planning
- Cleaner fleets, micro-freight consolidation, go-low pilot, incentivise EV fleet cf. Uber in London
- Invest in commercial PV on rooftops

Civil society and citizens:

- Need for ownership of problem and solutions – communication is key, voting, empowered & educated citizens, believe they can make a difference
- Lobby local councils and government for improvements, mobilise in local community groups
- Messaging and consultation re banning cars, encouage safe culture, discourage anti-social behaviour on public transport
- Invest in green investment banks

5 Impacts of implementing citizens' views

This chapter discusses the potential impacts of implementing the citizens' views on future policies on air quality (section 5.1), health (section 5.2), carbon emissions (section 5.3), costs (section 5.4) and on citizen behaviour (section 5.5). It is based on ClairCity modelling to which the disclaimer formulated in Textbox 5-1 applies.

Textbox 5-1 Disclaimer ClairCity modelling versus national modelling

> "ClairCity modelling differs from local and national models in the United Kingdom based on different modelling assumptions and inputs. Although the utmost care has been taken to calibrate the ClairCity models to local conditions, a detailed comparison of ClairCity modelling assumptions to those of local and national models in each country was considered to be outside the scope of this project. Therefore ClairCity modelling outcomes cannot be one-to-one compared with the outcomes of national and local models; they should be regarded as indicative and can deviate from measured and modeled concentrations in the United Kingdom."

The modelled potential impacts are based on a 'Unified Policy Scenario' (UPS) that was prepared by combining citizen preferences for future policy measures with policy maker reflections and quantifying them where possible. Main assumptions made for preparing the UPS are given in Annex CB. The impacts of the UPS are compared with those of a 'Business-As-Usual' scenario (BAU) that is based on all city policy measures implemented in Bristol in the base year 2015[19].

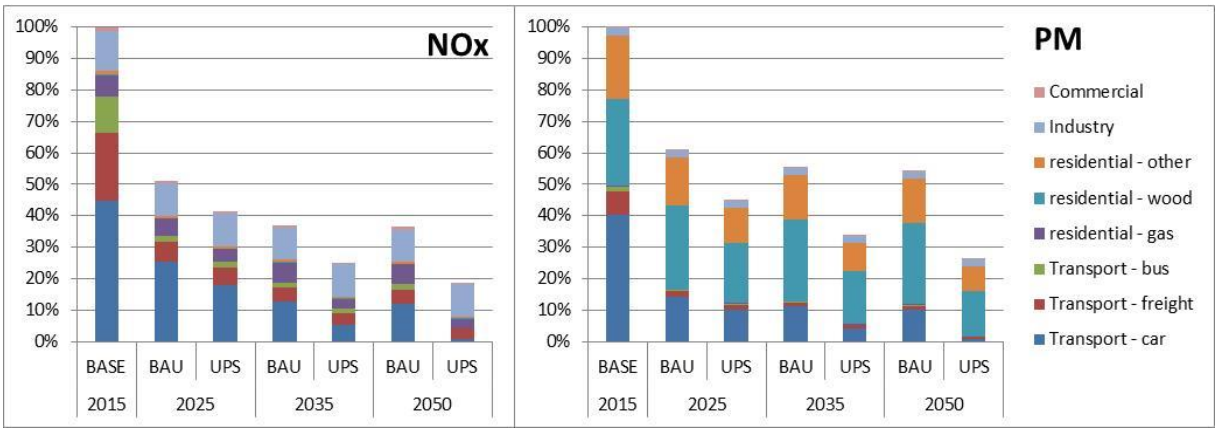
Overall it is concluded that implementing the suggested policy measures of citizens as quantified in the UPS, and thereby enabling alternative behaviours and activities, would result in substantially better air quality and a reduction in the number of premature deaths caused by air pollution in the city. Also, a cost-effective implementation of these measures in principle seems possible, but will depend very much on how the measures will be designed in practice.

5.1 Impacts on air quality

Figure 5-1 shows the differences in NOx and PM emissions in Bristol between the base year 2015, the 'Business-as-Usual' (BAU) scenario and the 'Unified Policy Scenario' (UPS).

[19] Policy changes and stricter targets formulated in Bristol since 2015 (e.g. the carbon neutrality target) could not be incorporated in the baseline. This obviously affects the differences between BAU and UPS scenario.

Figure 5-1: Trend of PM and NOx emissions in the policy scenario, compared to the business as usual scenario



From Figure 5-1, it can be seen that the UPS scenario is successful in further decreasing the emissions from transport beyond the reductions already in the BAU. Transport NO_x emissions are reduced to about 10% in 2035 compared to 2015 in the UPS scenario, while in the BAU emissions in that year are still 19% of the 2015 emissions. Transport emissions in the UPS scenario are reduced to 5% for NOx and 3% for PM in 2050 compared to 2015. This is not the case in the BAU scenario.

A side-effect of the UPS scenario is that it increases the importance of emissions from other sources that are not affected by the policy measures. For example, while PM emissions of residential sources are decreasing, the slower pace of reduction is making residential sources the dominant sources of primary PM emissions over time: the contribution of these emission rises from about 47% of the total in 2015 to 85% in 2050. The contribution of residential wood burning ('solid biomass'), promoted as a renewable energy source to reduce carbon emissions, specifically increases from 27% to 55% if no additional policy measures are taken. This holds even though in absolute terms, emissions will be decreasing. Paying specific attention to informing citizens about the effects of biomass burning therefore seems justified (Textbox 5-2).

Textbox 5-2 Informing citizens about mixed effects of biomass burning

Biomass is often promoted as a 'renewable' and 'climate-friendly' energy source. However, this is increasingly under discussion. In addition, its impacts of biomass combustion on air quality are clearly negative. Awareness raising of the mixed effects of biomass combustion on the environment would therefore be important to inform citizens when considering biomass heating at home.

Figure 5-2 NO_2, PM_{10} and $PM_{2.5}$ concentrations in the BAU and UPS scenario in 2050

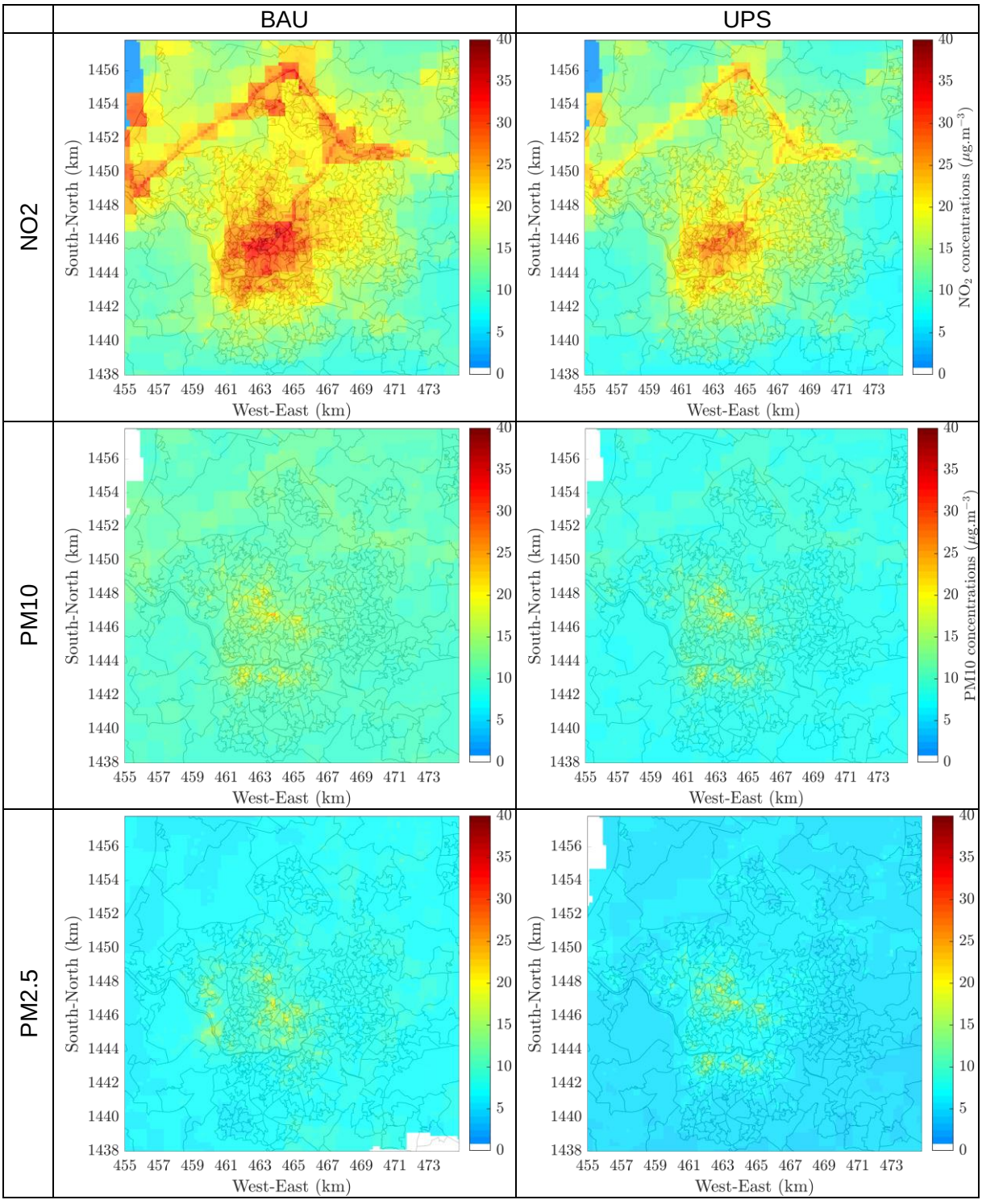


Figure 5-2 gives an overview of modelled NO_2, PM_{10} and $PM_{2.5}$ concentrations in the BAU and UPS scenario in 2050. More detailed modelling results can be found in Annex B. The overall analysis of modelling results, comparing UPS and BAU modelling results with legal limit values and WHO guideline values, shows that:

– **The UPS scenario leads to compliance with legal NO_2 limit values in 2025, whereas the BAU scenario doesn't.** In the BAU scenario, the maximum NO_2 concentration will be equal to 45.5 µg.m $^{-3}$ in 2025. Exceedences will occur in 5 cells of the domain. In the UPS

scenario in 2025 the maximum NO_2 concentration will be equal to 40.4 µg.m $^{-3}$, showing only an exceedance in one grid cell of the limit value in 2025. The UPS scenario will reduce the maximum NO_2 concentrations by 11 and 17% respectively in 2025 and 2050, as compared to the BAU scenario.

- **For PM_{10}, the BAU and UPS scenario comply with the legal limit values. Neither BAU nor UPS result in compliance with WHO guidelines, but the UPS scenario reduces concentrations more than BAU.** In 2025 the maximum value in the UPS scenario corresponds to 22.1 µg.m $^{-3}$ and to 20.5 µg.m $^{-3}$ in 2050, translating into a 7% reduction of the maximum concentration compared to BAU. Based on the EU limit values there aren't any exceedances, but for the WHO guidelines in 2025 2 cells were exceeding and in 2050 1 cell was still exceeding the WHO limit in the UPS scenario. When comparing the UPS scenario with the BAU scenario, the maximum concentrations will be reduced by 5 and 11% respectively, in 2025 and 2050.

- **For $PM_{2.5}$, BAU and UPS scenarios comply with legal limit values, but even in the UPS scenario there are still significant exceedances of WHO guideline values in 2050.** In 2025 the maximum value in the UPS scenario corresponds to 20.1 µg.m $^{-3}$ and 18.7 µg.m $^{-3}$ in 2050, translating into a 7% reduction of the maximum concentration compared to BAU. Based on the WHO guidelines, 239 grid cells will still show exceedances in the UPS scenario in 2025. By 2050 this number is reduced to 152 cells. When comparing the UPS scenario with the BAU scenario, the maximum concentrations will be reduced by 4 and 8% respectively in 2025 and 2050.

5.2 Impacts on health

Table 5-1 summarises the modelled health impacts of UPS and BAU scenario compared to the baseline situation in 2015. It shows that the UPS scenario significantly improves human health compared to the current situation and to the BAU scenario. In the base year 2015, the number of premature deaths as a result of NO_2, PM_{10} and $PM_{2.5}$ is 429, 336 and 404 respectively. The BAU scenario reduces these numbers by 26%, 17% and 87% in 2050 respectively, but the UPS scenario results in far larger reductions: 52%, 79% and 94%. When comparing both scenarios, the reduction in premature deaths related to NO_2, PM_{10}, and $PM_{2.5}$ is 26%, 44% and 29% for 2025, and 35%, 75% and 53% for 2050, respectively[20].

The reduction in the number of premature deaths is higher than the average concentration reduction when comparing the baseline (2015) and future emission scenarios. This discrepancy indicates that the reduction of emissions particularly occurred in grid cells with high population density. The largest difference between concentration and premature deaths reduction is for PM_{10} when comparing the UPS scenario with the BAU scenario, 4.4 and 3.2 times for the year 2025 and 2050. These figures suggest that PM_{10} reduction occurs more in areas with high population.

[20] As stated, ClairCity modelling figures differ from Bristol City Council figures due to different modelling assumptions. A detailed comparison of ClairCity and BCC modelling is outside of the scope of this project. ClairCity figures therefore should be regarded as indicating overall trends only.

Table 5-1: Number of premature deaths as a result of NO_2, PM_{10} and $PM_{2.5}$ in the current situation and BAU and UPS scenarios

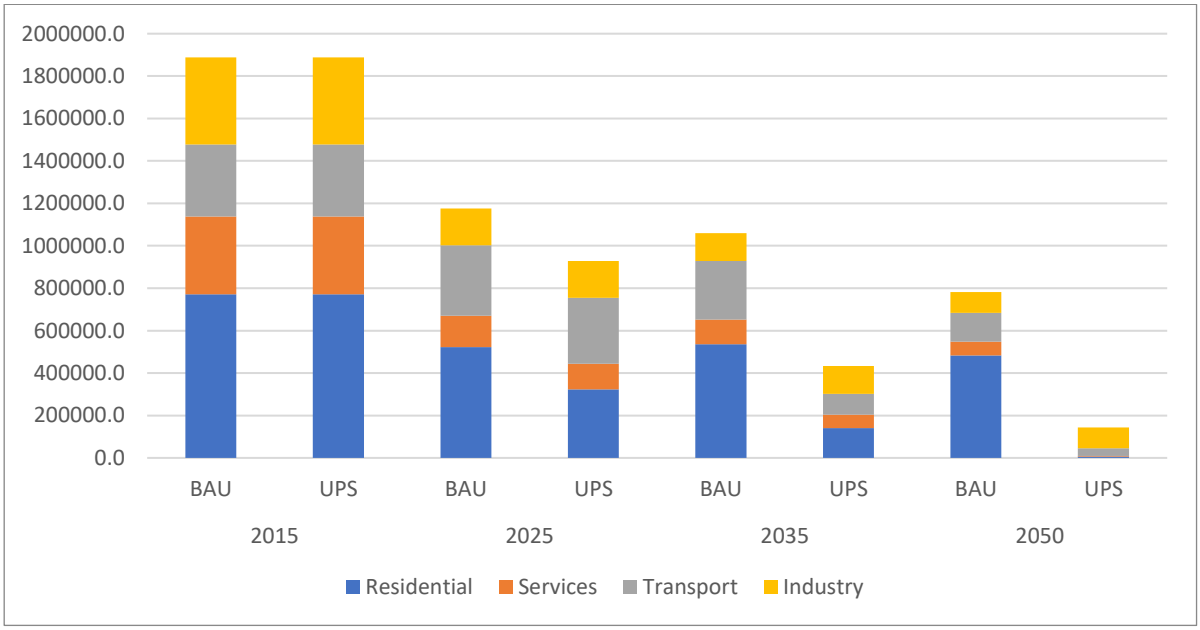
	NO_2				PM_{10}				$PM_{2.5}$			
	2015	2025	2035	2050	2015	2025	2035	2050	2015	2025	2035	2050
Current situation	429				336				404			
BAU		344	323	317		281	279	279		51	50	49
UPS		254	222	206		156	136	70		36	32	23

5.3 Impacts on carbon emissions

Figure 5-3 shows the impacts of UPS measures compared to the BAU scenario in terms of Carbon Footprint. The figure clearly shows that the UPS measures have an important impact in particular after 2035 and make the city of Bristol – contrary to the BAU - achieve near carbon neutrality in 2050.

The largest differences between UPS and BAU are found in the built environment sector, where the UPS measures contrary to BAU lead to almost zero emissions in 2050 as a result of e.g. the introduction of district heating. In order to achieve these emission reductions, also a change in the behaviours of citizens towards a higher share of renewable-based heating and the replacement of individual wood based heating must be promoted and supported.

Figure 5-3 Carbon emissions of UPS scenario compared to BAU (tonnes of CO_2-eq on life cycle)



5.4 Impacts on costs

Table 5-2 gives a qualitative estimate of the cost of the measures in the UPS scenario versus the BAU. More detail on the method applied can also be found in Annex C. We distinghuish

between estimated monetary costs to citizens, costs for government/ city council (no distinction is made between different levels of government) and a net total cost to society, summing up both. On top of that, for an exact calculation of benefits also the indirect benefits of health improvement of citizens (saved public health costs) have to be taken into account. This was beyond the scope of the ClairCity modelling.

In total, net monetary cost effects of the 11 UPS measures vary substantially and will sometimes result in additional costs and other times in net benefits for citizens and for government. Exact costs will also depend on how measures are designed in detail. Further detail of the assumptions made is given in annex B. The annex also gives an order-of-magnitude cost estimate of car user costs, car charging revenues and bus subsidies in the UPS compared to the BAU scenario.

However, the overall balance of direct costs of all measures in the citizens' UPS scenario together suggests that a cost effective execution of the UPS for citizens and city council / government is very well possible, as measures with a net direct cost to society can be balanced by measures with net revenues. This balance would be even more positive if also the indirect health benefits of improved health of citizens would be added.

Table 5-2 Estimated cost impacts of citizen measures that are part of the UPS scenario in Bristol

#	Policy measure	Citizens	Government	Society
1	Ban polluting cars	-	0	-
2	Cheaper Public Transport	+	--	-
3	Cleaner buses	0	-	-
4	Walking & cycling	n/a	n/a	n/a
5	Charge polluting vehicles entering the city	-	+	0
6	Reduce private car road space	n/a	n/a	n/a
7	Improve energy efficiency in housing	+	0	+
8	Promote electrical vehicles	+	-	-/0/+
9	Increase solar and wind	+	+	+
10	Property developers to consider air quality and climate change	n/a	n/a	n/a
11	Spread economic opportunities across the city	n/a	n/a	n/a

(+) assumed net positive effect/ benefits for target group; (-) assumed net negative effect / costs for target group; n/a effect of measure cannot be assessed

The assumed cost effects per measure are explained in more detail below:

1. Banning polluting cars leads to early scrappage of the existing car fleet, and hence to a loss of capital for private owners (-). The measure is assumed to be cost neutral for government (0)[21], leading to an overal net negative cost effect on society (-).
2. Cheaper public transport is operationalised in the UPS scenario as a higher subsidy for buses to be provided by government (--). This measure leads to a cost decrease for citizens (lower fares) (+), yet at a greater expense for the government as incremental model shift to public transport is assumed to require a larger subsidy and also conincides

[21] Contrary to an active scrappage scheme by government, which would lead to net costs for government

with a drop of government income from other alternatives (i.e. cars). The overall societal cost effect is therefore considered to be negative (-).

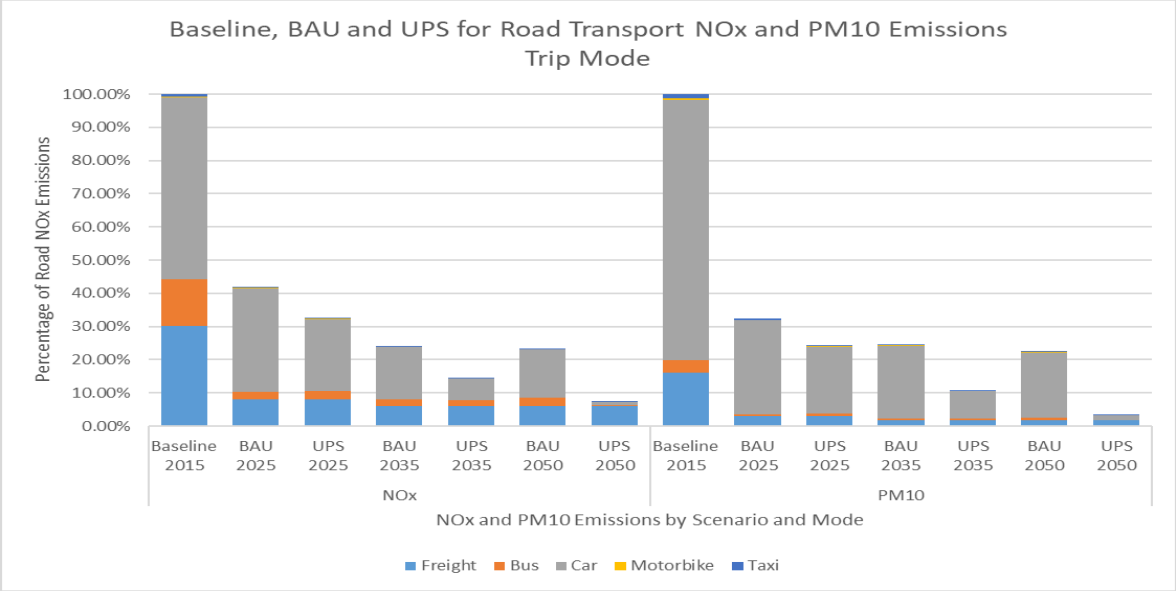
3. Cleaner buses require extra investment at a cost to the government (-) without a cost effect on citizens (0), leading to an overal net negative cost effect on society (-)[22].
4. The cost impact of stimulation of walking and cycling cannot be assessed without extra information. When assuming a reallocation of the (fixed) investment fund in infrastructure (i.e. from road for cars to infrastructure for walking and cycling), there is no extra cost. When assuming an aggressive investment strategy in new walking/cycling infrastructure, this measure would come at an (extra) cost to the government. As a consequence, we did not consider this measure to have a direct measurable cost effect.
5. A vehicle emissions based charging scheme generates revenue for the government (+) at the expense of the citizen (-). The effects are assumed to compensate each other at societal level (0).
6. Same as [4]
7. Though requiring an upfront investement, on the long term energy efficicency is leading to cost benefits for citizens (+), as the initial investment cost will be offset by lower fuel cost, leading to a net benefit for citizens. We assume only private housing is affected, so no cost impact on government (0), leading to a net postive effect for society as a whole (+).
8. The promotion of electrical vehicles (EVs) is assumed to entail a subsidy for electric vehicles at as cost for the government (-), leading to lower prices for EVs, a benefit for citizens (+). The overall societal effect depends on the cost differential between conventional cars and electric cars. Currently, EV's are still more expensive, so an incentive scheme leads to a net negative societal effect (-). This will change in the future as EVs will then become more cost-competitive (-/0/+).
9. Wind/solar investments are leading to cost benefits for citizens on the long run (despite short-term private investments required) (+). They also lead to benefits for government (public investments) (+) as the cost of renewable technology is dropping below levels of conventional technology. This will lead to a net benefit for citizens, government and society as a whole (+).
10. We did not consider this measure to have a direct measurable cost effect
11. We did not consider this measure to have a direct measurable cost effect

5.5 Impacts on citizen behaviour

Finally, the potential impacts of UPS and BAU scenarios on citizen behaviour compared to the baseline situation in 2015 was assessed (see Annex C for modelling assumptions). The analysis of transport modes shows that not only car use is reduced substantially in both scenarios, but also public transport (bus) use decreases since total transport use is declining (Figure 5-4).

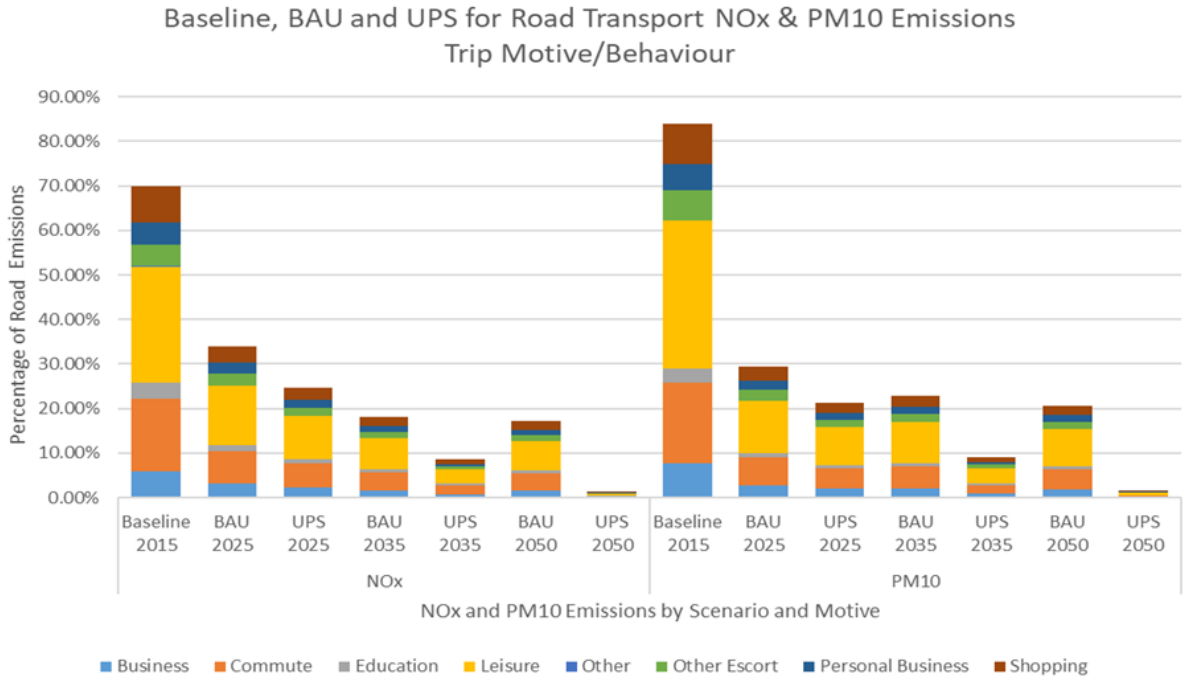
[22] Alternatively, the bus company could invest, with no public costs (0), but then costs would have to be incurred by higher fares, hence net costs to citizens (-). Overall, this would give the same net negative cost effect for society.

Figure 5-4 Road transport NOx emissions based on different transport mode for the Baseline, BAU and UPS (including freight)



Looking more specifically into detailled behavioural practices, in particular leisure and commuting behaviour of citizens are reduced. UPS reduces these behaviours more than the BAU scenario (Figure 5-5).

Figure 5-5 Road transport NOx and PM emissions based on different transport motives/behaviour for the Baseline, BAU and UPS Scenarios (excluding freight)



6 Bristol and other ClairCity cities – Mutual learning

In this chapter, main institutional conditions and barriers for implementing citizen policy preferences are discussed (section 6.1), as well as lessons from Bristol for citizen-inclusive policy making in other cities (section 6.2) and lessons from other ClairCity cities for Bristol (section 6.3).

6.1 Institutional conditions and barriers for citizen-inclusive policies in Bristol

From interviews with stakeholders and policy makers in Bristol, an extensive literature search of Bristol policies and a cross-city comparison of all ClairCity cities, several specific institutional conditions were identified that appear relevant for a successful implementation of citizen-inclusive policies. Political framing, finance, the existing citizen-engagement culture in city policy making and links with other stakeholders and governance levels were identified as relevant categories of institutional conditions, next to a category of 'other' conditions.

Political framing

Compared to other ClairCity cities, in Bristol a strong political framing towards ethnical and income equality was found. This framing in practice has influenced the realisation of citizen-inclusive air quality policies for instance in being used as an argument for having to examine more closely the impacts of a possible clean air zone on low-income citizens. The framing therefore contributes to the voice of all citizens being heard.

Finance

Finance is a crucial precondition for the realisation of policy measures asked for by citizens and policy makers alike – in particular for expensive measures such as infrastructure, public transport improvements and building stock renovations. For Bristol a relatively strong dependence on project-based finance from a national level was found as a potential hurdle for the realisation of policy measures asked for by citizens, as city policy makers have to apply on a case-by-case basis and in a competitive process for national funds. This dependence was recently somewhat mitigated by the installation of a regional development fund,

Citizen-engagement culture

Citizen engagement in policy making is an ongoing process in Bristol, mainly through public consultations. Also, it was found that many NGOs work as an intermediary between citizens and policy makers. The NGOs traditionally have a larger focus on energy and heating rather than on transport, although recently new NGOs with a transport focus are emerging.

Links with other stakeholders and governance levels

Important for Bristol are also the links with other policy levels. While the transposition of EU laws has previously strongly driven UK air quality policies, this driver will cease with Brexit. National level policies directed at climate are also sometimes found impeding local air quality policies, such as a preferential tax treatment for diesel vehicles and support policies for biofuels.

National carbon policies in the United Kingdom, on the other hand, seem to be relatively well developed, with a climate law and institutional mechanisms already implemented for several years. Nevertheless, national policies for energy efficient housing (nearly zero emissions requirements) have been blocked in recent years or have failed with no replacement (Green Deal) – with a Bristol housing stock that is relatively poorly insulated;

Other

The comparison with other ClairCity cities also revealed that local measurements can sometimes be important for the implementation of measures, since they can provide a basis for comparison with modelled emissions and concentrations on a larger scale. In that sense it was noted that the limited number of local measurement stations in particular for PM concentrations can potentially impede implementation of furthergoing policy measures in Bristol in the future.

6.2 Lessons from Bristol for other cities

Bristol has advanced air quality and climate policies and ambitious policy goals. Making policies citizen-inclusive is also already a topic in Bristol policy making. In several respects therefore the city can be an example for other cities wishing to implement similar policies.

Regarding citizen-inclusiveness, for instance Bristol's specific focus on deprived groups can be an example for other cities aiming to include the voice of all citizens and in particular for those with a similar political framing. In the execution of measures aimed for by citizens, it is found that Bristol is also relatively advanced in some areas. Examples are for instance the integration of regional and local public transport – which is an issue in all ClairCity cities – where Bristol has made important steps via the Metrobus system.

Bristol also has a relatively advanced cycling culture which can be an example for other cities, and in turn Bristol could learn lessons from cycling culture in Amsterdam. Its discussion of working place parking levies and congestion charging as instruments contributing to the implementation of measures asked for by citizens is not found in any of the other ClairCity cities either. Finally, Bristol is relatively advanced in preparing a clean air zone for the city and its process towards implementation could be of interest to other cities as well.

6.3 Lessons from other ClairCity cities for Bristol

Bristol in turn could profit from exchanges with several other ClairCity cities that have sometimes more developed renewables, energy efficiency and district heating policies, or that are more advanced in transport policies such as the introduction of clean air and pedestrian zones, parking permit and electrical vehicle policies or the stimulation of active transport (cycling and walking).

Clean Air Zone

Several types of Clean Air Zones and bans of different kinds of vehicles were found in the ClairCity cities. None of the cities had a congestion management or charging system. Evidence from other ClairCity cities suggests that a gradual introduction and some political courage to overcome initial resistance – without going too much against dominant public culture in the city - contribute to a successful implementation of a Clean Air Zone in Bristol.

Textbox 6-1 Relevant experiences from ClairCity for the Bristol Clean Air Zone

- In **Amsterdam**, the CAZ was introduced gradually for different types of vehicles, initially not implementing a ban for private cars. Now that citizens are used to the zones for mopeds, buses, taxis and freight transport and these zones are more or less accepted, also a ban for polluting private cars will be implemented, making the city centre 'emission free' by 2030.
- **Ljubljana** has converted the inner city centre into a pedestrian zone, including a free biking scheme and electrical short-distance taxis. Initial resistance of citizens and business against the pedestrianisation has now turned into massive support as living quality and economic development in the form of tourism have substantially increased over recent years.
- **Genoa** wanted to introduce a clean air zone ban of older Vespas. Strong resistance against this ban from Vespa-drivers in the city of origin of the Vespas meant that the proposed ban was withdrawn. Only recently has it been reconsidered.

Active transport

City modal shift policies towards active transport in ClairCity cities were found to focus in particular on cycling and to consist of a combination of education and awareness, increasing road space for cycling and walking, and a simultaneous reduction of space for cars in the city (e.g cycle lanes, reducing car parking space). The experiences in other ClairCity cities suggest that an effective stimulation of active transport could comprise in initial stages of implementation awareness raising at schools and in later stages large-scale infrastructural adaptations such as bike parkings. Experience from the other ClairCity cities also suggests that stimulating active transport should go hand in hand with making private car access to the city less attractive, e.g. through increasing parking tariffs or introducing and/or reducing the number of residents' parking permits.

Textbox 6-2 Relevant experiences from ClairCity for stimulating active transport

- **Aveiro** focuses on school pupils in stimulating cycling from an early age. While only realised at a small scale now, bringing kids to school by bike and teaching them how to repair a bike at school are central elements in reintroducing the bike as a central means of transport in the city.
- In **Amsterdam**, cycling is already a central part of city transport culture. Cycling traffic lights, bike lanes and paths as well as an integrated train and bike-rent system are already implemented since several years. Providing sufficient bike parkings, reducing car road space in favour of bikes, and spatial planning for short as well as long-distance biking are now central elements in further scaling up of cycling in Amsterdam. Through high parking tariffs for the city centre (7 euros an hour) and reducing the number of residents' parking permits, access to the city by car is made less attractive.

Public transport

Bristol is already implementing large-scale improvements of public transport in the city with MetroBus and MetroWest. The experiences with these projects can be helpful for other ClairCity cities. In addition, the experiences in other ClairCities show that one ticket for all public transport and integration of the public transport ticket with bike rent can be helpful.

Textbox 6-3 Relevant experiences from ClairCity for stimulating public transport

- **Ljubljana** has integrated its city and regional transport, which can now be travelled with one ticket. According to interviewees, commuting by public transport into the city has been much facilitated in this way.
- **Amsterdam** and the Netherlands have a popular integrated train, bus and bike-rent system that can be travelled with one ticket, which facilitates door-to-door transport.

Cleaner transport

Bristol is already engaged in cleaning its bus fleet together with the operators. The public charging network for electric cars is gradually expanded. ClairCity evidence suggests that reserving scarce public parking space for electrical vehicle recharging can contribute to the attractiveness of electric cars.

Textbox 6-4 Relevant experiences from ClairCity for stimulating cleaner transport

- Interviews in **Amsterdam** suggest that the scarcity of parking space in the city has led some car owners to switch to an electrical car in order to be able to park their car at a parking space reserved for electrical car recharging.

Energy measures

Most policy measures in Bristol selected by citizens focused on transport. However, citizens also pointed to possible measures regarding energy. These concerned in particular district heating, renewables and a more energy efficient housing stock.

Bristol is now developing a heat network starting with the inner city centre. Other ClairCity cities, such as Sosnowiec, Ljubljana and Amsterdam do already have substantial experience with district heating and are also considering expansion of their heating networks. All ClairCity cities are working on expanding energy efficiency of their housing stock. Development of rooftop PV is expanding particularly rapid in Amsterdam. Biomass burning is a policy measure that deserves attention in the future, as it is assumed to be positive for climate change targets but has also negative impacts for air pollution.

Textbox 6-5 Relevant experiences from ClairCity for stimulating energy measures

- **Sosnowiec** and **Ljubljana** show that wood and waste burning – partly from the surroundings (Ljubljana) can have strong detrimental impacts on air quality. This has to be taken into account in particular as wood burning is now often seen as a positive measure from a climate policy point of view.

Other measures

Finally, in the ClairCity cities there was a wealth of other best practices or interesting developments found that could provide inspiration for, and contribute to further policy development in Bristol. Two examples are new ways of providing air quality feedback to citizens and engaging citizens in air quality measurement. Also, in all cities it was found that NGOs are a very important intermediate in engaging citizens. Hence, maintaining good relationships with, and support for these NGOs seems to be an important way to stimulate citizen-inclusive policies.

Bristol in turn could inspire other cities for its specific attention to deprived groups in air quality and carbon policy making and for its discussion – like in other UK cities – about a working place parking levy. The latter was not found to be part of the policy discussion in any of the other cities, while such a levy could be one of a range of policy instruments needed to solve the crucial question of financing future measures for citizen-inclusive policies.

Textbox 6-6 Relevant other experiences from ClairCity for air quality and carbon policies

- **Sosnowiec** provides real-time air quality information to citizens through the electronic transport information system in the city. In this way, awareness of changes in air quality in the city is increased.
- In **Amsterdam**, there exists an active network of citzens that measure air quality at home with amateur equipment. These measurements supplement the official air quality measurements in the city

7 Citizen-inclusive air quality and carbon policies in Bristol: Conclusions and recommendations

This chapter outlines the main conclusions of the ClairCity citizen engagement process and analysis in Bristol. Section 7.1 first provides main conclusions, section 7.2 gives the main recommendations for future policy making in Bristol.

7.1 Conclusions

In ClairCity, citizen-inclusive policy making was interpreted as to consist of three main activities: analysing the detailed current behaviours of citizens, asking them about their preferences for their own future behaviours and asking them about their preferred city policies for the future. Preferred policies of citizens were discussed with policy makers, quantified and assessed for their impacts in three different ways: regarding emissions and concentrations of CO_2 and air pollutants, regarding health and regarding costs. Institutional conditions and barriers for implementing citizen measures were examined and compared with experiences in other ClairCity cities. The main conclusions of all these activities are discussed below.

7.1.1 Current city policies in Bristol

Wideranging policy measures are required to further improve air quality and reduce carbon emissions in Bristol.

Air quality and climate policies are currently high on the political agenda in Bristol. For air quality the clean air zone is the most prominent topic, whereas for climate the declared 'climate emergency' by the Mayor and the announced action plan to address this emergency are a priority. In both policy areas, substantial further emission reductions are required: NO_2 legal limit values are still exceeded in several places, whereas PM emissions – despite being within legal limits - are exceeding WHO guideline values. There is a local measurement network in Bristol, but measurements of PM are limited. For CO_2, there are no legal requirements on a local level, but the Mayor has announced that Bristol should become carbon neutral by 2030.


Bristol plans to become carbon neutral by 2030

Decision gives city the most ambitious emissions targets of UK's core cities group

Hence, in both policy areas in the years to come many policy measures have to be taken that will also impact the daily lives of Bristol citizens. Several policy plans already outline the main directions and details of planned policies. The city is also in touch with citizens through public consultations and sometimes on a project basis. Nevertheless, neither public support for the policy plans nor possible alternatives preferred by citizens are regularly and systematically assessed.

7.1.2 Current behaviours of citizens in Bristol

Current behavioural practices of citizens substantially contribute to air pollution and carbon emissions in the city.

Regarding current behaviours of citizens in Bristol, it was found in ClairCity that transport for leisure in Bristol currently causes far more emissions than commuting. Also citizens with a higher income, women and lower-educated persons generate more emissions through their transport behaviours than their respective counterparts. Further, it was found that there are substantially fewer Black or Minority Ethnic (BME) respondents currently only using a car than white respondents.

For current heating behaviour the differences between gender, ethnicity and education level seem relatively small. One difference is that BME respondendents have some more gas heating (86%) than white respondents (76%).

7.1.3 Behavioural preferences of Bristol citizens for the future

Many Bristol citizens would be willing to change their own transport and heating behaviours as a contribution to ambitious air quality and carbon policies in Bristol.

Regarding behavioural preferences of Bristol citizens for the future, the ClairCity research showed that there is substantial scope under Bristol citizens to change their current shopping, leisure and commuting transport behaviour using a private car into a larger use of public transport or active travel (walking, cycling): for commuting, 75% of the respondents want to use public transport or change to active transport in the future, compared to 54% public and active transport now. For shopping and leisure, 66% wants to use public or active transport in the future, compared to 38% now;

A main stated reason for not being able to change the current behaviour of using predominantly a private car is the current unattractiveness of public transport. Electric vehicles are not yet a popular choice for future and neither is home delivery seen as an important replacement for shopping and leisure transport (only mentioned by 9% of the respondents).

For home heating, a massive change towards renewables is envisaged by the respondents: from 2% now to 62% in the future. Only a very limited number of the respondents (8%) wants to continue using solid fuels. These respondents state either to be not a home owner or to want to use a mix of fuels in the future, of which solids are one. Air quality was not mentioned as a reason not to continue with solid fuel use.

A remarkable finding regarding future behaviour was also that, irrespective of gender, ethnicity and education, all groups of respondents envisage to use more public transport and to cycle more, but to walk less in the future. BME respondents generally have fewer cars at present, but a higher share than white respondents want to continue using a car in the future.

Higher educated respondents are using less cars at present and more often want to change to public or active transport in the future than lower educated respondents;

For heating behaviours, differences between gender, ethnicity and education are less pronounced, although some more BME respondents are currently using gas and less want to change to renewables (but still a large majority).

7.1.4 Policy preferences of Bristol citizens for the future

Many Bristol citizens support more ambitious air quality and carbon policies in the city. Policy makers confirm overall implementability of the preferred policy measures of Bristol citizens.

In the ClairCity engagement process, it was found that many Bristol citizens support more ambitious air quality and carbon policies for the future. Measures that were most frequently mentioned covered a wide range of transport and energy policy measures relating to the clean air zone, stimulation of active travel and public transport as well as to energy efficiency and renewables. More general measures frequently mentioned spatial planning, work related issues and awareness building.

Overall, it was found that the general policy preferences of citizens align strongly with policies that are already commited to in the city, but that citizens ask for a faster or more ambitious implementation of measures. Also, it was concluded that a successful implementation of the citizen measures requires a multi-stakeholder process, which includes various levels of government, business as well as citizens.

The policy preferences of citizens were dicussed with Bristol policy makers in order to provide more detail about their implementation possibilities. Subsequently, the measures were quantified and modelled for their impacts in a ‘Unified Policy Scenario’ (UPS). These were compared to a business-as-usual scenario comprising policy measures implemented and planned until 2015 (BAU).

7.1.5 Consequences of the policy preferences

If implemented, the citizen measures could result in substantial and cost-effective carbon emission reductions, air quality improvements and health improvements for citizens compared to a business-as-usual scenario taking 2015 as a baseline.

It was found that the UPS scenario leads to a substantially faster compliance with legal NO_2 limit values and larger reductions of PM_{10} and $PM_{2.5}$ concentrations than the BAU scenario. However, even in the UPS scenario, in particular $PM_{2.5}$ concentrations would require further attention - as there would remain significant exceedances of WHO guideline values in 2050. Main source of these is the burning of solid fuels in the residential sector, in particular biomass. For carbon emissions, in particular after 2035 the citizens’ scenario would lead to substantially lower emissions than the BAU scenario. Contrary to the BAU scenario, the UPS scenario would also lead to near-zero carbon emissions in 2050;

In addition, it was found that the UPS scenario could reduce the number of premature deaths by about half compared to the BAU scenario. A qualitative assessment of the costs of UPS measures further suggested that a cost-effective execution of the policy measures proposed

by citizens could be very well possible, since measures with an assumed net cost to citizens and government could be compensated by others that are likely to have a net profit.

7.1.6 Institutional conditions and barriers for implementation of citizen policies

Political framing, finance, relationships with other policy levels and other institutional conditions influence the implementation of citizen-inclusive policies in Bristol. Mutual learning with other cities could contribute to a successful implementation of such policies.

ClairCity research pointed to several specific institutional conditions in Bristol that were considered to be relevant for a successful implementation of the preferred policy measures of Bristol citizens. Political framing of policies towards ethnical and income equality for instance influenced implementation of the clean air zone. Also, the organisation of finance with project money to be applied for on a national level in a competitive process has an impact on the continuity of long-term investments to be made. In recent years, the installation of a regional investment fund somewhat mitigated this condition. Further, it was found that there are a relatively limited number of local measurement stations for PM concentrations, although more are planned. Finally, it was found that NGOs are a key intermediary between citizens and policy makers in Bristol, therefore their influence in expressing citizens' views should be regarded as important. Most NGO activities were found to focus on energy and heating rather than on transport, although in recent years more NGOs seem to focus on transport as well.

Important for Bristol is also that while the transposition of EU laws has previously strongly driven UK air quality policies, in the future this will no longer be the case. In addition, national climate policies sometimes seem to have negative impacts on local air quality, as is the case with a preferential tax treatment for diesel vehicles or support for biofuels. UK carbon policies in the United Kingdom seem to be relatively well developed in relation to EU targets, with a climate law and institutional mechanisms already implemented for several years. Nevertheless, national policies for energy efficient housing (nearly zero emissions requirements) have been blocked in recent years or have failed with no replacement (Green Deal), leaving the Bristol housing stock relatively poorly insulated.

Compared to other ClairCity cities, Bristol seems advanced in developing an integrated regional/city public transport system. It also has a relatively developed cycling culture. On a financial level, Bristol is discussing finance instruments like a working place parking levy and congestion charing that are not found in other ClairCity cities. The city also has made significant progress in preparing a clean air zone for the city. These experiences could be useful for the other ClairCity cities for planning and implemenation of their future air quality and carbon policies.

Bristol in turn could profit from exchanges with several other ClairCity cities that have more developed renewables, energy efficiency and district heating policies, or that are more advanced in transport policies such as the introduction of clean air and pedestrian zones, parking permit and electrical vehicle policies or the stimulation of active transport (cycling and walking).

7.2 Policy recommendations

The analysis of current behaviours of Bristol citizens, their preferred future behaviours and their preferences for future behaviours together with an impact and institutional analysis leads to policy recommendations that can tailor policies to current behavioural practices, preferred future behaviours and preferred future policies. Such policies could also address the institutional barriers found and facilitate experimentation and mutual learning.

7.2.1 Tailoring policies to current behavioural practices and preferred future behaviours

Detailed analysis of current and preferred future behaviours of citizens can be used for tailored policy measures and communications. Taking into account that the ClairCity engagement process did not reach a fully representative sample of the Bristol population, nevertheless several detailed practices were found that could be addressed by specific policies.

- **Intensify cooperation with destinations of leisure and shopping transport, and stimulate local leisure and shopping**

Leisure and shopping transport in Bristol were found to cause more air pollution and carbon emissions than transport for commuting. An intensified cooperation with destinations of leisure and shopping transport, such as retailers, shopping malls, sports clubs, theaters or cinemas in order to make them promote active transport (walking, cycling) for reaching their venue could therefore also have a significant impact on reduced pollution. In addition, the barriers that citizens encounter for changing their behaviour, such as current limitations of public and active transport infrastructure, should be addressed. In addition, local leisure and shopping options should be stimulated.

- **Promote alternatives to private car use, address car use as a status symbol and make public transport more attractive and feasible.**

Women and people with lower educational attainment are more likely to use a car as their only means of transport. Also Black and Minority Ethnic (BME) Groups were found to use disproportionally less cars than other parts of the Bristol population. However, in the future they want to travel by car more than other Bristolians. Promotion of alternatives to private car use (including also car sharing), addressing car use as a status symbol and making public transport more attractive could be measures that contribute to these aims and in additon could offer new opportunities to citizens. Such measures should be part of a whole city transport plan that shows that a private car is not the only feasible way to get to work, shops, leisure destinations or caring responsibility appointments.

- **Facilitate cycling and promote walking**

It was found in the ClairCity analysis that Bristol citizens want to cycle more, but walk less in the future. Therefore cycling should primarily be facilitated, e.g. by dedicated spatial planning

that includes infrastructural measures such as cycle lanes and paths in order to make cycling safer, cycling traffic lights and bike parking facilities or by better integration with public transport via for instance a train-bike rent system. The attractiveness of walking on the other hand could be promoted by awareness campaigns that instance stress its health benefits or by more extensive pedestrian zones that also include electrical mini-taxis for residents and free bike systems.

- **Support local PV implementation and pay attention to mixed effects of biomass burning**

The ClairCity engagement process showed that many citizens want to change to renewables for home heating in the future. Dedicated spatial planning, promoting the expansion of national support for rooftop solar PV, increasing rooftop solar on public buildings and supporting local citizen cooperatives for renewables generation could be measures – for instance to be included in a future 'City Leap Prospectus' - that contribute to a more rapid implementation. In addition, attention should be paid to the mixed aspects regarding climate change and air quality of biomass burning, for instance by awareness raising measures or public debate.

7.2.2 Tailoring policies to citizen policy preferences for the future

- **Make citizen support for current and planned policies more explicit and accelerate policy implementation**

TheClairCity analysis revealed that many citizens support air quality and carbon policies in the city that are already in place, but ask for more ambition and speed in their implementation. It was also shown that a faster and more ambitious implementation would have significant benefits in terms of CO_2 emissions, pollutant concentrations and health of citizens. Policy makers involved in the engagement process generally considered these citizen policy preferences as feasible. Communication of the citizen support for existing policies therefore could contribute to a wider acceptability of policies. Further support could be created by making the year-by-year planned implementation of long-term policy ambitions as explicit as possible in communications and by examining where the implementation of planned policies could be accelerated.

7.2.3 Addressing institutional barriers and mutual learning

- **Compensate costs of required infrastructural measures by local financial instruments and communicate the need for such instruments.**

Finance is a key institutional condition that determines the possibilities for implementing citizen-inclusive policies. Policies in Bristol are sometimes hindered by discontinuity of national funding. Compensating costs of infrastructural measures by generating local funding through e.g. parking fees and permits, congestion levies or workplace parking levies could mitigate this hurdle. As such financial measures are likely to be less popular with citizens, their need should be properly communicated and possibilities to reward behavioural change (e.g. bike parkings and rentals offering discounts at local shops) should be examined.

- **Adopt an even stronger health framing of policies and support policies by more public and citizen measurements.**

Health is one of the motives mentioned by Bristol respondents to change behaviour. Science also increasingly supports the health benefits of lower air pollution and more active travel. It is therefore suggested to support the existing equality framing of policies with a strong health framing of air quality policies in order to contribute to its appeal to all citizens. In addition, more public measurement stations and 'citizen-science' air quality measurements could contribute to further awareness and add local evidence to national modelling results. Finally, it is considered important to maintain good relationships with NGOs as an important intermediate to hear citizens' views.

- **Look for low-barrier, but long-term relationships with other cities to encourage experimenting and mutual learning.**

Institutional conditions in the six ClairCity cities were compared. All cities struggle with similar implementation issues for citizen-inclusive air quality and carbon policies as Bristol. It is therefore recommended to maintain a regular and long-term exchange with a diverse network of cities. Since cooperations are often dependent on project funding, in particular low-cost and little-effort opportunities for regular exchange beyond such funding (e.g. video-conferencing, informal networks) should be examined.

- **Intensify cooperation with other partners inside and outside the city in order to implement citizen-inclusive policies**

Bristol City Council is only one of the parties that is needed to successfully implement citizen-inclusive policies in the city. Stable long-term relationships with partners inside and outside the city are therefore needed to realise the actions suggested by Bristol policy makers in an implementation plan for citizen-inclusive policy making:

City:
- Integrated infrastructure planning together with WECA, including multimodal hubs
- Renewables and energy efficiency targets and implementation (via Bristol Energy as a municipality owned social enterprise?), using the generated energy as much as possible locally
- Parking permits, workplace levy and congestion fees to fund city council measures
- Electric taxi charging points to be installed
- Reallocation of road space in favour of public transport, walking and cycling, could also include closing the city centre for cars and extending resident parking space by closing roads
- Segregation of cycle lanes, loan bikes, free bike training, subsidies for electric bikes, BCC cycle/walking group and general promotion of active travel on foot or by bike

Region / WECA:
- Integrated regional transport planning stimulating P&R, train and bus, regional bike and (tourist) walking routes (including lighting)
- Integrated spatial energy planning (e.g. for renewables and district heating)
- Tendering for bus companies' licenses

National government and Europe:
- Promote health as a driver for transport policy
- Consistent long-term policies away from car use, including subsidising bus travel for under-18s and a higher fuel duty, scrappage schemes and mobility credits
- Reintroduce feed-in tariffs, spatial planning to favour wind farms
- Cross-border grid connectivity and learning from best practices
- Funding for rail electrification and for CAZ schemes

Business:

- Contribute to funding through work place parking levy, subsidising sustainable staff travel
- Promotion of alternative travel for staff through e.g. car clubs, better on-site facilities (showers, lockers and bike racks), restricting on-site car parking, cycle to work schemes, active travel champions
- Voice for change e.g. cycle business charter, flexible working hours, route planning
- Cleaner fleets, micro-freight consolidation, go-low pilot, incentivise EV fleet cf. Uber in London
- Invest in commercial PV on rooftops

Civil society and citizens:

- Need for ownership of problem and solutions – communication is key, voting, empowered & educated citizens, believe they can make a difference
- Lobby local councils and government for improvements, mobilise in local community groups
- Messaging and consultation re banning cars, encouage safe culture, discourage anti-social behaviour on public transport
- Invest in green investment banks

Annex A. The ClairCity process in detail

This annex explains in more detail the ClairCity process and the positioning of this 'Bristol policy package report'.

The ClairCity project consists of three phases and seven work packages (Figure A-1):

Phase 1: Establish the Baseline Evidence

The primary aim of Phase 1 is to understand and quantify the baseline status of air quality, carbon emissions and related public health in our cities. Phase 1 is achieved with the following main activities:

1. **Benchmarking behaviour**: Understanding the local demographic data and establishing the citizen practice-activity data to feed into the air quality models.
2. **Quantify the baseline**: Quantification of the baseline air quality emissions and concentrations, carbon emissions and public health impacts in a city.
3. **Assessment of Policy**: Collation and analysis of current policies (local, regional, national and EU) that influence the city.

Phase 2: Citizen and Stakeholder Engagement & Co-creation of Scenarios

Phase 2 has three key aims: (1) understand citizens' current behaviours, practices and activities, (2) enable citizens and stakeholder to co-create and visualise their low carbon, clean air, future city and (3) raise awareness of the environmental challenges and their solutions. Phase 2 utilised evidence from Phase 1 to help frame and inform the engagement activities. Phase 2 is achieved with the following main activities:

Citizen and stakeholder engagement & co-creation

1. The ClairCity Delphi method uses citizens as local experts to generated qualitative evidence of their entrenched behaviours and what enabling interventions would allow them to act and behave differently in future (WP4).
2. The Mutual Learning Workshop brings citizens and stakeholders together to debate the challenges facing the city and co-create policy interventions for cleaner, healthier futures (WP4).
3. The ClairCity Skylines Game 'crowd-sources' the public perceptions and public acceptability of difference policy interventions (WP4)
4. Citizens and stakeholders come together in a Stakeholder Dialogue Workshop to review and debate the Delphi, Mutual Learning Workshop and ClairCity Skylines evidence and co-create scenarios for a low carbon, clean air, health futures (WP4 and WP7).
5. The scenarios generated in the Stakeholder Dialogue Workshop go through a rapid quantification step (WP5) and are then returned to the local citizens/stakeholders to discuss in a Policy Workshop (WP6) and to agree a single Unified Policy Scenario (WP7).

Public Engagement & Awareness: Additional awareness raising activities are also implemented across the project in each city (WP4). These include:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689289

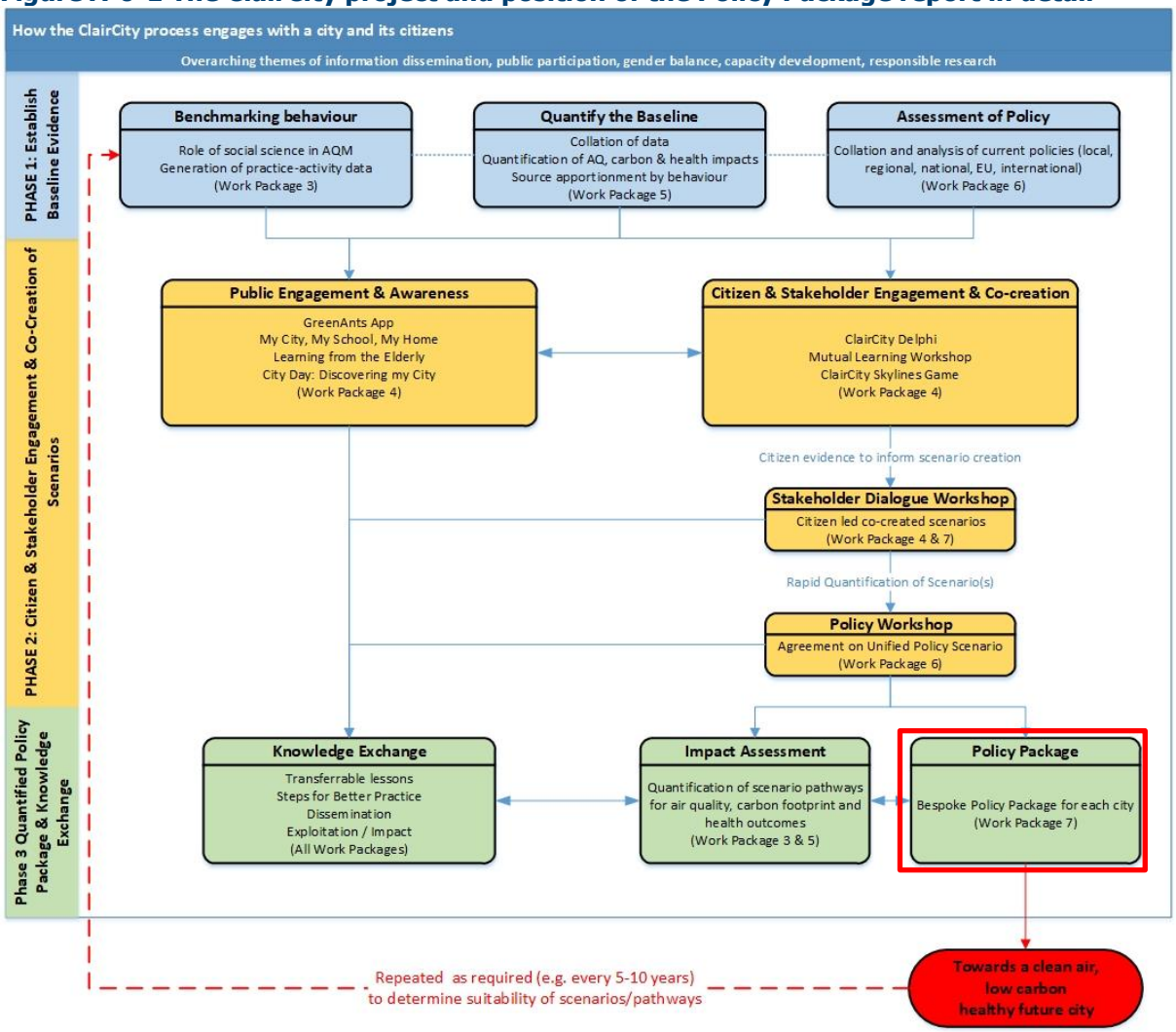
6. The GreenAnt App which allows citizens to become a citizen scientist and monitoring their transport activities, emission generation and exposure using mobile GPS data.
7. The School Competition: My City, My School, My Home engages young people in the air quality, carbon and public health debate utilising an online platform for the students to select the interventions that influence their housing, transport and use of resources in order to be able to design tools for change towards smart consumption, reduced emissions and healthy lifestyles.
8. Learning from the elderly filming activity engages the older, potentially vulnerable, community to talk about the changes in their city, their personal mobility and the steps they take to minimise their exposure to air pollution.
9. The City Day: Discovering my City helps disseminate the final project results and provide healthy and smart tips to promote non-motorised mobility of citizens by highlighting availability and benefits of walking and cycling routes in the city.

Phase 3: Quantified Policy Package & Knowledge Exchange

The primary aim of the final Phase 3 is to collate the evidence and lessons learned from Phase1 and Phase 2 to generate a quantified, bespoke, citizen-led and citizen-inclusive policy package for each city. Phase 3 is achieved with the following main activities:

1. **Knowledge Exchange**: Collation of transferrable lessons and steps for better practice based on the experiences of the ClairCity project to inform other environmental and public health practitioners (WP3, WP4, WP5, WP7).
2. **Impact Assessment**: Rapid quantification of the scenarios generated in the Stakeholder Dialogue Workshop (WP4) and detailed impact assessment of the final Unified Policy Scenario generated in the Policy Workshop (WP6). This quantification includes an assessment of the source apportionment by behaviour or purpose; air quality emissions and concentrations, carbon emissions, air pollution related health impact and interventions cost analysis (WP5).
3. **Policy Package**: Development of a bespoke Policy Package for each city drawing together the findings from across the whole project (WP7).

Figure A-0-1 The ClairCity project and position of the Policy Package report in detail



Annex B. The ClairCity citizen engagement process

The citizen engagement process developed by ClairCity consisted of policy focused activities and of awareness raising directed activities. These are discussed in Annex A. For a more comprehensive overview and analysis, the more detailed ClairCity reports on each activity can be consulted on the ClairCity website: http://www.claircity.eu/reports/

B.1 Policy focused engagement activities

Three main engagement activities directly informed the policy workshop and the policy recommendations: the Mutual Learning Workshop, the Delphi process and the Skylines game.

Mutual Learning Workshop

The Bristol Mutual Learning Workshop (MLW) engaged with a variety of stakeholders from different sectors and organisations (Table B-1).

Table B-1 Participants in the Bristol Mutual Learning Workshop

Stakeholder group	Number of participants	Organisations
Industry (including transport)	6 (18%)	First Bus, ARUP, Eunomia, AQC, UHB
Science/Academia	9 (26%)	UWE, University of Bristol, REC
Civil/Civic Society (including NGOs/Partnerships and Networks)	11 (32%)	Bristol Green Capital Partnership, Sustrans, RADE, Bristol Walking Alliance, KWMC, SERA, Ambition Lawrence Weston, Bristol Health Partners, At Bristol, Bristol Energy Cooperative
Policy Makers (including councilors and public servants)	7 (21%)	Bristol City Council, South Gloucestershire Council
Investors/Business sector	1 (3%)	Cater Business Park

In the workshop, the participants created in different table groups a poster for 2050 with their vision for a “clean air” healthy zero-carbon Bristol related to their organisation.

The participants from the At-Bristol Science Centre focused on operational and engagement practices. Their vision included a carbon neutral site, the majority of parking spaces for electric cars charged from a zero-carbon supply, and visitor numbers having increased with visitors arriving on foot, bike and public transport. The organisation will be a hub bringing all stakeholders together and engaging people from across Bristol.

The vision of the participants from the First Bus Group included half to three quarters of their fleet running on gas or cleaner energy, producing cleaner engines through working with their suppliers and reducing waste oils. In addition, their organisation would be powering their infrastructure using solar energy, encouraging people to use public transport and working with schools and universities to change behaviours with regards to emissions.

The participants from Bristol Energy Cooperative focussed on technical and energy planning features in their vision. All new houses would be built to passive house standard. Bristol would generate enough renewable energy to power itself, utilities would be publically or

locally owned and the Avonmouth Port would be a centre for renewable energy excellence. In addition, residents would feel empowered to control their own energy use.

In the workshop challenges and barriers for realising the 2050 were also identified by the participants. These can broadly be categorised as: political; business/market; housing; citizen challenges; cultural; housing.

In the political category, many comments identified lack of government funding or government inaction as barriers along with “short-termism” and business as usual approaches. Challenges for citizens were noted around a lack of options in terms of the “school run”, flexible working hours and access to public transport. In terms of culture, ignorance of evidence and acceptance and social expectations around the conflict between sustainability and current travel behaviours were raised. Transport challenges and barriers focussed on the lack of a quality alternative to car use and the inefficiencies of public transport. For housing affordable and efficient housing for a growing population was highlighted. Business/market challenges identified the need to think about alternatives to government spending to pay for training and new technologies.

Delphi process

The Delphi process consisted of two broad survey rounds of Bristol citizens and a series of face-to-face events, concluded with a ‘Stakeholder Dialogue Workshop’ (SDW). The surveys and events resulted in the following participation:

- 500 responses to Round 1 survey: a mix of open and closed questions presented online and face-to-face by interviewers and in self-completed forms

- 230 responses to Round 2 survey: a mix of open and closed questions presented online

- Four events in Barton Hill, Bishopston, Knowle West and Bradley Stoke: face-to-face events facilitated by ClairCity staff, with groups of between 5 – 35 citizens at a time. (Reported in ClairCity Deliverables *D4.2* and *D4.3*.)

Bristol Round 1 survey received 500 respondents, out of a city population of 428,100. The respondents were 57% female.
Our representation of age for the adult population was roughly approximate, with 29% over the age of 51 compared to 28% of the city population, and 11% of our respondents aged 16-24 compared to 15% of the city.
The average education level of our respondents was less representative; our sample is highly educated compared to the city average – 58% of our dataset have a degree or higher, compared to 32% of the general population. Only 1% of our respondents have no qualifications, compared to 20% of the city population.
15% of the city population are BME (Black and Minority Ethnic), and 13% of our respondents in Round 1 also identified themselves as BME. Within these categories, we had slightly fewer “Black or Black British” (3% compared to 6% of the city) but more “Mixed (White & Black Caribbean, White & Black African, White & Asian, Other mixed)” (4% compared to 3% of the city).

ClairCity Bristol made extra efforts to visit venues which are the community hubs for under-represented groups. These included Eastville, an area predominantly frequented by people from Black and Asian groups, and Southmead and Knowle West, areas which are frequented by people from lower socio-economic status groups. The surveys were then conducted in an face to face oral format. Extra communication efforts were also made to use the channels which under-represented groups in Bristol use. These included BCFM radio station, the Green and Black ambassador scheme and radio show, and the Bristol Older People's Forum and Newsletter.

The Bristol Stakeholder Dialogue Workshop, intended to work out in more detail the citizens' measures, enablers and constraints before handing them to policy makers for a discussion and further specification in the policy workshop, was attended by 21 persons. The attendants discussed the priority policy measures of citizens that were derived from the questionnaires in the Delphi process (Table B-2).

Table B-2 Example policy discussions in Stakeholder Dialogue Workshop (selected policies)

Policy	Enablers/policy	Constraints
Ban/phase out most polluting vehicles (not just charge more)	Clean delivery services - increase no of services to reduce private car use (2025) Not just a clean air charge - congestions charge - not applying to Evs. Taper scheme with lots of forewarning of increase in ban/charging (2023) Create sharing economy around car use & ownership - building on car clubs - + local leadership and funding for whole city/area scheme (2021) Apply for mitigation funds from WECA for local scrappage scheme (2020) Start charging most polluting vehicles (2020) (Older vehicles not euro 5)	Small businesses/car drivers low income - concern about equality of banning cars Inequalities of any scheme - businesses and delivery drivers Financing - sunk cost of vehicle ownership Lack of national budget for vehicle scrappage scheme Big companies will potentially invest in increasing clean delivery services but not gig economy (e.g. deliveroo)
Make buses cleaner and greener	Low emissions grant for bus services increased to higher level than bus service operator grant.	
Cheaper public transport	Increase frequency & reliability of services(2023) Changing terms of rail franchising (if not nationalised) (2020) WECA demand a transport authority (2019) WECA Transport Authority created (2020) Reopen rail freight lines for passenger services. Review Social Value Act so it includes environmental and health costs and is applied to all WECA decisions. (2019)	Rail franchising system Commerce bus network model Unreliable and infrequent services stop people switching. Congestion an issue even if lots of evs & cleaner PT - people don't use service & can't reduce price Network rail business case Cost/benefit appraisal system does not allow for non-financial costs such as on health/environment
Create good alternatives to car use - walking & cycling infrastructure	Create safer cycling environment through lane segregation, reduced parking and public awareness campaigns Guaranteed annual budget for active travel infrastructure that is relative to funds given to road space and public transport (2020) Strategic review of road travel space in Bristol to increase space for cycling (2019) - examine parking, and use of smaller roads as designated cycle route as part of phased ban on polluting vehicles.	Money for cycling is only available if linked to work journeys Reducing road space could increase congestion Space conflict between walking/cycling, public transport and parking Complaints when you take car space away Bristol Streets Zero budget for walking and cycling

Skylines Game

ClairCity Skylines is a 'serious game', designed to capture citizen decision making about issues in their city, where players travel between areas representing a city's environment, economy and its citizen's health & satisfaction, collecting ideas for policies to enact to achieve a low carbon, clean air, healthy future before 2050 (Figures B-2 and B-3).

Figure B-2: Google Play Store listing

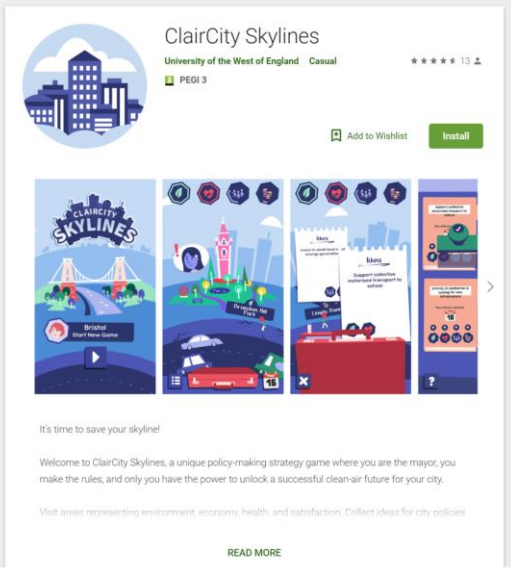


Figure B-3: Six playable cities completed

Bristol was the first of the six partner cities to to be included in the game, and launched in April 2018. An updated, localised version of ClairCity Skylines was launched in Amsterdam following a significant database upgrade in November 2018 based on the findings of the Bristol pilot. The upgrade allowed the final 4 cities/regions to launch simultaneously in Ljubljana, Sosnowiec, Aveiro and Liguria in January 2019, with primary data capture closing at the end of March 2019. The game includes English, Dutch, Slovenian, Polish, Italian and Portuguese localisations for game text, UI and the policy database.

B.2 Awareness related engagement activities

Four activities in the ClairCity engagement process were mainly awareness related: a film competition for the elderly, a 'city day' and the GreenAnts app. The GreenAnts app still has to be launched, but the other activities also indirectly informed the process towards the policy recommendations.

Reason for the focus on young people and the elderly is that ClairCity builds on the WHO Policy Framework and the European Commission's Clean Air Policy Package that promote public health by paying special attention to more vulnerable groups, such as children and senior citizens. The aim is to empower these citizens to better understand the specific challenges and opportunities that their city currently offers and to engage them into moving towards reduced air pollutant emissions and carbon footprints. The project has therefore collected their perceptions and ideas on sustainable lifestyles and a *'better quality of life'* within their city in the future.

Elderly film competition

ClairCity activities with the elderly focused on promoting non-motorised mobility of citizens in Bristol to show the health, environmental and social benefit of active travel. The activity invited older citizens from the cities to tell about their experiences in short films. In Bristol, the filming did not include a competitive element.

Local residents participating in the ClairCity Bristol video project shared a range of thoughts and ideas:

- Older people in Bristol use walking and cycling as efficient modes of transport to get around the city, as well as leisure activities in their own right.
- Walking and cycling are enjoyable, social experiences. They allow people to connect to their surroundings, nature and other people in their community.
- Walking and cycling are important health activities for older people, whether for staying generally fit and active, recovering from injury or managing long term conditions.
- Older peoples' experiences of walking and cycling are varied. Speed, joy and pushing physical limits are part of these activities for older people, not only for younger people.
- Walking or cycling with friends or in a group can help to motivate people, combining a social experience with health benefits.
- Older people walking and cycling recognise that their choices have benefits for the whole community in reducing traffic and congestion, as well as for the person taking the action.
- Older people can experience feeling less safe when walking or cycling related to the time of day, walking alone and experiences of certain areas being more risky. People develop a range of strategies to deal with these issues.
- Many older people identify air pollution as a risk to their health and a negative experience for their community, related to conditions that they suffer and the impact on their friends and families.

City Day

The Bristol ClairCity City Day took place as part of the ALD Automotive Clean Air Zone event on 6th November 2018. This event was run by ALD Automotive as part of national and local conversations in the UK about changing urban transport priorities, charging for transport access in urban areas, electrification of business fleets and increasing use of electric cars. The event was free and took place at UWE Bristol's Exhibition Centre, widely known to the public.

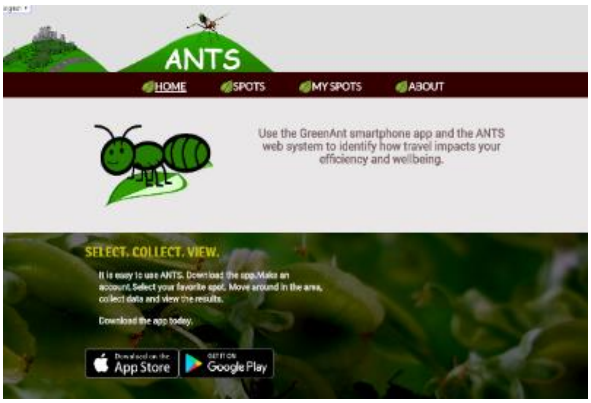
The Bristol ClairCity staff attendance and participation in this event was the culmination of several activities and events to generate "smart mobility tip" videos from older people, with residents discussing their walking and cycling choices and experiences. The videos were shown at the event.

GreenAnts App

Ants is a system identifying how travelling impacts efficiency and wellbeing developed in ClairCity. It consists of:

1. GreenAnt – a smartphone application collecting information about travel patterns using GPS and motion sensors on the phone

2. ANTS - a web tool for analysing and presenting data, from investigated zones.



To use the system, it is necessary to register zones on the web tool named ANTS, where you want to collect data about how people travel. Users can assign themselves to the zone by downloading the GreenAnt smartphone app. When the user is within the zone, route and transportation data will be collected and later stored on the server.

At the moment of writing this report, the rol out of the GreenAnts system in Bristol was not yet completed.

Annex C. Bristol citizen engagement impacts: scenarios and modelling

C.1 Modelling impacts of the citizen scenarios

Impacts of citizen measures were modelled in three steps.

1. **Step 1:** Reproducing the air quality situation in 2015 in a modelling environment ("baseline");
2. **Step 2:** Estimating future emissions in a scenario with existing policy measures in 2015 and model the resulting air quality. This business-as-usual ("BAU") scenario aims to capture the changes in air quality if no further measures are taken, only accounting for changes in the emissions due to policy measures made or committed until the base year and taking into account expected technological and/or behavioral changes;
3. **Step 3:** Estimate future emissions in a 'Unified Policy Scenario' (UPS) with additional policy measures as identified and supported by Bristol citizens. Main assumptions made for quantifying the citizen measures after discussion with policy makers in the policy workshop are given in Table C-1.

Table C-1 Approach for modelling citizen measures in Bristol UPS scenario

Measure	Modelling approach	Impact
1. Ban polluting cars	Progressive ban starting in 2019 with ban Euro 3 and worse diesel (euro 2 and worse for Petrol) and ending in 2030 with a ban of all combustion engine vehicles.	The bans leads to a lower average emission factor of cars compared to BAU (+/- 30% in 2025, factor 2 in 2035, factor 12 in 2050) - in combination with other measures that impact the fleet [8]
2. Cheaper Public Transport	Reduced public transport ticket cost by 50%	Transport demand impact: car: -1.5% / BUS: +32%). The lower public transport price also attracts trips previously done on foot or bike
3. Cleaner buses	All buses comply with EURO 6 by 2025. Assumed is a 50/50% gas-electric share of buses by 2035 and all-electric by 2050	Cleaner buses lower the average emission factor for bus compared to BAU (+/- 20% in 2025, 30% in 2035, negligible emissions in 2050)
4. Walking & cycling	Manual match of values observed in the Netherlands, adding up to a total of 65% with public transport. This means walking and cycling would have the same attractiveness in Bristol as in Amsterdam.	Transport demand impact: car: factor 2 decrease / bike: factor 10 increase
5. Charge polluting vehicles entering the city	Adding 1 GBP to the cost of car trips.	Transport demand impact: car: -35% / BUS: +45%) - combined effect with [6] & [11]
6. Reduce private car road space	Adding 20% travel time to car trips and making public transport trips 20% faster.	transport demand impact: car: -35% / BUS: +45%) - combined effect with measures [5] & [11]
7. Improve energy efficiency in housing	Assumed is meeting the target from City Council reduction targets (-60% on 2035 and -80% on 2050)	Energy consumption of residential decreases accordingly. Combined with measures [9] & [10]

Measure	Modelling approach	Impact
8. Promote electrical vehicles	Assumed is a stronger overall EV-uptake, of which exclusive EV in public fleets could be a component. These higher EV uptake shares correspond to IEA 2030 scenario.	Lower emission factor for car compared to BAU (+/- 30% in 2025, factor 2 in 2035, factor 12 in 2050) - in combination with other fleet effect measures [1]
9. Increase solar and wind	Assumed is meeting the City Council targets (-60% on 2035 and -80% on 2050)	Combined with measures [7] & [10]
10. Property developers to consider air quality and climate change	Combining the growth in the number of dwellings and population with a goal of almost zero fossil energy consumption of new dwellings;	combined with measures [7] & [9]
11. Spread economic opportunities across the city	All commuting distances are reduced to 75% of original	Transport demand impact: car: -35% / BUS: +45%) - combined effect with measures [5] & [6]

Citizen measures that were not modelled due to modelling constraints: awareness, working from home, flexible working hours. Some measures are combined, e.g housing closer to employment, more local shops was modelled as improving equal spread of economic opportunities throughout the city

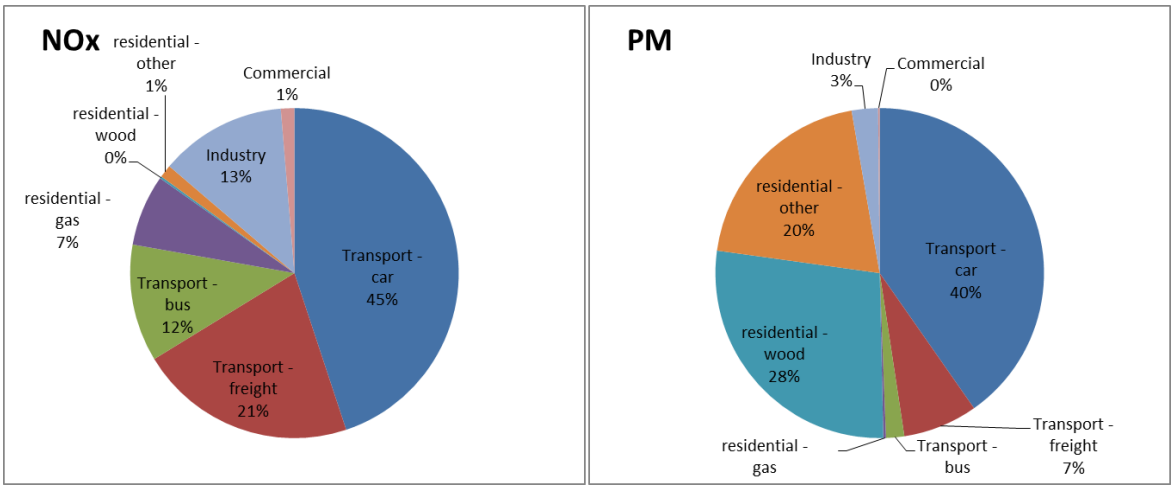
The results of the modelling exercise consist of three parts:

- Results for the situation in 2015 (baseline)
- Expected future with 2015 policy measures implemented (BAU)
- Future with additional policy action (UPS)

C.1.1 Baseline

Figure C-1 shows the emissions by source in the baseline situation (year 2015), for 2 key pollutants: NOx and $PM_{2.5}$.

Figure C-0-1 relative importance of different sectors for NOx and PM emissions



The figure shows that for NOx, transport is the most important source of emissions, accounting for about 3/4th of total emissions. This is due to NOx-emissions from mostly diesel cars, buses and freight vehicles. While emission standards ought to curb these emissions, the legacy of “dieselgate” has caused NOx-emission from transport to stagnate or even rise in recent years. Other sources of NOx-emissions, in particular from industry, have decreased in recent years, thus making transport the dominant source.

For PM, transport is still an important source, though less dominant compared to NOx, accounting for about half of the emissions. Most of these PM-emissions (+/- 2/3) are non-exhaust but related to break and tyre wear and tear and road surface abrasion. Transport exhaust PM emissions have fallen dramatically in recent years as emission standards forced the adoption of particulate filters for new diesel cars. PM emissions from the commercial and industrial sector are negligible, leaving the other half ot PM emissions coming form the residential sector. In particular wood burning for heating (functional as well as recreational) accounts for about 28% of total PM emissions.

Assessment of air quality for the baseline

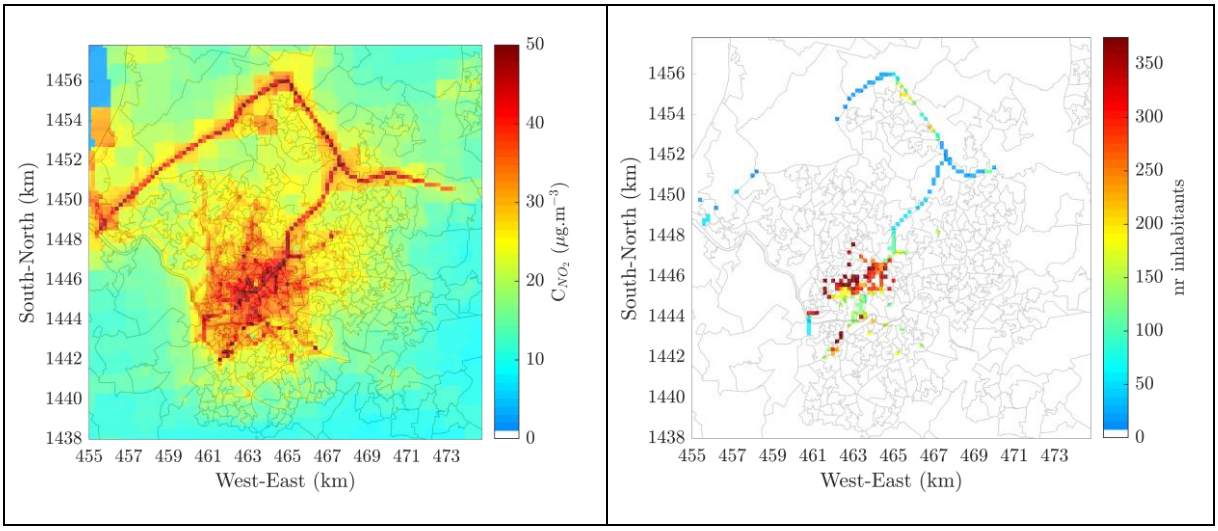
The second-generation Gaussian model URBAIR was setup and run at an urban scale for the computational domain over the urban area of Bristol. The baseline simulations were performed for the full-year using the meteorological vertical profiles from the WRF-CAMx system and the emissions available on the ClairCity emissions database.

A preliminary comparison of the URBAIR outputs with the observations in Bristol points out a clear underestimation of the simulated concentrations. The underestimation of the simulation results is mainly associated with the lack of other emission sources contributing to the concentrations within the area, as well as the background concentrations. Therefore, a procedure was defined to account for the background concentrations and other remaining sources, following the background concentration maps published by the UK's Department for Environment Food & Rural Affairs (Defra). The background air pollution maps made available by Defra are the total annual mean concentrations based on modelled data on 1 km x 1 km grid squares. The background concentrations added to the NO_2 concentrations simulated with URBAIR model included the contributions from the following categories: aircraft, rail, other and rural, while for PM_{10} and $PM_{2.5}$ the added background accounted for the following categories: rail, other, secondary PM, residual and salt.

The simulation results together with the added background concentrations were again calibrated against the measurements through an adjustment procedure. The adjustment procedure comprises the establishment of the linear regression between the measurements, including the continuous and diffusion tube measurements, and the simulation concentrations obtained for the cells corresponding to the location of the measurement points. The slope of 1.6154 from the linear regression is applied as a correction factor over all the domain, together with a unique correction factor applied to each cell with a measurements available.

Figure C-2 a) shows the resulting NO_2 annual average concentrations. Figure C-2 b) points out the population potentially exposed to NO_2 concentrations above the EU legal limit value of 40 $\mu g.m^{-3}$.

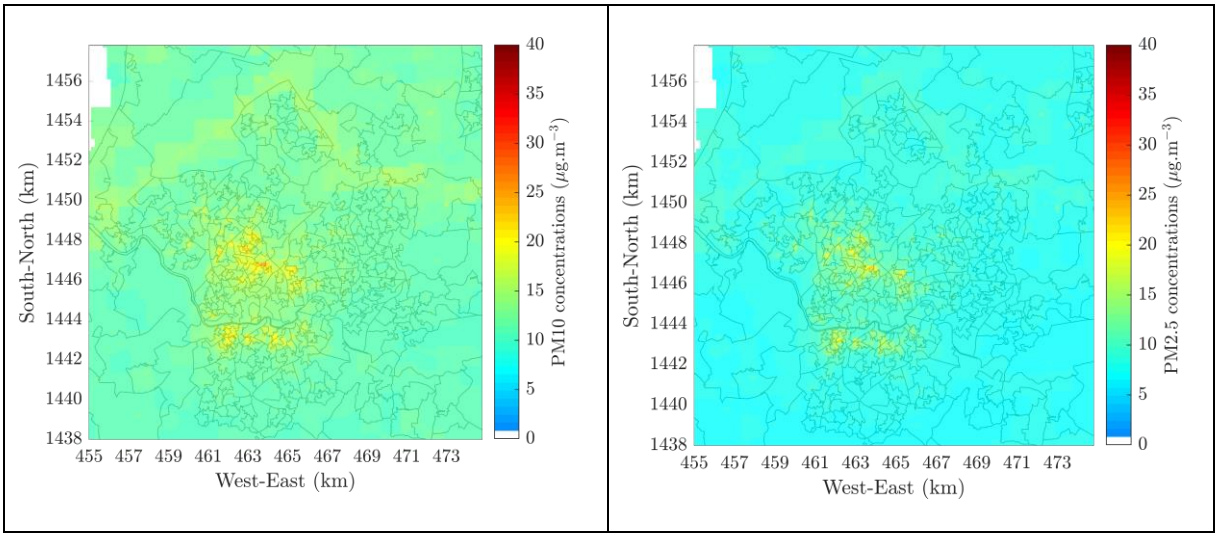
Figure C-0-2 NO_2 contour maps: a) annual average of NO_2 concentrations and b) number of inhabitants within the cells exceeding the EU annual limit value of 40 µg.m^{-3} in 2015



The simulation results indicate a maximum concentration of 91.2 µg.m^{-3}, simulated within the urban area over the M32 motorway. The EU annual legal limit value for NO_2 annual concentrations is exceeded in 231 cells corresponding to 5% of the total population within the urban area potentially exposed to those concentrations.

Figure C-3 presents the PM_{10} annual average concentrations (Figure C-3 a)) and the $PM_{2.5}$ annual average concentrations (Figure C-3 b)).

Figure C-0-3 (a) PM_{10} annual average concentrations and (b) $PM_{2.5}$ annual average concentrations in 2015

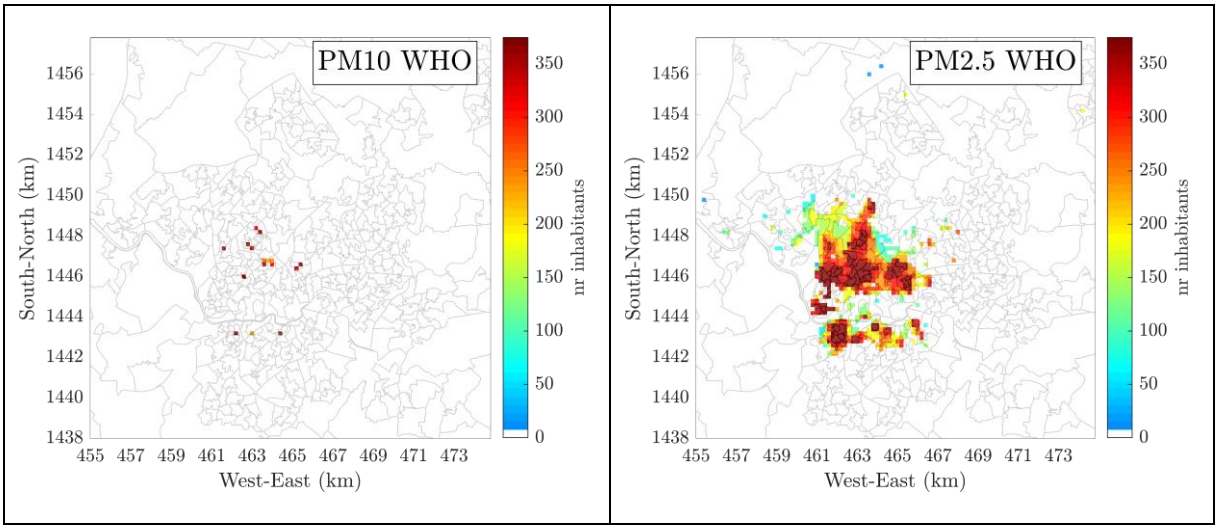


The maximum value of PM_{10} concentrations is equal to 25.1 µg.m^{-3}, which is simulated over the urban area, while the simulated maximum concentration of $PM_{2.5}$ is equal to 22.3 µg.m^{-3}. The PM concentration contour maps point out no exceedances of the EU legal limit values for PM_{10}, equal to 40 µg.m^{-3}, and for $PM_{2.5}$, equal to 25 µg.m^{-3}.

However, despite the compliance of the EU legal limit values for particulate matter concentrations, the annual concentrations indicate exceedances of the WHO guideline values. Figure C-4 a) shows 16 cells exceeding the WHO guideline value, which represents

1% of the population within the simulation area potentially affected by PM_{10} concentrations above the recommended value. For $PM_{2.5}$, 655 cells are exceeding the guideline value, denoting that 25% of the population within the simulation area are potentially exposed to those concentrations (Figure C-4 b).

Figure C-0-4 Number of inhabitants within the cells exceeding the WHO air quality guideline values: a) of 20 µg.m-3 for PM10 concentrations, and b) of 10 µg.m-3 for PM2.5 concentrations in 2015



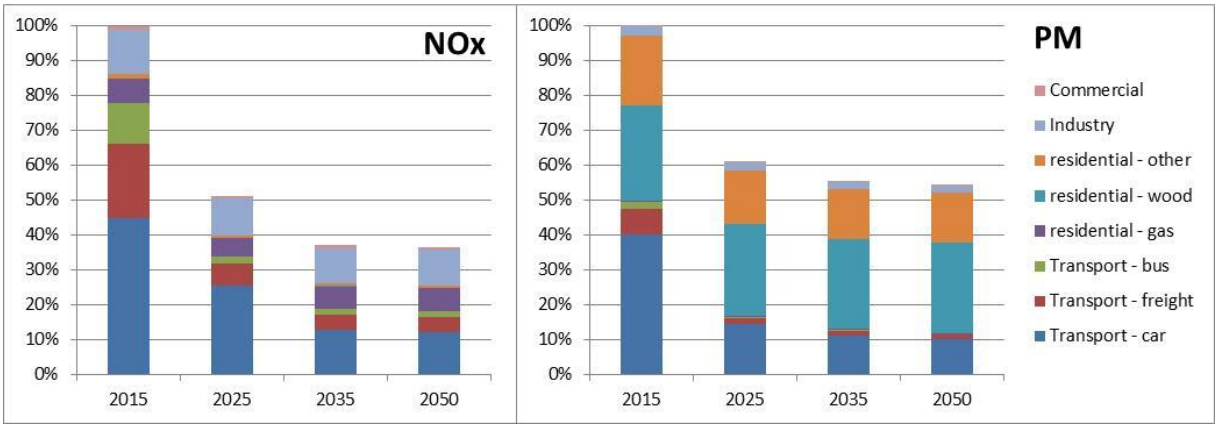
C.1.2 BAU

In the BAU scenario we estimate future emissions for 3 future years: 2025, 2035, 2050. This includes technological changes (e.g. uptake of new technology) and behavioural elements (e.g. future demand for transport, by mode). The BAU-scenario includes all active policy measures agreed until 2015 that will take effect in the future. A typical example are emission standards for new vehicles that only gradually take effect as the car fleet is evolving over time.

Observed emission trends in the BAU scenario are presented in Figure C-5. We expect significant reductions of the emissions in the BAU scenario, across most sectors. For NOx, we expect emissions to half in 2025 compared to 2015, mainly as a result of emission reductions in the transport sector, a consequence of more stringent emission standards for diesel cars and trucks taking effect.

For PM, the transport exhaust emissions are expected to decrease, as more cars with particulate filters enter the fleet. Meanwhile, we expected limited changes in the PM emissions from the residential sector, amplifying the importance of domestic wood burning as a source for PM emissions, responsible for almost half of the PM emissions as of 2025.

Figure C-0-5 trend of PM and NOx emissions in a business as usual scenario



BAU impacts on air quality

The substantial reductions of the NOx emissions in the BAU scenario will lead to significant reductions of the NO_2 concentrations. Figure C-6 presents as example the NO_2 annual average concentrations considering the impacts of BAU scenarios for 2025 and 2050. The maximum NO_2 concentration will be equal to 45.5 µg.m $^{-3}$ in 2025 and to 38.0 µg.m $^{-3}$ in 2050, corresponding to an overall reduction of the maximum concentration of 17%. In the BAU scenario, the NO_2 concentrations will still exceed the EU limits and WHO guidelines in 2025, showing exceedences in 5 cells of the domain.

Figure C-0-6 NO_2 annual average concentrations for the BAU scenarios: a) 2025 and b) 2050.

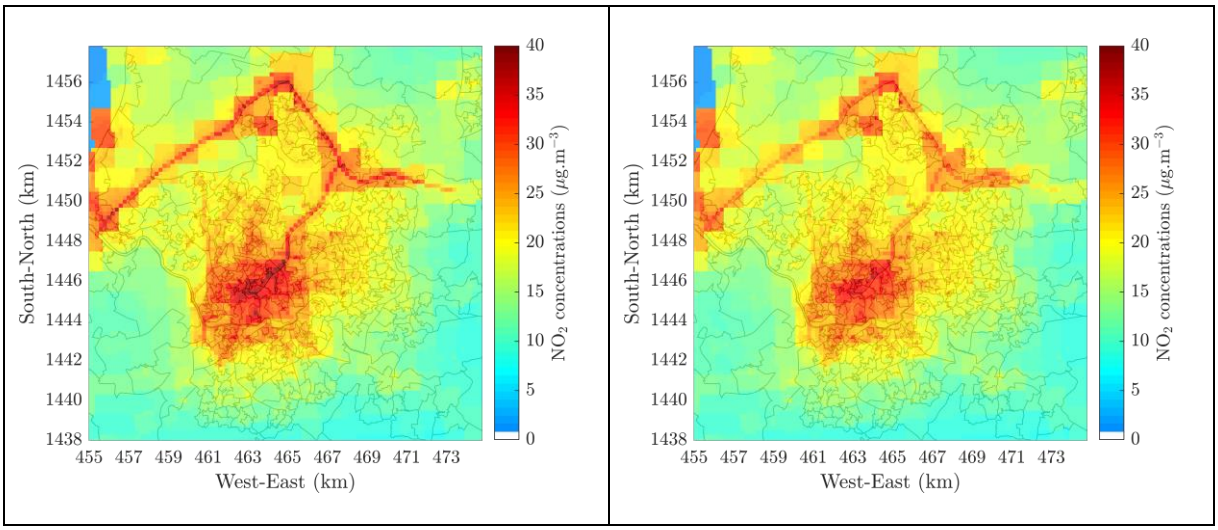
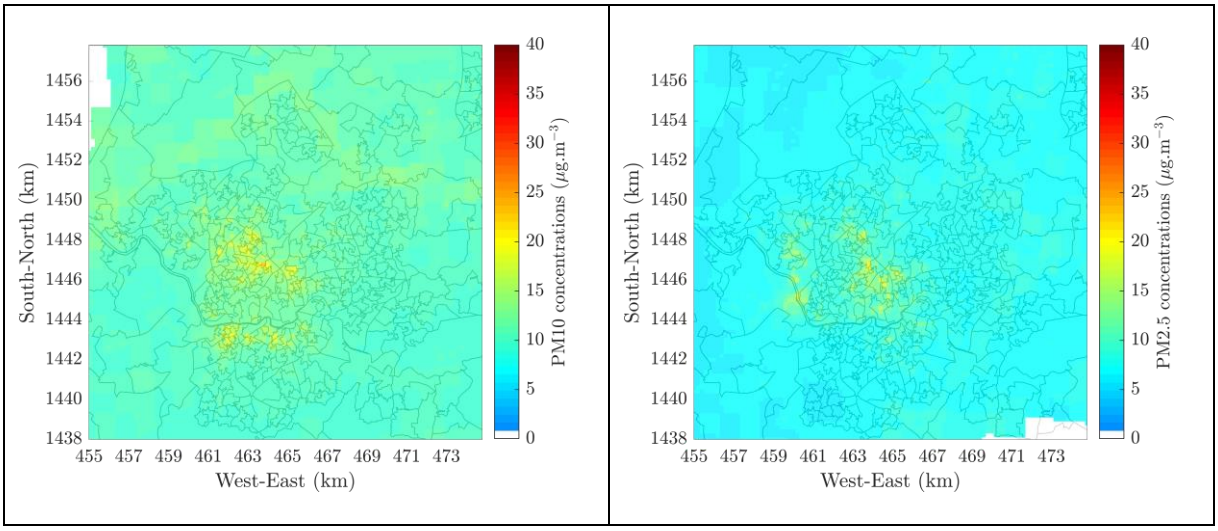


Figure C-7 (a) presents the PM_{10} annual average concentrations for 2050 and (b) the $PM_{2.5}$ annual average concentrations for the same year. The simulated maximum values of PM_{10} concentrations range from 23.3 to 23.0 µg.m $^{-3}$ between 2025 and 2050, while the simulated maximum concentration of $PM_{2.5}$ vary from 20.9 to 20.6 µg.m $^{-3}$. Therefore, the BAU scenarios will lead to the reduction of both PM_{10} and $PM_{2.5}$ concentrations showing compliance with EU limit values in 2025. However, for the WHO guideline values for PM_{10} there are still 3 cells exceeding this limit in 2025 and for $PM_{2.5}$ 348 cells.

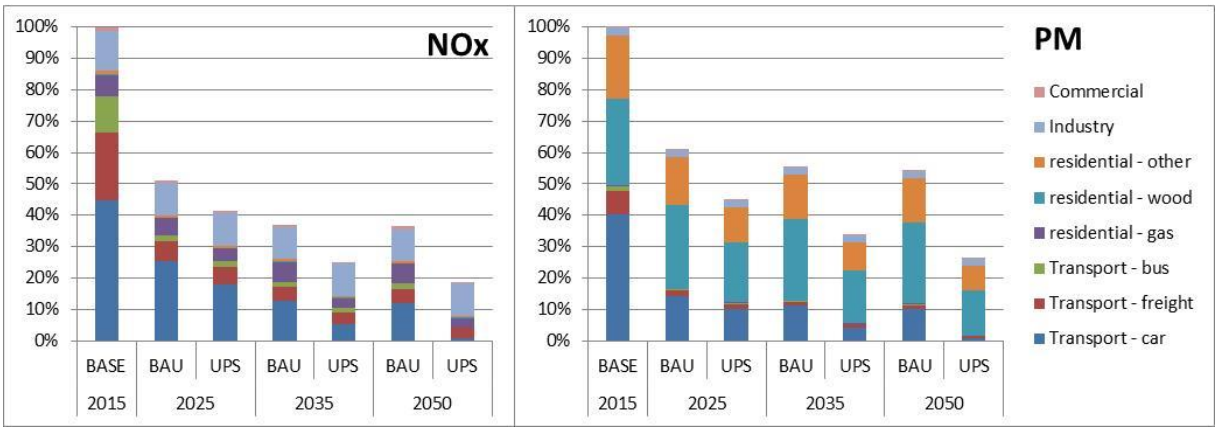
Figure C-0-7 Particulate matter annual average concentrations for the BAU scenario in 2050. a) PM_{10} and b) $PM_{2.5}$ concentrations.



C.1.3 UPS

In the UPS scenario, on top of the BAU scenario the citizens' measures are implemented (see Table C-1). The combination of all these measures leads to the emission reductions shown in Figure C-8.

Figure C-0-8 trend of PM and NOx emissions in the policy scenario, compared to the business as usual scenario



From Figure C-8 it can be seen that the UPS scenario is succesful at further decreasing the emissions of particularly transport compared to the BAU. Transport NOx emissions are reduced to about 10% in 2035 compared to 2015 in the policy scenario, while in the BAU these emissions are still at 19% of 2015 levels. Transport emissions are reduced to 5% for NOx, 3% for PM in 2050 compared to 2015.

As in the BAU, the emission reductions in the transport sector increase the importance of other emission sources where the measures have limited or no impact. For example, while PM emissions of residential sources overall are decreasing, their slower emission reduction pace compared to transport is making residential sources the dominant sources of PM emissions over time, from about 47% in the 2015 to 85% in 2050. Residential wood burning specifically increases from 27% to 55%, if no further measures are taken.

UPS impacts on air quality

The significant reductions of the NOx emissions in the UPS scenario comparing with the BAU scenarios will lead to even more significant reductions of the NO_2 concentrations. Figure C-9 shows for example the NO_2 annual average concentrations considering the impacts of UPS scenarios for 2025 and 2050. In 2025 the maximum NO_2 concentration will be equal to 40.4 $\mu g.m^{-3}$ and in 2050 equal to 38.0 $\mu g.m^{-3}$, showing only 1 grid cell exceedence of the legal limit value in 2025. Comparing UPS and BAU scenario, the maximum concentrations will be at 11 and 17% compared to 2015.

Figure C-0-9 NO_2 annual average concentrations for the UPS scenarios: a) 2025 and b) 2050.

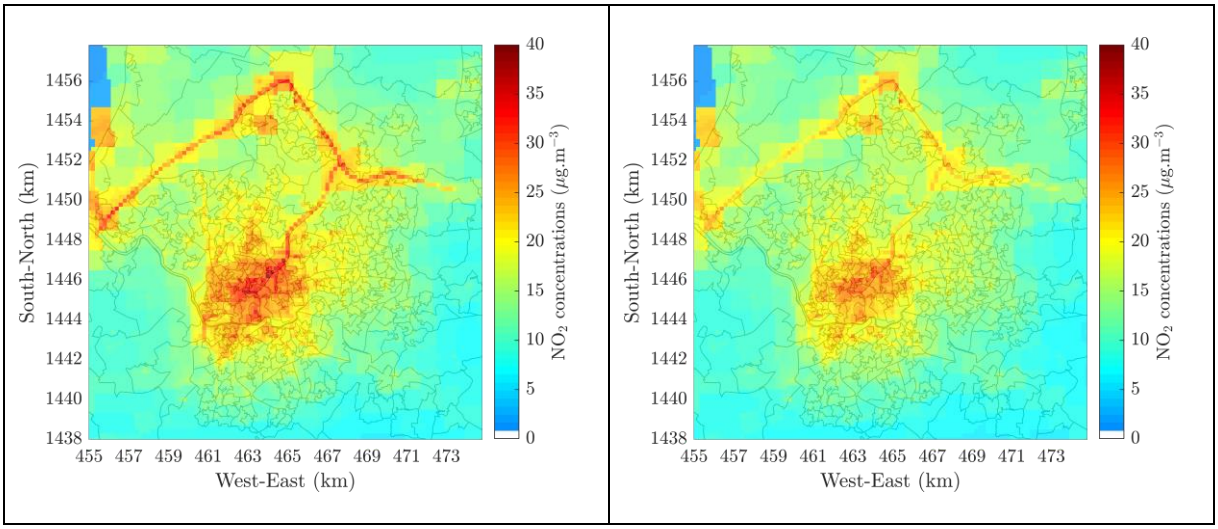


Figure C-10 presents the UPS PM_{10} annual average concentrations (a) in 2025 and (b) in 2050. For PM_{10}, in 2025 the maximum value corresponds to 22.1 $\mu g.m^{-3}$ and 20.5 $\mu g.m^{-3}$ in 2050. This means that there are no exceedances of the EU limit values, but the WHO guideline values were exceeded in 2 grid cells in 2025 and in 1 cell in 2050. Compared to the BAU scenario, the UPS scenario will reduce the maximum concentrations by a further 5 and 11% in 2025 and 2050.

Figure C-0-10 PM10 annual average concentrations for the UPS scenario: a) in 2025 and b) in 2050.

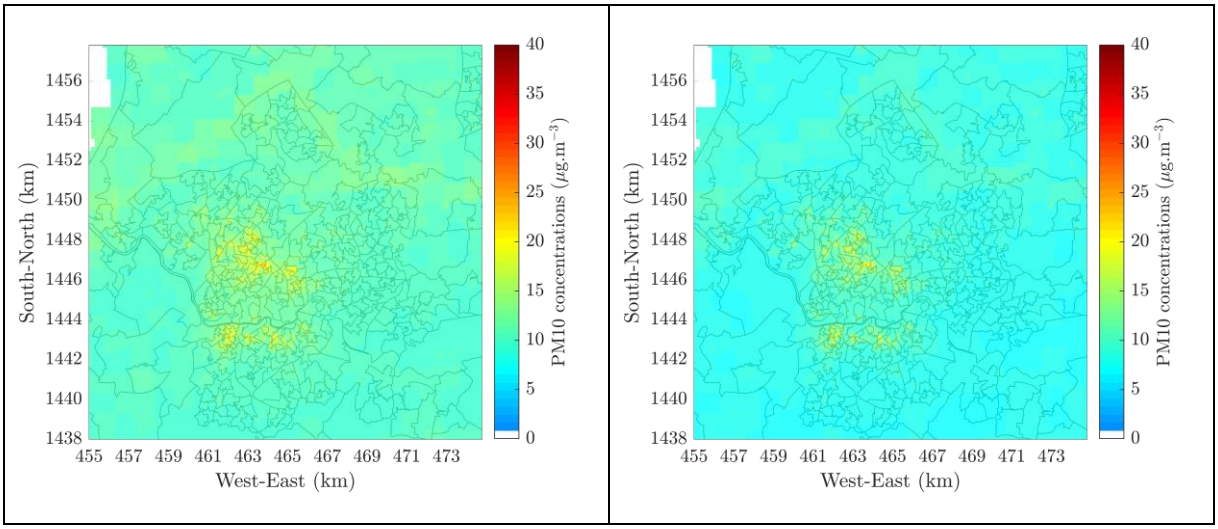
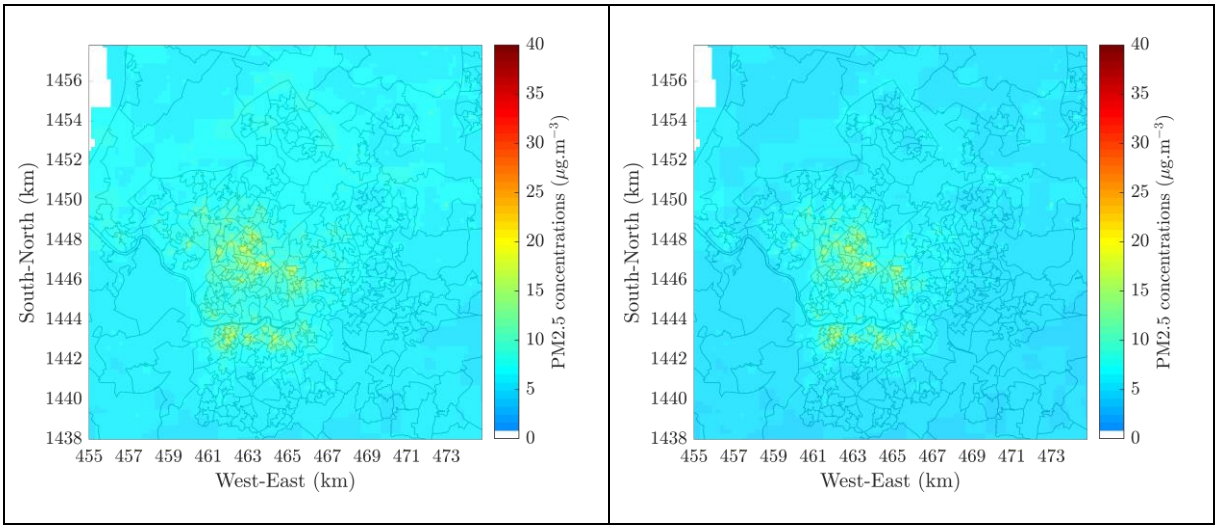


Figure C-11 presents the $PM_{2.5}$ annual average concentrations in the UPS scenario (a) in 2025 and (b) in 2050. For $PM_{2.5}$, in 2025 the maximum value corresponds to 20.1 µg.m $^{-3}$ and 18.7 µg.m $^{-3}$ in 2050, translating into a further 7% reduction of the maximum concentration compared to BAU. Based on the WHO guidelines in 2025, 239 cells show exceedences, and by 2050 this number is reduced to 152 cells. The UPS will reduce the maximum concentrations by a further 4 and 8% in 2025 and 2050 as compared to BAU.

Figure C-0-11 PM2.5 annual average concentrations for the UPS scenario: a) in 2025 and b) in 2050.



UPS impacts on health

To illustrate the health benefits related to the air pollution reduction scenario, the following health impact indicators were calculated for different air pollutants: i) number of premature deaths and ii) years of life lost (YLL). Premature mortality is a standard measure of the burden of the population's health as it is expected that most deaths are preventable before a person reaches an expected age. YLL is defined as the years of potential life lost due to premature deaths. Since YLL take into account the age at which deaths occur, relative to life expectancy, a greater weight is given to deaths at a younger age than at an older age. Life expectancy can also be differentiated by country and sex (de Leeuw and Horálek, 2016)[23].

The burden of disease associated with ambient air pollution is estimated by relating air concentrations to health outcomes. Gridded annual averages were used as input to quantify the relative risk in a population, based on concentration-response functions (CRF). CRFs reflect the effect of a pollutant on a health outcome, e.g., NO_2 on mortality from cardiopulmonary diseases. Relative risk is based on epidemiological studies and is expressed as the increase in incidence or prevalence per unit increase in concentration. The risk ratios used in this work are described in Figure C-12. This table also oulines the mortality causes, age interval, and concentration threshold consider when calculating the health outcomes for

[23] de Leeuw, F. & Horalek, J. 2016. Quantifying the health impacts of ambient air pollution: methodology and input data. European Topic Centre on Air Pollution and Climate Change Mitigation.

each air pollutant. The threshold concentration is the concentration level below which no health effects are expected.

Figure C-0-12 Risk ratios (RR) for mortality

Pollutant	Value [per 10 µg/m^3]	Type	Reference
$PM_{2.5}$	RR 1.062 (95 % CI 1.040-1.083) No threshold	All-cause (natural) mortality in ages above 30 (ICD-10 codes A00-R99).	WHO 2013a[24]
PM_{10}	RR 1.04 (95% CI, 1-1.09) No threshold	All-cause (natural) mortality in ages above 30 (ICD-10 codes A00-R99).	Beelen et al., 2014[25]
NO_2	RR 1.055 (95 % CI 1.031-1.08%) Threshold: 10 µg/m^3	All-cause (natural) mortality in ages above 30 (ICD-10 codes A00-R99).	WHO 2013a

Premature deaths can be estimated at grid-cell level by multiplying the population attributable fraction (PAF), crude death rate (CDR) broken down by age and sex, and total population within the grid cell and summing over all ages and sex pairs. PAF is defined as the reduction in population mortality if exposure to a risk factor were reduced to an ideal exposure scenario (e.g. concentrations equal to zero). PAF can be calculated from the relative risk. CDRs by age, for 5-year age groups (all ages above 30), and by sex, were calculated from natural all-cause mortality in 2015 (ICD codes A00-R99) and total population, both at country level[26]. It is assumed that CDRs is constant throughout the country population. YLL are calculated at grid cell level by multiplying premature deaths with life expectancy by age and sex. Life expectancy data is based on data published by the UN.[27] The expected burden of disease attributable to air pollution in one specific area can finally be estimated by summing over all grid cells in the area of interest for the indicator of interest. Reductions are subsequently calculated for each of the scenarios by benchmarking against the baseline scenario (2015) results.

UPS impacts on costs

For the assessment of costs, we used 3 indicators. We focused on the transport measures only, as almost all Bristol citizen measures are transport-related. The 3 indicators are:

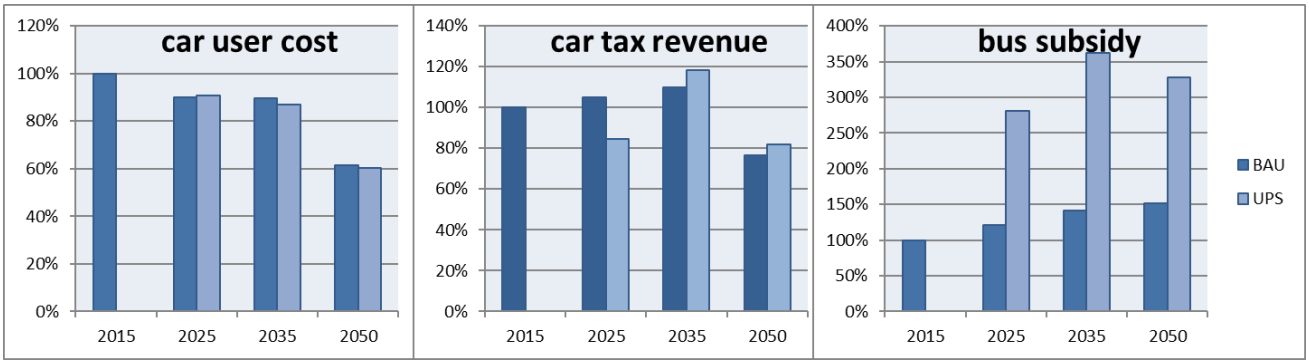
1. The car user cost: to what extend does the cost to drive a car changes relatively over time in the BAU as well as under influence of the scenario's
2. The government tax revenue from car transport, combing fuel excises, registration taxes as well as any levy's (e.g. cordon charge)
3. The government expenditure on public transport, i.e. bus subsidies

[24] WHO 2013a. Health risks of air pollution in Europe - HRAPIE project. Recommendations for concentration-response functions for cost-benefit analysis of particulate matter, ozone and nitrogen dioxide. Copenhagen, Denmark.
[25] Beelen et al. 2014. Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. The Lancet 383 pp 785-795
[26] Population data available here: https://population.un.org/wpp/Download/Standard/Population/ Tables F15-2 and F15-3; mortality data available here: http://apps.who.int/healthinfo/statistics/mortality/causeofdeath_query/start.php
[27] Life expectancy at exact age and average age at death is available here: https://population.un.org/wpp/Download/Standard/Mortality/ Tables F16-2, F16-3, F17-2 and F17-3

The indicators on tax revenue or subsidy expenditure do not distinguish between different types of government (local, regional, national).

With these indicators, we assessed qualitatively the likely costs of measures for citizens, government ('Bristol city council') and society at large. Costs for society were assumed to be the net sum of citizen and government costs. The cost estimations have to be seen as order-of-magnitude estimations only, as the real costs until 2050 will depend on many variables that were not included in the ClairCity modelling. Figure C-13 gives an overview of these order of magnitude costs of the UPS scenario compared to the BAU scenario.

Figure C-13 trends of user cost (left), government tax revenue (mid) and bus subsidy (right) in all scenario's



Car user cost

The car private user cost is expected to decrease over time in the BAU, despite stricter emission standards. The cost decrease over time, in the BAU, is due to the combination of the cost benefit of more fuel efficient cars (fuel savings offset the higher purchase cost) as well as the uptake of electric vehicles (EVs) that are becoming ever cheaper in the future, reflected in the strong decrease of user cost in 2050 due to massive uptake of EVs. The car private user cost is initially slightly higher in the UPS, mainly due to road pricing costs which make driving initially more expensive to private car users. In later years, when more people will have switched to EVs, which are charged less, overall car user cost will be lower in the UPS compared to the BAU.

Car tax revenues

The tax revenue increases and then drops in 2050 in the BAU. This is due to current limited taxation of EV's (there are no excise duties on electricity as is the case for diesel and petrol). This is expected to change over time as the market share of EV increase and the decreasing tax revenue of excise duties on diesel and petrol will become apparent to public authorities. In our simulation, we've kept the taxation levels constant.

Tax revenues are higher in the UPS scenario due to the road charge, but decrease in the more ambitious scenario as there is a major modal shift in the more ambitious scenario, hence also reducing the tax revenue from cars.

Bus subsidies

Bus subsidy increase strongly in the UPS due to reduced ticket cost as well modal shift due to cheaper prices. The massive modal shift in the UPS (mainly by facilitating public transport and reducing the accessibility of car) leads to huge increase in bus subsidy costs. We estimate that at least a factor 3 additional subsidy would be needed for public transport to satisfy demand at the lower ticket cost, which is likely unsustainable from a public spending perspective.

Additional ad hoc simulations have shown that with maintaining higher ticket costs (thus requiring less subsidy), still a high modal shift would be achieved by enhancing bus service (e.g. increase frequency, reliabilty, bus lanes to reduce travel time,…) in combination with decreasing car accessibility. Hence, further reducing public transport fares, as asked for by citizens, would be not required to let citizens still shift towards public transport.

Costs of other measures

Cost impacts of measures like “Streetscapes to make streets more open” and “awareness creating” have not been included. On investments (e.g. in cycling infrastructure), we assume these come at the expense of other investments and are phased in gradually thus leading to a shift in existing (investment) expenditure rather than new investments. To estimate cost, the measures would have to be described in more detail, with a full investment plan including suspended investments to compensate for the costs made. This was considered outside of the scope of the exploratory excercise.

Overall, the order-of-magnitude modelling suggests that the increase of costs of transport from a user perspective in the UPS scenario is limited. Shifts in government / city council revenues and costs seem to be higher, so that care will be needed from a city governance perspective to balance new spending for measures with new income, especially for public transport.

C.2 Modelling source apportionment by motive/behaviour

A fine granular dataset of road transport emissions was generated that allowed source apportionment not only at the typical level of mode choice (e.g. car, bus, taxi, cycling, walking etc) but also the underlying behaviour or motive (e.g. shopping, commuting, leisure etc) and socio-economic properties of the people travelling (e.g. gender, age, income etc). The scientifically robust yet flexible methodology is designed to allow it to use different types of public datasets, which can be applied to different cities in similar fashion. The methodology had two primary steps:

1. A simple traffic demand generation and assignment algorithm to establish traffic flows at link level to calcuate total emissions; and
2. Merging the emission dataset from step 1 with travel survey data holding information on the underlying motives and socio-economic properties of travellers of individual trips.

C.2.1 Step 1: Traffic Demand Generation

The first step is to develop emissions at link level. This is done with the following sequential steps:

1. **Establishing a noded network of the city**. We use OpenStreetMaps (OSM) to establish the network. OSM holds all details necessary for traffic assignment including:

road type (residential, regional, highway) number of lanes, directions, speed limits, etc. We developed a Matlab script to convert the OSM map to a simple network
2. **Generation of transport demand from land use information to an origin-destination table**. We use a generalised approach focusing on peak travel demand that allows different data-sources for land-use. OSM in itself is a potential source we have tested, but for the case of Bristol we've used land-use information of UrbanAtlas
3. **Assigning demand on the network to generate traffic at link level**. We use a static assignment and generic assumptions on trips distance and flexible assumptions on preferences for different types of road insofar as they are available from [Step 1]
4. **Calibrate the traffic demand with a limited amount of counting points**. The traffic generation form [Step 2] is highly uncertain and is to be scaled in such a way that the resulting traffic demand at link level corresponds to measurements. The amount of counting data available, determines the quality of the traffic demand estimation
5. **We multiply the traffic demand with common emission factors**. The emission factors are derived from the publicly available COPERT V methodology, taking into account the fleet composition (age, fuel type, EURO-standard etc.) at country level.[28]

C.2.2 Step 2: Linking to Travel Survey Data

In the second step, we link the traffic demand data with travel survey data to further break down the emissions by motive. Travel survey data typically hold detailed information about travel behavior, combining information of the individual as well as information of the trip. In this particular case, we have travel data at:

1. The individual scale
    a. Income group (3 groups)
    b. Age group (5 groups)
    c. Gender
    d. Car ownership (0, 1, more)
2. The trip-scale
    a. Transport mode (bicycle, bus, car, motor, taxi, train, walk)
    b. Trip motive (Business, commute, education, leisure, other escort, personal business, shopping, other)
    c. Time of day (morning, midday, evening, night) as well as day type (weekday, weekend)

The data fusion focusses on the matching trip distances observed from the travel survey data, which only holds a sample of all trips with the estimated traffic demand from estimated transport volumes (and emissions) at link level. This fusion results in a dataset that allows us to understand the underlying source of the emission by properties of the citizen (age, income, sex) as well as the behavioral element (trip motive).

The trip motive / citizen behaviour activity definitions are taken from the UK National Travel Survey (HM Government, 2018). These are defined as:

- **Commuting**: trips to a usual place of work from home, or from work to home;
- **Business**: personal trips in course of work, including a trip in course of work back to work. This includes all work trips by people with no usual place of work (e.g. site workers) and those who work at or from home;

[28] Initial estimates used fleet at local level but revealed a similar fleet composition at country level, so we opt for country level fleet composition as typically more data is available at country level compared to city level.

- **Other**: trips to work from a place other than home or in course of work, e.g. coming back to work from going to the shops during a lunch break. In most tables this is included with 'personal business';
- **Education**: trips to school or college, etc. by full time students, students on day-release and part time students following vocational courses;
- **Shopping**: all trips to shops or from shops to home, even if there was no intention to buy;
- **Personal business:** visits to services, e.g. hairdressers, launderettes, dry-cleaners, betting shops, solicitors, banks, estate agents, libraries, churches; or for medical consultations or treatment; or for eating and drinking, unless the main purpose was entertainment or social;
- **Leisure**: visits to meet friends, relatives, or acquaintances, both at someone's home or at a pub, restaurant, etc.; all types of entertainment or sport, clubs, and voluntary work, non-vocational evening classes, political meetings, etc.;
- **Escort**: used when the traveller has no purpose of his or her own, other than to escort or accompany another person; for example, taking a child to school. 'Escort commuting' is escorting or accompanying someone from home to work or from work to home. Similarly, other escort purposes are related to the purpose of the person being escorted.