ClairCity: Citizen-led air pollution reduction in cities

D6.3 Evaluation of approaches cities take to emission footprints and city carbon initiatives

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Document Details

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Description	This report testifies a study of the different approaches in air quality and city carbon initiatives, primarily focusing on the European area but including case studies from New Zealand and South Africa. The research is based on a three level method comprising literature review, survey and case study interviews. The main objective of the research is to inform the development of “bespoke city policy packages to reduce emissions”.

Version History

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Executive Summary

The aim of this study has been to build an understanding of better practice in citizen engagement through city initiatives and carbon and air quality inventories. This study supports ClairCity's aims to apportion air pollution emissions and concentrations, carbon footprints and health outcomes by city citizens' behaviour and day-to-day activities and make emission reduction relevant to the choices people make about how to live, behave and interact within their city environment. The conclusions may help inform various elements of the ClairCIty process and specific work package activities.

The study has taken a mixed method, triangulation approach of literature review, survey and case study interviews. Initially a systematic literature review has explored local, national and international policy and governance structures to identify areas of better practice in city policy and how that may impact on citizens and their city's future. The review has also examined how cities currently apportion air pollution emissions and compile "inventories" and "footprints" of carbon emissions as part of local air quality and carbon management. In addition to considering the inventory processes cities use, the review has examined the benefits of membership of different initiatives in terms of how they support carbon and air quality management, in particular focussing on how initiatives facilitate, or do not facilitate, the engagement of citizens with emissions data.

The findings of the literature have been supplemented by the survey of cities and interviews with three case study cities – Durban South Africa, Wellington New Zealand and Glasgow UK. In turn, the survey and interview responses allow for a comparison with the findings of the literature review and start a process of validating our understanding of inventories and the benefits of city initiatives and how it feeds into future ClairCity outputs.

The main conclusions of the study are summarised as follows:

- The literature review and case studies both support the need for internationally agreed carbon inventory frameworks.
- There is a needed for greater inclusion of bottom-up, activity data related to citizen and business behaviour in inventories.
- Development of an inventory process that can include both air pollutants and carbon emissions is an area that requires further exploration.
- Further research is required to identify the trade-offs between air quality and carbon policies at the city-level across Europe. Two conflicts within the UK are identified in terms of historical incentivisation of diesel cars and current incentivisation of biomass burners in homes.
- There is very little evidence in the literature of the potential benefits of greater engagement with citizens on both air pollutant and carbon emission inventories. This appears to be a research/knowledge gap.
- In developing an emission inventory methodology greater consideration needs to be given to the time and resource constraint of local governments. A potentially role of city initiatives is to help facilitate this process.
- Pioneer cities at the forefront of climate change mitigation policies can work as test cases of new ambitious approaches and methodologies.

- Inconsistencies between local and national policies can hamper cities' progress on emission reductions.
- There are a lack of initiatives focussing on air pollution and air quality issues, even as a co-benefit of addressing climate change mitigation.
- Citizen engagement is not consistently a part of city initiatives and networks

This study makes the following recommendations for the ClairCity project (the work package in () indicates which ClairCity work package this recommendation is most relevant for):

- ClairCity should investigate how to include more behavioural, bottom-up elements in city level emission inventories for both air pollutants and carbon emissions and consider how this feeds into the ClairCity toolkit structure and outputs. To do this ClairCity should:
    - Explore how cities integrate behavioural/bottom-up elements through a review of the city-level grey literature and policy documents for identified cities (WP6.2).
    - Identify other sectors where behavioural, bottom-up elements are included in quantitative reporting and benchmarking to guide policy, perhaps through a strategic review of the literature on systems approaches (WP3 and WP6.2).
    - Build recommendations through the research and knowledge generated in ClairCity especially related to the practice-activity and micro-simulation work and how this can feed into bottom-up inventories (WP3).
- There is a need to investigate the barriers and challenges of integrating air pollutant and carbon emission inventories. An assessment of the ClairCity case study cities and regions should ascertain whether there is any desire to do this from a local authority inventory users point of view (WP5).
- The project should keep a watchful eye on carbon, air quality and environmental management practices, particularly in China and other Asian countries where increasing urbanisation and creation of mega-cities presents challenges for inventories. With this in mind, ClairCity should consider connecting into other work in this area (WP6 and WP2).
- The citizen engagement approach of ClairCity is currently missing from both inventory methodologies and city initiative processes. The project should seek opportunities to engage with cities through dissemination and communication activities to pilot their activities, share the projects policy-messages and approaches to engagement (WP2 , WP4 and WP5). This may be achieved by:
    - Reviewing the processes of transnational city initiatives such as Covenant of Mayors and C40 to identify any changes to their practices or innovative attempts to engage citizens with inventory processes (WP6.2).
    - Working with the ClairCity city/regions to trial increasing citizen engagement with carbon and air quality emission inventories and reporting (WP4 and WP5).
    - Build on the relationships created in this work package to identify opportunities to engage citizens in trial processes with city/regions outside of the project consortium, for example, Glasgow in the UK (WP2).

1 Background

The ClairCity project aims to apportion air pollution emissions and concentrations, carbon footprints and health outcomes by city citizens' behaviour and day-to-day activities with the focus on how to make the issues of air pollution and carbon emissions relevant to the choices people make about how to live, behave and interact within their city environment. The outputs from this research will inform the development of bespoke city policy packages to reduce emission, informed by the voices of citizens in the project's six pilot cities/regions: Amsterdam, Bristol, Aveiro, Liguria, IT, Ljubljana, and Sosnowiec.

In order to develop these policy packages it is essential to understand current local, national and international policy and governance structures to identify areas of best practice in city policy and how that may impact on citizens and their city's future. Part of this exploration necessarily involves examining how cities currently apportion air pollution emissions and compile "inventories" and "footprints" of carbon emissions as part of local air quality and carbon management. In the future, this knowledge on inventories will feed-in to bespoke city policy packages as part of the development of a ClairCity toolkit for our pilot cities, which can subsequently be rolled out to all EU cities with more than 50,000 citizens.

As will be explored, city initiatives and networks play a significant role in climate change governance at the city level across the globe. For some initiatives, part of this role involves supporting cities to compile carbon emission inventories, by either creating or promoting emission inventory methodologies and standards, or providing a network of other cities to compare against and share knowledge. Therefore, in addition to considering the inventory processes cities use, this report will also examine the benefits of membership of different initiatives in terms of how they support carbon and air quality management. In particular, we will focus on how initiatives facilitate, or do not facilitate, the engagement of citizens with emissions data. This piece of work will develop an understanding of best practice in citizen engagement with city initiatives and inventories, as well as identifying the gaps in this area that the ClairCity project can fill in its toolkit structure.

For carbon management at a city scale, there are a number of different emission calculation and reporting methodologies such as Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) in addition to various city level reporting frameworks (e.g. Carbonn Climate Registry, Carbon Disclosure Project etc.) and initiative specific tools (e.g. Covenant of Mayors Sustainable Energy Action Plans). Through an extensive review of EU and international literature, a city survey and in-depth interviews, we will explore the policy and governance structures that influence the adoption of these methodologies, reporting frameworks and initiatives. We will also determine the benefits and transferrable experiences of cities engaged with city initiatives and compiling emission inventories.

This study will ensure that a broad range of approaches and initiatives, international, national and local, will be investigated in detail in a thorough review of the literature, survey and interviews but it is recognised that we will not be able to provide evidence on all initiatives. To address this issue, the survey and case studies interviews presented in this report s are part a longer series of city case studies in an information gathering process that extends beyond this deliverable.

1.1 Structure of the report

This document consists of three main sections followed by a synthesis of the research findings and a conclusions and recommendations section, briefly described below:

Methodological approach: Outlines the mixed method triangulation approach used in the research to ensure data validity and reliability. It describes the process for searching for and identifying relevant papers on carbon inventories, air quality inventories and city initiatives, the procedure for building a database of city initiatives and projects and the case study design including a survey and interviews with city representatives.

Literature and city initiative review: Presents the findings from a systematic review of the literature related to three overlapping areas: city-level carbon inventories, footprints and accounting methods; conventional air pollutant inventories; and city initiatives and networks focussed on climate change mitigation and air quality. The section also includes information from the database of city initiatives and projects developed for the ClairCity project. It concludes by summarising the main findings from the literature review and the gaps in knowledge, which will be considered in the survey responses and city case studies.

City case studies: Provides an overview of the responses to the open and closed survey questions on carbon inventories and decision-making, conventional air pollutant inventories, use of inventory data and city initiatives and benefits of membership. Presents three city case studies with representatives of Wellington in New Zealand, Durban in South Africa and Glasgow in the United Kingdom exploring in greater detail why cities use particular inventories and the benefits of city initiatives.

Conclusions and recommendations: summarises the main research findings and makes recommendations for cities using carbon and air quality inventories, and engaging with city initiatives and networks.

1.2 Clarification of scope and terms

This report aims to answer the following research questions:

- How do cities and local authorities account for air quality and carbon emissions and how do they consider citizens in the process?
- How do they use the data from their inventories/carbon footprints?
- What is the value to cities of participating in transnational networks and initiatives, such as the Covenant of Mayors, Rockefeller 100 Resilient Cities or Clean Air Asia?

2 Methodological approach

The following section outlines the methodological approach implemented to evaluate and understand the approaches cities take to emission footprints and the value to cities in participating in city networks and initiatives.

In conducting this research, we employ mixed-method research tools for data gathering.

1. A desk based assessment of available literature, relevant city initiatives and research projects.
2. A survey of cities and city case study interviews.

The core of the research is based on a multiple case-study design. A case study is 'an empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context" (Yin, 2014, p. 16). As such, we will investigate different cases (i.e. different initiatives) in different contexts (i.e. different cities). The responses from the case study interview

2.1 Data validity and reliability

We used triangulation as a method to ensure data validity and reliability. Triangulation is a mixed research strategy in which *'multiple observers, theoretical perspectives, sources of data, and methodologies'* are used in a study (Denzin 1970 pg310). However, triangulation as employed in this study is, but not restricted to, a form of '*complementarity*' triangulation in which each type of data acquisition and analysis enhances the other. In this way, qualitative data from document data analysis and questionnaire surveys are cross-checked by the case study interviews carried out in the third phase of the research (Bullock et al 1992, de Vaus 1996, Mason 1996, Creswell 1998). An obvious advantage to this is the utilising of the individual strengths, weaknesses and biases of each method that brings greater confidence in the research findings (Walker, 1985, Deacon et al. 1998). Hence, triangulation will be used in this study to broadly validate the research findings from different vantage points. Apart from resulting in greater confidence in the findings, this methodology provides the benefits of depth and detailed evaluation of the processes, personalities and bureaucracies involved in the subject being studied without constrains imposed by predetermined categories of data collection and analysis that may exists in the quantitative strategy (Patton, 1987).

2.2 Literature Review and City Initiative Assessment Methodology

2.2.1 Systematic literature review

This review aims to cover both a research and a policy perspective and was conducted with a special focus on city carbon footprinting approaches, air pollutant inventories and city initiatives. This review contributes to resolving the three research questions.

As part of the evidence gathering process, we conducted a systematic review using *Scopus*, a large research database that allowed us to retrieve academic papers from multiple disciplines.

The timeline for the literature search was defined as 1997 to present. This aligns with the signing of the Kyoto Protocol, which extended the 1992 United Nations Framework Convention on Climate Change (UNFCCC) committing State Parties to reduce greenhouse gas emissions and putting the obligation to reduce current emissions on developed countries and identified a growing role for cities and local governments. In 1987, the Brundtland Report recognised the role of cities and local authorities in sustainable development and their role was emphasised during the 1992 UN Conference on Sustainable Development in Rio de Janeiro, which called for cities to develop a Local Agenda 21 (LA21) (Tu, 2017). Five years later, in 1997, the UN held a special session on Agenda 21 and adopted a new Resolution (S-19/2)[1] that strengthened the international community's commitment to local sustainable development. For this reason, we started the searching timespan to the years 1997-2017 (although some 2018 articles were available already).

We considered only documents under the category "Article or Review" and we excluded from the subject areas disciplines that were strictly concerned with atmospheric chemistry.

We divided the search process into two broad topics: the first was related to carbon emission inventory and cities, and the other one focussed on air quality management/inventory and cities. Two further separate searches focussed specifically on city networks or initiatives. The search strings developed for this review were based on the following keywords:

Scopus search terms:	AND
"carbon emission inventory", OR "carbon emission reporting"OR"carbon emission accounting"	"cities"
"air quality reporting" OR "air quality inventory"OR "source apportionment"	"cities"
"carbon emission inventory"	"smart cities"
"carbon emission inventory"	"city networks"
"air quality reporting"	"city networks"

[1]Resolution Adopted by the General Assembly (S/19-2) Programme for the Further implementation of Agenda 21 http://www.un.org/documents/ga/res/spec/aress19-2.htm

The search was conducted in August/September 2017 and the search protocol returned an initial sample of 1329 documents for carbon and 696 documents for air quality. An initial screening of titles and abstracts was conducted by three researchers who collectively assigned a score value of 1 to 3 to each document based on the relevance of the topic in the papers for this deliverable, geographical coverage, methodology (where 1=most relevant and 3=least relevant). This allowed the researchers to only focus on papers which scored 1. At the end of the first screening, 212 documents were kept for carbon and 180 for air quality. With reference to city networks and initiatives, the search returned 48 documents for carbon management and 3 for air quality management. Given the paucity of the papers dealing with initiatives and networks, the search on this topic was extended to Google scholar and included mentions to specific networks, such as the Covenant of Mayors. At the end of the extended research process, 61 papers were kept in total for the review of the literature on city initiatives and networks.

2.2.2 City initiative database

A database of city initiatives and projects was established. City initiatives were identified through a different search process than for the literature review, using climate change initiatives databases and platforms such as the Climate Initiatives Platform[2], through the Global Development Research Centre list of international, national and regional city networks[3] and through a google search of city initiatives. The google search and search through the GDRC list of city initiatives and networks focused on key words such as 'greenhouse gas', 'carbon management', 'climate mitigation', 'air pollution', 'local government/cities', 'transport', 'energy', 'public health'.

In addition, a search of EU FP7 and Horizon 2020 projects in the CORDIS[4] database using key word searches of carbon emissions, greenhouse gas emissions, air pollution and air quality identified a number of projects with policy toolkits and accounting inventory processes. These were also added to the database.

2.3 Case study survey and interview methodology

2.3.1 Participant identification and selection

Using the initiatives database we developed a list of potential initiative/network contacts through whom we could approach the city representatives with the relevant knowledge of carbon and air pollutant inventories and engagement with city initiatives. We focussed on the larger initiatives in the network and ones known to be engaged with carbon inventory

[2] http://climateinitiativesplatform.org/index.php/Welcome
[3] http://www.gdrc.org/
[4] http://cordis.europa.eu/

methodologies and standards such as Covenant of Mayors and ICLEI, or those engaged with air quality such as Clean Air Initiative Asia.

For the more in depth city case study interviews we selected from survey respondents to ensure a wide geographical spread of city location. Case study interviews were conducted with representatives in Europe, Africa and Australasia, in cities that belong to a number of different city initiatives.

Risk assessment of participant identification and selection identified that the nature of the questions asked in the survey and case study interviews, as well as the focus on three broad areas of understanding (carbon inventories, air quality inventories and city initiatives) meant there would be limited personnel in city governments able to complete all aspects. The survey link was shared with large initiatives and emailed to many city contacts to maximise the possibility of reaching the correct responders. The expectation is that identifying the correct personnel to answer the survey and interview questions is part of an ongoing piece of work to build a large network of case study cities and collate data from all over the world.

2.3.2 Open and closed questions

The construction of the survey and the nature of the questions is very important, particularly to avoid over- or under-defining. The questions consisted of a mixture of short answer questions choosing from a drop down list, and longer, descriptive, qualitative questions to 'set the scene' for different city case studies. Questions were designed to ensure that the researcher's views were not imposed on the respondents. Although open-ended questions tend to be harder to answer and require more input from the participants (and there is also an increased risk that respondents choose not to answer) it was important that the ideas and themes in the survey and later interview answers came from the respondents to limit bias. Both short and long questions were drawn from initial findings from the literature review.

The survey was divided into five sections:

1. Background Information
2. Carbon emission inventories and decision making
3. Conventional air pollutant inventories
4. Use of inventory data
5. City initiatives and benefits of membership

For the full list of survey questions see Appendix 1.

The extended questions asked in case study interviews focussed on carbon emission inventories and why people use particular methodologies, and the benefits of membership of different city initiatives. They were adapted according to the survey responses of different cities but were broadly based on a list of questions, presented in Appendix 1.

2.3.3 Administering the survey

This research used online survey software to produce and manage the city survey. The circulation and completion of questionnaires was carried out online via Qualtrix. Online survey software has some limitations but these were not judged to be a problem in this research. The survey was circulated to cities via 'gatekeepers' at large city initiatives and networks such as Covenant of Mayors and Clean Air Initiative Asia. The advantage of using 'gatekeepers' is that the survey comes from a familiar and reliable source for the respondents and increases the likelihood of the survey reaching the correct personnel able to answer the different themes of questions. ClairCity project followed up circulation of the survey by initiatives with promotion of the survey link on social media.

The survey was also sent to a list of city contacts who are members of Rockefeller 100 Resilient Cities. Though the initiative is not directly focussed on carbon inventories, the initiative is very focussed on knowledge sharing and network building and many people we contacted were able to identify the correct people in their city to answer the survey and put us in contact with them. This was also a useful approach for identifying case study cities from those cities that completed the survey.

2.3.4 Correspondences and contacting

For the survey distribution, we contacted city representatives by email, either directly or through an initiative contact. For the case study interviews initial contact was made by email using email addresses left by survey respondents. Interviewees in Durban and Glasgow were emailed the follow-up questions prior to a telephone interview. A representative of the City of Wellington in New Zealand answered the interview questions by email due to the time-difference making contact by phone or skype difficult.

2.4 Ethics and Data Protection

2.4.1 Ethics

This research study was given ethics consent by the Research Ethics Committee of the Faculty of Environment and Technology, University of the West of England, UK researchethics@uwe.ac.uk.

People participating in the survey were given the following information before deciding whether to proceed and were assumed to have consented to their data being shared in the way described:

It is up to you to decide whether or not to take part in this survey. By proceeding and completing the questionnaire you consent to the data you provide being used in the following way: Your answers will not be identifiable to you and will be grouped thematically with other respondents. ClairCity will treat your information in accordance with the terms and conditions

of the 1995 EU Data Protection Directive. Overall outcomes from the research will be published in reports to the European Commission, on our website www.claircity.eu and through wider media.

This study was given ethics consent by the Research Ethics Committee of the Faculty of Environment and Technology, University of the West of England, UK researchethics@uwe.ac.uk.

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

If you have any comments or queries about this survey, please contact us.

Only people who left their contact details in the survey response were contacted to see if they would be a city case study. Interviewees were informed that their responses would not be attributed to them personally and would only be linked to the city they represented. They were also informed that if they wanted to give answers completely anonymously then we would report them anonymously and separately to their case study in a general section of the report.

2.4.2 Data protection

The survey responses have been exported from the Qualtrics platform (from a password protected) account and are stored on a password protected laptop and in a secure, personal drive on the University of West of England's server. Personal data has been removed before sharing the data in this report. Responses from case studies interviews carried out on the phone were noted by hand. The personal data of interviewees has not been shared in this report.

3 Literature and City Initiative Review

3.1 Introduction

The aim of ClairCity is to decide the best local options for a future with clean air and lower carbon emissions. Carbon and air pollutant inventories are a key part of cities' toolkit when it comes to identifying which activities in which locations are contributing to emissions and subsequently where local options, policy actions and strategies are needed and should be directed. City initiatives are an integral part of the carbon inventory process in cities. The Covenant of Mayors and ICLEI have developed their own inventory methodologies and frameworks for members in the past and support the need for a standardised methodology to make city carbon inventories comparable. In comparison, conventional air pollutant inventories are less supported by initiatives and there is not the same focus on developing methodological frameworks, as will be discussed.

The aim of the literature review and city initiative review is to understand the decision making processes behind GHG and conventional air pollutant accounting at the city/regional level, how this relates to developing local strategies and actions, and the role of city initiatives and networks within this process.

The review will:

- Describe what makes an effective city-level GHG or air pollutant inventory by considering current frameworks and methodologies;
- Explore cities' decision-making processes for compiling and reporting inventory data ;
- Examine how city GHG and air pollutant inventories are used to support policymaking and citizen engagement;
- Identify why cities join city initiatives and networks and the main benefits of membership;
- Compare how city initiatives and networks engage with cities and their citizens, focussing on reduction of GHG and conventional air pollutant reduction.

3.2 Background

3.2.1 International climate change mitigation agreement

Over the last two decades, there has been growing acceptance of the need to stabilise rising greenhouse gas concentrations in the atmosphere due to human activity to minimise the potential dangerous impacts of climate change. In 1997, the Kyoto Protocol (linked to the 1992 United Nations Framework Convention on Climate Change) was adopted, committing its Parties to "internationally binding emission reduction targets" (UNFCCC, 2017). The Kyoto Protocol entered into force in 2005 with the detail for its implementation set out in the "Marrakesh Accords" at COP 7 in Morocco, 2001. The UNFCCC has 197 Parties and the Kyoto Protocol has been ratified by 192 of those.

Though Kyoto can be seen as the start of an international commitment to GHG emission reduction targets, international efforts to tackle climate change precede its adoption in 1997. The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 by the World Meteorological Organisation (WMO) and United National Environment Programme to provide policymakers with information on the scientific basis of climate change, prediction of future impacts and risks, and adaptation and mitigation options. Part of their climate change mitigation programme has focussed on the development of IPCC Guidelines for National Greenhouse Gas Inventories. These aim to support policy makers in calculation of legally binding targets as "methodologies for estimating anthropogenic emissions by sources and removals by sinks of greenhouse gases" (IPCC, NGGIP, 2017).

The European Commission also states a long commitment to international effort on Climate Change, and in 1991 issued the first Community strategy to reduce CO_2 emissions and improve energy efficiency. In June 2000 the EC launched the first European Climate Change Programme (ECCP I) and was developed with relevant stakeholders to include the necessary elements to implement the Kyoto Protocol. In 2007, EU leaders agreed the 2020 Climate and Energy Package, an integrated approach to combat climate change and increase energy security whilst strengthening competitiveness, and in 2008 put forward binding legislation to implement the 20-20-20 targets. (A 20% cut in GHG emissions against a 1990 baseline, 20% of total energy consumption from renewable generation, and a 20% increase in energy efficiency). The longer-term goal is for the EU to cut its emission by 80 - 95 % against 1990 levels. EU action towards these targets involves a combination of financial support and regulation such as the EU's emission trading system and legislation requiring member states to:

- support renewable energy sources to reach green energy targets (i.e. the 2009 Renewable Energy Directive revised in 2016)
- reduce energy use in buildings and industry, and to improve the energy efficiency of equipment and appliances (i.e. the 2010 Energy Performance of Buildings Directive, the 2012 Energy Efficiency Directive and the Energy labelling Directive to be replaced with new (2017) Energy Labelling Regulation)
- reduce CO_2 emissions from vehicles

In 2008 the UK Climate Change Act set the world's first legally binding national emission reduction targets of an 80% reduction by 2050 against a 1990 baseline. Other nations have since followed suit, setting targets that commit them to action to mitigate the impacts of future global temperature rise.

Climate change is recognised as a problem with a global impact requiring an integrated, international response. Though developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the impacts of climate change will be felt around the world, especially by developing countries who may face greater challenges when it comes to adapting to global temperature increases. As a result the approach to climate change governance has been top-down from the international to national to city/urban level. Growing understanding of the role of cities and their inhabitants in mitigating climate change is leading to a bigger focus on the city-level and the role of transnational collaborations and networks to find solutions to the problem of carbon emissions.

3.2.2 Air Pollution Legislative Landscape

Most people living in urban areas are regularly exposed to poor air quality. EEA, (2017) estimate that fine particulate matter continues to cause premature death of >400,000 Europeans annually with road transport, agriculture, power plants and industry and households being the biggest emitters in Europe. To address this challenge national and international governments have to take account of a number of legislative requirements. This legislative landscape for air quality management at an international, national and local level is quite complex as there are a number of interconnected international conventions, protocols and in Europe, Directives, which directly or indirectly impact on management approaches adopted by member states and cities. This legislative landscape has also influenced the engagement of citizens in those processes.

The UNECE Aarhus Convention, which covers 'Access to Information, Public Participation in Decision Making and Access to Justice in Environmental Matters' was adopted in 1998 and aimed to strengthen the role of members of the public and environmental organisations in environmental protection issues and provides greater access to information held by public authorities. In 2003, the Kiev protocol on Pollutants Release and Transfer Registers (PRTR) was adopted which aimed to 'enhance public access to information through the establishment of coherent, nationwide pollutant release and transfer registers'. In the European Union Air Quality Framework Directive (96/62/EC) (European Commission, 1996) and subsequent daughter Directives were developed, which Member States were required to transpose into national legislation by 1998. Today, modern air quality legislation in Europe has a substantial number of directives that influence air pollution directly through industrial, transport, fuel regulation etc. From an air pollution emissions perspective there a number of key protocols and directives which national governments operate within:

- The Gothenburg Protocol to the UNECE Convention on Long Range Trans-boundary Air Pollution (CLRTAP) sets emissions ceilings for pollutants and includes countries outside the EU. This Protocol was revised in May 2012 to set stricter emission reduction obligations from 2020. The Protocol has also been extended to set emission reductions for PM2.5.
- Within Europe, the National Emissions Ceiling Directive (2001/81/EC) aims to reduce national emissions through the application ceiling limits for certain atmospheric pollutants such as SO_2, NO_x, NMVOC and NH_3. This Directive has been replaced by the Directive 2016/2284/EU. These ceilings have to be met by Member States and are supported by a range of sectoral measures such as fuel quality or product standards to control emissions from road transport, industry, agriculture etc.
- The Ambient Air Quality Directive (2008/50/EC) consolidated the 1996 Framework Directive and its first three daughter directives. The aim of the directive is to protect human health and the environment. The Directive sets out legally binding limit and target values for ground level concentrations of a number of pollutants and sets provisions which oblige Member States to prepare and implement plans and programmes in the case of non-compliance.

3.2.3 The role of local government: why cities?

Environmental sustainability issues including noise, congestion, waste, high levels of energy consumption, poor air quality, and GHG emissions (Lombardi et al, 2017). By 2014 approximately 54% of the world's population resided in urban areas and this is projected to rise to 66% by 2050 (UN, 2014). Rapid growth of urban populations will put pressure on energy, resources and the environment as new infrastructure is built, and more services such as housing, water supply and digital communication are needed (Li and Yao, 2009). Though the exact, relative contribution of cities and their citizens to global greenhouse gas emissions is often disputed (Dodman, 2009,) urban growth requires urban areas to play an essential role in the response to both climate change mitigation and adaptation (Broto and Bulkeley, 2013). Climate change is a global problem requiring global governance, but GHG emissions arise from the activities of citizens in towns and cities and are influenced by the policy decisions of regional and local government (Bulkeley and Kern, 2006). Likewise, because the sources of GHG emissions and conventional air pollutants in cities are largely the same, air quality is also influenced by local activities and decisions. In addition, poor air quality has a direct detrimental influence on citizen's health meaning environmental governance has to consider the interdependencies with local health provision.

In terms of a requirement for local authorities to act on poor air quality, GHG reduction or other area where humans impact on the environment, Agenda 21 set out a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups at the UN Conference on Environment & Development in Rio de Janeiro in 1992 (UN, 1992). Since then, though cities have come to be seen as the most important level from which to tackle issues such as climate change and emissions (Egger 2006; McEvoy et al. 1998; Giardet 1999), they generally have to comply with policies and directives coming from higher institutional level be that regional or national, EU or international. Most environmental policies are multilevel (Wälti, 2010, p. 411; Huisingh, Zhang, Moore, Qiao, & Li, 2015) and require a collaborative approach, but this has an impact on the autonomy of cities to solve environmental problems. In recent years, efforts to combat climate change and other environmental issues such as air pollution have devolved from national level to city and regional level governance, and to include non-state actors as well. The inclusion of city initiatives and networks has the potential to provide a shared space between different actors to exchange information, standards and commitments, and to network, but could potentially lead to further fragmentation and incoherence when it comes governance and decision-making (Wilderberg et al, 2016).

3.2.4 City-scale carbon and air quality management

There has been an increasing amount of interest over the last approximately 10-20 years in quantifying urban greenhouse gas emissions on a sub-national level (Betsill and Bulkeley, 2007). See, for example, Lindley et al, 1996 for an early example of estimation of regional scale atmospheric emissions in the North West of England. Institutions, NGOs, researchers and policy makers have made considerable effort to develop methodologies, frameworks and standards for greenhouse gas emission inventories with which to aid urban policy

makers, and engage urban governments in mitigation pledges and strategies. They are many initiatives involved in the process of climate change governance and city-scale carbon management. Examples include the 'Urban and Regional Carbon Management' research initiative of the Global Carbon Project, transnational networks like ICLEI's 'Cities for Climate Protection', or; the 'C40 Cities' group; and the EU Covenant of Mayors initiative. Such groups and tools have been found to be important for advancing the technical knowledge around quantifying carbon emissions, necessary for successful climate protection policies but there are still gaps in this knowledge and a lack of evidence on their actual contribution to emission reductions.

The processes for gaining a technical understanding of city emissions, although improved in recent years, is still problematic. In 2010, Dhakal and Shrestha stated that *"a fully agreed framework and methods for such inventories of cities' greenhouse gas emissions are yet obscure"* (p.4754). In 2017 though there are now some established methodologies for carbon emission inventories (namely the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories) as the literature shows, difficulties in comparing cities and quantifying the impact of different activities remain. The challenges of quantifying and managing emissions have been well documented, by Dhakal 2010, Dhakal and Shrestha (2010, Kennedy et al (2009) and others, and the technical/data challenges for local authorities are discussed in more detail in section 3.3. In addition to technical difficulties cities also face political issues (see section 3.5.4) meaning that a lack of green leadership or political commitment to emission reductions also impacts on the ability of local authorities to successfully and substantially quantify and manage carbon emission.

From a policy and a management perspective in Europe it has been the EU Directives that have been the catalyst for the evolution of modern air quality management in urban areas over the last two decades. It is responsibility of each Member States to transpose EU Directives into their national legislation but not all Member States take a uniform approach as to the way in which the manage air pollution at a city scale. For example, in the UK, there is a policy disconnect between national and local air quality management approaches. The UK Government is responsible for compliance with the EU Directives while UK local authorities work within the Local Air Quality Management process set out in primarily legislation (Environment Act, 1995) and are responsible for 'working towards' air quality objectives set out in the National Air Quality Strategy, 2007 (Longhurst et al., 2009). Conversely, Malta has not devolved air quality management responsibilities and instead manages air pollution at a national level while working closely with city stakeholders.

The Ambient Air Quality Directive sets provisions with oblige European Member States to prepare and implement plans and programmes in the case of non-compliance. When a zone or agglomeration exceeds a limit value, the Directive requires Member States to take all necessary measures not entailing disproportionate costs. PM_{10} and NO_2 limit values were exceeded in all but five EU Member states and the target value for $PM_{2.5}$ in six Members States in 2014 (European Commission, 2016). As urban areas are usually the locations most effected be poor air quality, cities have become the focal point for areas of non-compliance, air quality assessments and the implementation of mitigation strategies.

While management processes at the city scale can vary from city to city and country to country the level of resource required is often commensurate with the scale of the air quality challenge and the legislative landscape within which that city operates. Gulia et al., (2013) reviewed air quality management approaches for urban environments and found that the successful implementation of urban air quality management plans had the follow key components e.g. air quality standards, air quality monitoring networks, emission inventory, air quality modelling, emission control strategies and public participation mechanism.

As discussed, the processes for quantifying and managing carbon and air quality at the city level are largely carried out separately but there is an argument for co-managing them because measures directed at one are likely to positively affect both. For example, Baldwin et al (2008 and 2009) consider the case for integrating local air quality and carbon management in the South West of England and set out the barriers and opportunities. The ClairCity is researching both air pollutants and carbon emission reductions and by examining the inventory processes for air quality and carbon management, this literature review will consider whether there are complementary areas that would support an integrated approach.

3.2.5 City initiatives and networks

In order to meet their environmental and climate change targets, local governments often engage with city-level initiatives and networks that support them in applying new methodologies and creating new partnerships with peer-cities, also at the international level. While there is not a standard definition of city initiatives, in this report they are the ways in which local governments' authorities engage with departments, citizens, business and in general stakeholders to tackle an issue. Based on Kern and Bulkeley (2009), transnational municipal networks can be defined according to three characteristics:

1) Members are free to join and leave;
2) They are characterised by non-hierarchical and polycentric governance
3) Members directly implement decisions taken within the network (Kern and Bulkeley, 2009, pp. 309-310).

Furthermore, this document will focus only on urban climate initiatives and networks that primarily focus on mitigation and emissions reductions. Examples of initiatives include the 'Urban and Regional Carbon Management' research initiative of the Global Carbon Project. The Urban and Regional Carbon Management is 'a place-based and policy-relevant scientific initiative to enhance understanding of the complex linkages between urbanization and carbon at different spatial levels from diagnostic as well as solution-seeking viewpoints' (Dhakal and Betsill, 2017, p. 550).

Examples of transnational municipal networks include ICLEI's 'City for Climate Protection', which supports local governments in their emissions efforts through a five milestone process

of ‘measurement, commitment, planning, implementing and monitoring’ (ICLEI, n.a) [5]. Another example is the C40 Cities’ group, which is a hub for networks that cover ‘mitigation, adaptation and sustainability topics of highest priority to C40 cities and with the potential for the greatest climate impact’ (C40, n.a)[6]. Finally, the EU ‘Covenant of Mayors’ involves cities committed to voluntary reduce GHG emissions. In particular, signatories commit to reduce CO2 emissions by at least 40% by 2030. The Covenant of Mayors has 7639 signatories [7]primarily based within the EU (but not exclusively) and has both a mitigation component and an adaptation component (Mayors Adapt).

Such city-level initiatives and transnational municipal networks have been found to be important for advancing the technical knowledge seen as a “critical foundation” for successful climate protection policies (Betsill and Bulkeley, 2007). While a review of each individual initiative and network is beyond the scope of this document, the characteristics, the benefits of engaging with these initiatives and networks, the barriers, the strengths and the limitations will be analysed through a literature review (section 3.5). Furthermore, the three case studies of Wellington, Durban and Glasgow will contribute to integrate the understanding of cities’ engagement, which will primarily informed by the literature review.

3.3 GHG emission inventories and footprinting

3.3.1 International GHG emission inventories

The United Nations Framework Convention on Climate Change’s (UNFCCC) ultimate objective is to achieve “stabilisation of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous interference with the climate system” (UNFCCC, 2017). To achieve this objective, estimation of GHG emissions and removals by Parties of the UNFCCC is considered essential and industrialised countries are required to submit annual inventories of their greenhouse gas emissions for all years since the 1990 baseline.

At COP 3 in Kyoto 1997, the UNFCCC reaffirmed that the 1996 IPCC Guidelines for National Greenhouse Gas Inventories should be used by member states as “methodologies for estimating anthropogenic emissions by sources and removals by sinks of greenhouse gases” in calculation of legally-binding targets during the first commitment period (IPCC, 2017). The IPCC Guidelines underwent a methodological revision in 2006 (IPCC, 2006). The revised 2006 Guidelines provide an internationally agreed, detailed methodological framework for all member states to develop national emission inventories and assessing GHG emissions from four main sectors: Energy; Industrial Processes and Product Use; Agriculture, Forestry and Other Land Use; and Waste.

[5] Cities for Climate Protection Campaign http://archive.iclei.org/index.php?id=10829 [last access 30/10/2017]
[6] C40 cities Networks - http://www.c40.org/networks [last access 30/10/2017].
[7] On the 30th of October 2017

An internationally agreed framework for national reporting of GHG emissions allows inventories to be relevant, complete, consistent, transparent, accurate, and, most importantly, comparable. This allow countries to consider their progress against other Parties and for estimation of national contributions to global atmospheric concentrations of emissions. The rest of this section will examine how city-level emission inventories and accounting methodologies have developed from the IPCC national guidelines, and will consider the efficacy of applying national, as well as corporate methodologies at the city-level to support emission reduction actions and strategies.

3.3.2 City-level emission inventory methodologies

There is no international binding requirement to produce emission inventories or account for carbon at the city level and, as of yet, no global, all-inclusive, harmonised protocol for quantifying GHG emissions in cities and regions. However, the recognition by civic leaders, businesses and policy-makers that cities and urban areas are where the majority of people live (54% of the world's population in 2014 (UN, 2014)) and where the majority of changes will need to occur has led to the development of standards and methodologies aiming to fill this gap. Traditionally, city-level inventory methodologies are based on the IPCC Guidelines for National Greenhouse Gas Inventories (described above) and the GHG Protocol: A Corporate Accounting and Reporting Standard for Sustainable Development from the World Resources Institute and the World Business Council (Li et al, 2017).

Ibrahim et al (2012), Pandey et al (2011) and Bader and Bleischwitz (2009) compare a number of international and corporate frameworks for producing city-level emission inventories and carbon footprint/accounting methods of estimation. These include the ICLEI Global Reporting standard in the International Local Government GHG Analysis Protocol, the European Commission's Covenant of Mayors baseline emissions inventory, the UN/World Bank International Standard for Reporting Greenhouse Gas Emissions for Cities and Regions and the Greenhouse Gas Inventory Protocol (GRIP) (2010). These methodologies have been developed by institutions for use by local government policy makers and can be considered as a direct tool for "urban climate action" in climate change governance (Widerberg et al, 2016). Two of the studies (Ibrahim et al, 2012 and Pandey et al, 2011) also consider corporate tools such as the GHG Protocol.

Though not universally used, the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) developed from both the IPCC guidelines and the GHG Protocol and published in 2012 (after all three studies) is probably the closest to an international standard. The GPC is a joint project by ICLEI Local Governments for Sustainability, the World Resources Institute, C40 Cities Climate Leadership Group, World Bank, UNEP and UN. It defines and combines the reporting categories and Scopes from the IPCC Guidelines and the GHG Protocol and marks a development in city-level emission inventories to include a broader range of emission sources than national inventories.

GHG emission inventory or accounting approaches at the city/regional level have different requirements, which a draft working paper by UNEP, UN-Habitat and World Bank (20??) ascribes to emission attribution. For countries, inventories focus on production and the

emissions that are physically released within a geographical boundary. For cities it is more complex as they are areas with “many inflows and out-flows of goods and services” (p11, UNEP, 20??). The complexity of attributing emissions in an urban area is an issue that underpins much of the current literature on carbon inventories and defines the decision-making process around what data to include to inform policy making. Hermansson and McIntyre (2014), for instance, identify the importance of defining the spatial interdependencies that exist in the composition of the emissions total within regions and nations. Lombardi et al, (2017) in their more recent review of urban carbon footprint approaches classify different systems and inventory approaches as either “direct” and “spatial”, based on the IPCC national guidelines, or “life-cycle based” and “economic” methods taking bottom-up, top-down or bottom-up approaches. None of these approaches specifically include citizen participation as part of the development of a city tool kit for emission estimation.

The next two sub-sections of this report will look more closely at the range of decisions policy-makers need to make when developing urban carbon inventories or footprints, and the relationship between inventory data choices and policy actions. It will also examine the evolution of carbon inventory approaches and the ongoing utilisation of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories and well as development of perhaps more holistic, consumption-based approaches.

3.3.3 Decision making for carbon inventories and footprinting

Compiling city and regional scale carbon inventories requires decisions to be made about which methodology to use and what data to include that consider the resources, time and skills available to local authorities. The problems with compiling accurate and complete data sets in a timely manner are frequently identified in the review of the literature (see, for example, Li et al, 2017; Ramsden and Smardon, 2014; Kokani and Skea, 2014) and Dhakal (2010), Dhakal and Shrestha (2010) and other have documented the main challenges for cities. As this section highlights, the choice of inventory or footprinting methodology (discussed in section 3.3.4) will largely define the data requirements. Some inventory methodologies such as the widely used GPC are fairly prescriptive in their data requirements, which sets its own challenges for local authorities who may have difficulties accessing data for some sectors included in the framework. The advantage, as we shall see if that this approach includes fewer emission sources than inventories that include “Scope 3” emissions or lifecycle analysis, and additionally provide more reliable estimates of emissions.

Scopes

Emission “Scopes” 1, 2 and 3 were first defined in the corporate GHG protocol and are redefined for the city-scale in the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC):

Scope	GHG Protocol Definition	GPC definition for city level
Scope 1	All direct GHG emissions	GHG emissions from sources located within the city boundary
Scope 2	Indirect GHG emissions from consumption of purchased electricity, heat or steam	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary
Scope 3	Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities (e.g. T&D losses) not covered in Scope 2, outsourced activities, waste disposal, etc.	All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary

The literature review identified a large number of studies using approaches that include different combinations of Scopes 1, 2 or 3 in emission inventories and carbon footprints. Lombardi et al (2017) provide a useful summary of the different approaches. Urban carbon footprints can be either Spatial "direct" focussed on production-based emissions under Scopes 1 or 2 or they can be Economic "life-cycle based" including consumption based emissions as well under Scopes 1, 2 and 3. Criticism of using inventory frameworks based on the IPCC national guidelines is that only including, at most, Scope 2 emissions does not account for emission embedded in imports and exports. Cities are closely interconnected with the surrounding region and it is harder to define the inventory along territorial lines, as is done in spatial "direct" accounting than it is for national GHG inventories (Li et al, 2017). Kokoni and Skea (2014) compare territorial and life-cycle emission reporting and the relative uncertainty of emission estimates for each type.

Most emissions, notably CO2 and other energy sector emissions are estimated rather than measures by multiplying activity data such as the distance travelled annual by different vehicles by and emissions factor. Inclusion of "upstream" or "downstream" emissions in a life-cycle based accounting approach increases the uncertainty of estimates as it is harder to obtain accurate activity or emission factor data for consumption based emissions. Nevertheless, there are obvious benefits to including consumption-Scope 3 emissions in inventories. Millward-Hopkins et al (2017) argue that the main issue with city mitigation strategies is that they are too narrowly focussed on production-side emissions leaving a large proportion of a cities emissions and the behaviours that cause them ignored by policy strategies and actions.

Spatial boundaries and ownership

When compiling urban greenhouse gas emission inventories, methodological issues arise from “boundary problems”: where to allocate emissions (Dodman, 2009). As discussed, accounting for local emissions on a production basis only is agreed to be problematic as it may show progress against targets whilst ignoring the potentially problematic consumption habits of the city’s inhabitants. The smaller the scale, the greater the problem caused as it becomes increasingly difficult to identify which emissions should be allocated to a particular place.

A number of studies consider the issues with spatial boundaries in inventories. Chen et al (2017) examine spatial and intersectoral linkages in multi-region input and output, consumption based modelling (an emission estimating method discussed in the next section) and conclude that though there are a range of applications for modelling, further work is needed to understand the relationship between greater spatial disaggregation and the level of uncertainty of estimates. Hermannsson and McIntyre (2014) highlight the importance of understanding the spatial interdependencies that exist in the composition of regional emission estimates specifically looking at the city of Glasgow. They identify that the choice of accounting method defines the spatial boundaries of the emission estimates. In turn, this has an impact of the policy implications that can be reached from the data and influence which areas are identified as targets of mitigation activities.

An issue closely related to the boundary problem, is ownership and who is responsible for emission reporting and management of emissions which can be considered cross-boundary? Whichever accounting method is applied to a region, it is important to be aware of double counting, where either carbon emissions or savings are counted more than once in an inventory.

There are many choices to be made around data for emission inventories and it is beyond the scope of this literature review to explore all of them. Local authorities should also consider the baseline year they are using for comparison, emission factors and whether they use national averages or regional specific estimates, and which activity data to use to best represent behaviour and choices in the city. In making these decisions, local authorities need to decide what the purpose of the inventory is. Is the focus of emission inventories to be comparable with other cities or is it to identify action areas for policy-makers? How is the demand for accurate and complete data sets balanced against the time and resource available city authorities have and the level of expertise required for the analysis? These questions are considered in the next section which asks what makes an effective inventory.

3.3.4 The evolution of city level emission inventories

What makes an effective inventory?

In the literature, a number of studies make recommendations for inventories: UNEP (2010) highlight the importance of transparency when reporting emissions and the need to ensure the use of reliable and consistent methods wherever possible. As there is no agreed city-

specific methodology, there are no ‘rules’ about how to estimate a city’s emissions, but the more ‘standard’ the approach used the more easily comparable it will be. Their recommendations from 2010, with the aim of establishing a common standard for city emissions inventories include:

- Transparent, consistent, comparable, complete and accurate inventories sufficiently disaggregated for policy development.
- Using IPCC guidelines (IPCC, 2006) for determining emissions from energy, industrial processes and product use, agriculture and land use, and waste.
- Annual, calendar year emissions of all six Kyoto gases.
- Reporting in terms of CO_2e
- Including an uncertainty assessment and quality assurance.

Ibrahim et al (2012) have further advice:

- inventories should clearly distinguish between direct, in-boundary emissions and upstream emission
- regardless of which inventory methodology is used, cities should start reporting more complete direct and upstream emissions
- cities should always report activity data such as energy consumption and emission factors; emission inventories should include degrees of confidence with data
- cities should state who compiled the inventory and the emission sources, and clearly state the boundaries
- they should take care to avoid double counting and use terminologies and emission factors compliant with IPCC national inventories
- inventories should facilitate local or metropolitan reporting to maximise mitigation and funding opportunities
- cities should ensure consistency with state and national inventories

See also, Wright et al (2011) foe similar recommendation on including emissions data and the suggestion of using hybrid life-cycle assessment and environmental input-output process (see section 3.3.5.

The GPC inventory methodology (GHG Protocol, 2017) states that in order for cities to represent a fair and true account of emissions the following five accounting and reporting principles should be met: relevance; completeness, constancy, transparency, accuracy. Erickson and Morgenstern (2016) discuss the GPC principles in the context of the City of Seattle in the US and question the policy relevance of emission inventories if the focus is on meeting these standards. They argue that following the GPC methodology requires too much work for local authorities and the focus on completeness can lead to emission signals that can inform policy being obscured. In developing a ClairCity toolkit as part of a bespoke policy package for cities around emission reporting, the trade-off between data accuracy and completeness with policy relevance needs to be considered.

Input-output and life-cycle analysis: top down and bottom-up approaches

The definitions of top-down and bottom-up emission inventory approaches is described in section 3.4.4 in relation to air pollutants but is also relevant to carbon emissions with top-down inventories using more national level emission, statistical and economic data and

disaggregating to the regional level and bottom-up approaches making greater use of local data sources. In line with the recommendations given by UNEP (2010) and Ibrahim et al (2012) in recent years there has been a growing focus on including life-cycle analysis in emission inventory reporting and building on the GPC process to include more data in emission inventories. Life-cycle emissions include all direct and indirect emissions and are generally applied to goods and services or production processes Kokoni and Skea (2014). It covers upstream emissions associated with intermediate goods and services as well as downstream emissions associated with waste disposal. Though life-cycle analysis is a well-established procedure in corporate estimation of carbon footprints the data and time requirements at the urban level are significant as it is a bottom-up process. Lombardi et al. (2017) report that the literature does not recommend use of LCA for cities or regions for this reason.

Input-output modelling is a top down model with significant history in economics for analysing the embodied emissions in national trade. For city-level carbon inventories, multi-regional input output modelling has theoretical benefits in terms of capturing consumption based emissions but there is a high degree of uncertainty from the method which disaggregates territorial emissions to include in models of economic data and transaction matrices (Kokoni and Skea, 2014)

3.3.5 Using GHG emission inventory data

There is a large body of research on the use of emissions inventory data and accounting methods to support sector or country specific modelling of energy and emissions. This report provides a brief overview of some of the main approaches as applied at the city level and the objectives but it is not within the scope of this piece of work to review the full literature on quantitative modelling of carbon emissions data.

Broadly, modelling of emission inventory data serves two purposes. It allows for an analysis of the relative components due to different influencing factors on historical GHG emissions or it enables the development of scenarios for achieving emission reductions in the future. In the first category, decomposition analysis is a commonly used method for identifying the different components. Traditionally used to compare countries or sectors within countries (see for instance Ang 2004) the systematic review identified a number of papers using urban/city-inventory data in decomposition analysis, particularly in Chinese cities. See for example, Zhao et al (2014) and Yang et al (2016). Other studies have used other statistical analysis methods to quantify the influence of different factors on emissions, including input-output analysis discussed in the previous section. See for example the analysis of 49 Japanese cities by Long et al (2018).

In example of modelling to develop climate change mitigation scenarios and policy, Assoumou et al (2015) investigate long-term energy and CO2 emissions at the city scale using a bottom-up, disaggregation approach to analyse energy demand and emission data. At the international scale there is a long history of using inventory data to develop policy scenarios namely the IPCC special report on emission scenarios. A more in-depth review

of city-scale scenario development can highlight transferable approaches that could be used in the citizen focussed ClairCity toolkit for cities.

3.3.6 Emissions reporting and city engagement

This final section examining the literature related to city level carbon inventory processes considers how cities currently engage with their businesses and citizens. Stakeholder engagement in emissions reporting is highlighted as a requirement to maximise potential mitigation opportunities and potential funding by UNEP (2010). Assoumou et al 2015 consider the need to develop energy and environmental plans that raise citizens' awareness. They focus on bottom-up modelling of emissions and end-uses of energy at the sub-urban level which allows for a greater focus on behaviour. Bartling (2017) highlights the important role of citizens in advocating for robust climate change policy. Overall though, there is a gap in the carbon inventory literature on the processes for how to engage businesses and cities in compiling and reporting emissions and the wider carbon management process. This is probably because, traditionally, city-level carbon inventory methodologies have developed from national, top-down approaches to be used by local authorities, policy-makers and researchers.

It is unclear whether engaging citizens in this process has ever been examined as a potential benefit to cities. The aim of ClairCity is to engage citizens in finding the best local options to reduce air pollutants and carbon emissions. The ClairCity ethos suggests that greater engagement of cities in current carbon inventory approaches could lead to greater local action to reduce emissions and air pollutants. The lack of research in this area of the benefits of engaging citizens in emission inventories and reporting to both raise awareness and develop local policy options is a knowledge gap that ClairCity can seek to address.

3.4 Inventories for conventional air pollutants

3.4.1 International/EU inventory frameworks?

An emission inventory provides an accounting mechanism of all air pollution emissions and associated data from sources within a specified area and over a specific time interval. At the city scale, air pollution emission inventories have a multitude of applications, including the identification of sources of pollution and understanding their magnitude in terms of emission releases; input data to air quality models to support source apportionment; identification of source for mitigation strategies; and monitoring the improvement in emissions based on the implementation of mitigation strategies (Mohan et al., 2012). As with carbon emission inventories, air quality emission inventories are sensitive to a number of inherent assumptions and uncertainties depending on sectors being accounted, such as, emission factors utilised or activity data sources.

In recent decades, the emphasis has shifted from air pollution control (i.e. the control of emissions from discrete point sources) to air quality management (i.e. management of

ambient air pollution concentrations from a number of diffuse sources). It could be argued that the importance of city scale air pollution emission inventories has also shifted from a fundamental stand-alone tool in emission control to a important step in the larger methodological process of quantifying air quality concentrations in cities. The UK Air Quality Expert Group (AQEG, 2013) stated that:

> '*emission inventories are the cornerstone of air quality management and incorrect emission estimates will have important consequences for the whole air quality management process. Erroneous emission estimates will have a direct bearing on the quality of policies developed to mitigate air pollution and could result in ineffective or misdirected emissions control measures being implemented*'.

3.4.2 City scale air pollutant inventory methodologies and inherent challenges

At the city scale, for an emission inventory to be useful, it is important that the spatial (location) and temporal (time variation) distribution of emissions and their sources is as accurate as possible with a high resolution. However, many cities may not have the resources, expertise or legislative drivers required to develop local 'bottom-up' emission inventories and instead extrapolate local data from 'top-down' national or regional inventories.

- A **top-down** inventory is characterised by the use of high-level statistical data such as fuel consumption, production, vehicle activity statistics etc. with published emission factors. While these inventories lack detailed spatial and temporal information and emissions from individual sources, they can be collated with little effort and provide a good overview of the most significant sources.
- A **bottom-up** inventory is characterised by the inclusion of more detailed local knowledge of sources locations, specific emissions, specific consumption data etc. These bottom-up emissions give a much more useful insight to support local air quality management processes.

Unlike greenhouse gas inventories, conventional air pollution city-scale inventories do not have an internationally agreed methodological approach, equivalent to the GPC for example. However, there are a number of methodological guidebooks, toolkits and databases, which, whilst not specifically developed for that purpose, can support municipalities and local authorities in developing emission inventories. These include:

- **EMEP/EEA Air Pollutant Emission Inventory Guidebook** – formerly called the EMEP CORINAIR emission inventory guidebook, this guidance provides advice in estimating emissions from both anthropogenic and natural emissions sources. While the Guidebook is designed specifically for national reporting against the UNECE Convention on Long-range Transboundary Air Pollution and the EU National

Emissions Ceiling Directive (2016/2284/EU) it includes adaptable methodological approaches for city scale inventories[8].

- **US EPA AP-42 Compilation of Air Emission Factors** - The United States Environmental Protection Agency (USEPA) has developed a large compendium of emission factors, known as AP-42, which includes emission factors for most of the pollutants relevant for city inventories[9].
- **CiteAirII** – EU funded project that produced a guidebook on the integration of greenhouse gases into air pollutant emission inventories at a local scale[10].
- **FAIRMODE (Forum for Air Quality Modelling)** – a joint initiative between EEA and EC Joint Research Centre (JRC), FAIRMODE has a sub-group that addresses urban emissions and projections[11]. FARIMODE also provides tools such as SPECIEUROPE 2.0[12], which is a repository of source profiles in urban and background areas in Europe (Pernigotti et al, 2016) and the European Composite Map Platform[13].
- **Sector specific toolkits and data sources** e.g. Transport - TREMOVE is a policy assessment model that considers emissions from the transport sector[14], COPERT Road Transport Emission software[15] and HBEFA the Handbook Emissions factors for Road Transport[16].
- **Dispersion Model specific toolkits** – many atmospheric dispersion model software providers also provide linked emission inventory toolkits, for example:
    - EMIT Toolkit which is linked to ADMS-Urban (Cambridge Environmental Research Consultants, UK)[17]
    - Emissions View Toolkit which is a GIS-based emissions inventory system linked to commonly used dispersions models like AERMOD and CALPUFF (Lakes Environmental, Canada)[18]
    - Sparse Matric Operator Kernel Emissions (SMOKE) model which estimates the magnitude and location of emission source and feeds into the CMAQ suite of models (Community Multi-scale Air Quality Modelling Systems, US Environmental Protection Agency)[19]

Many of these toolkits and guides will be difficult for a local authority to access and interpret because they are principally designed to be used by researchers and consultants, rather than policy makers. There is currently a gap in air pollutant inventories for local authorities, where unlike GHG inventories there is no preferred or recommended inventory process making it difficult for local authorities to do the work “in house”.

[8] https://www.eea.europa.eu/publications/emep-eea-guidebook-2016
[9] https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors
[10] http://www.citeair.eu/fileadmin/Deliverables_and_documents/Guidebook_Integrated_Emission_Inventories_-_final.pdf
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[15] http://emisia.com/products/copert
[16] http://www.hbefa.net/e/index.html
[17] http://www.cerc.co.uk/environmental-software/EMIT-tool.html
[18] https://www.weblakes.com/products/emissions/index.html
[19] https://www.epa.gov/cmaq

3.4.3 Compiling city scale inventories

Air pollution emission inventories, like carbon inventories, are typically based on inherent assumptions, best guesses, statistical data and professional judgements (EEA, 2011). To evaluate these estimates, different approaches can be applied such as alternative emission assessment, examining the trends in ambient air concentration, inverse modelling, source apportionment and receptor modelling (Friedrich and Reis, 2004; Pulles and Builtjes, 1998). The validation of emission inventories is very challenging and complex. Practitioners utilise air pollution dispersion models to generate pollution concentrations using inventory data and then compare the results with ambient pollution monitored data. However, the verification of the model results makes it difficult to determine if variation exists due to a poor emission inventory or due to poor dispersion model performance. AQEG (2013), considered the linkage between emission inventories and ambient measurements. They concluded that feedback between the two areas tends to be *ad hoc* and not considered in a thorough and systematic way, leading to missed opportunities to improve inventory verification and provide confidence that there is consistency between emission estimates and concentrations in the atmosphere.

Differences exist between 'top-down' and 'bottom-up' inventories; typically the under/over estimations are due to variations in input data. Lopez-Aparicio et al (2017) assessed the discrepancies between 'bottom-up' and regional 'top-down' emissions inventories in Norwegian urban areas and found that the three regional emission inventories were under-estimating NOx and PM_{10} traffic emissions by approximately 20-80% and 50-90% respectively. This was thought to be linked to the absence of non-exhaust emissions due to suspension in the regional inventory for PM_{10} and activity data for NOx (the local inventory used actual measure traffic data while the regional inventory used national estimates using fuel sales and population data).

Guevara et al (2016) described the Δ-Emis tool for emission inventories, recently developed by FAIRMODE, that allows for the comparison of 'bottom-up' and 'top-down' emission inventories using four different comparison methods: pollutant emission comparisons across sectors; quantification of the differences between inventories allocated in terms of activity data and emission factors; emission per capita comparisons; and comparison of pollutant ratios. Related to this study, Thunis et al., (2016), were able to identify meaningful information in terms of discrepancies between the total emissions reported by macro sector and pollutant, contribution of each macro-sector to the total amount of emissions released by pollutant, and the identification and quantification of the different factors causing the discrepancies between total emissions. Both studies concluded that further roll out and application of the comparative approach in regions and cities across Europe would allow for the development of rules and guidance to improve the quality and consistency of inventories.

3.4.4 Using air pollution emission inventories

In the UK, the National Atmospheric Emissions Inventory (NAEI)[20] provides a Greenhouse Gas Inventory and an Air Quality Pollutant Inventory providing data on sulphur dioxide, nitrogen dioxide, non-methane volatile organic compounds, ammonia, particulate matter emissions from a number of sources including transport, industry and agriculture. At a national level, this data is used to report against international and EU legislative requirements (e.g. National Emissions Ceiling Directive). Most national government have similar national level inventories that can be adapted for local city-scale applications. As an example, for the purposes of Local Air Quality Management in the UK, this national level data within the NAEI is spatially and temporally disaggregated for local authorities and 1km x 1km resolution emission maps and datasets provided. Similar global emissions inventories such as EDGAR (Emissions Database for Global Atmospheric Research (Janssens-Maenhout et al., (2017); Huang et al, 2017)), REAS (Regional Emissions Inventory Asia)[21] and GAINS[22] provide low-resolution datasets that can be explored and utilised by cities. However, the accuracy of these national and global datasets may be different when compared to an emissions inventory that utilised local 'bottom up' data (see Section 3.4.2).

Granier et al (2011) compared global and regional inventories for different regions of the world. They conclude that the identification of all the reasons for the differences between the inventories is difficult to establish quantitatively. However, one of the key reasons cited suggested that different inventories are updated at different intervals and therefore their respective reference activity data and emission factors are not comparable.

Unlike greenhouse gases inventories that use Scope 1, 2 and 3 emissions (as described in section 3.3.3) to categorise and organise their data, city scale air pollution emission inventories use different categories. For example, inventories may categorise by the pollutant being studied (e.g. NOx, PM, O_3, SOx and/or VOCs), by source (road transport, shipping, aviation, energy/power, industry, domestic, agriculture, natural) and nature of that source (point, area, line) or by the specific purpose for which the inventory is generated (e.g. source apportionment studies, dispersion modelling studies, mitigation strategies). The following are examples of applications of emission inventories in isolation, or as part of a larger air quality study, at the city scale for the purposes of air quality management and research[23]:

Air pollution modelling at the City Scale - Borge et al (2014) utilised SMOKE to undertake an emission inventory at four different domains to support a modelling study of Madrid for NO_2. They conclude that emission inventories must satisfy a number of conditions such as consistency across the spatial scales involved in the analysis, consistency with the emission inventories used for regulatory purposes and versatility to match the requirements of different air quality and emission projection models. Holnicki et al (2017) used an emission

[20] http://naei.beis.gov.uk/
[21] https://www.nies.go.jp/REAS/
[22] http://www.iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.html
[23] The inclusion of these studies is not an endorsement of the quality of research and does not consider all studies that have used emission inventories, rather they are just illustrations of the potential application of emission inventories at the city scale around the world.

inventory to support their CALMET/CALPUFF modelling of air pollution in Warsaw identifying transport and the municipal sector as the major contributor.

Comparison study - Pouliot et al (2012) compared emission inventories and model-ready emission datasets between Europe and North America as part of the AQMEII project. A number of guides, toolkits and models were utilised and assessed in the study including the EMEP/EEA Air Pollutant Emission Inventory Guidebook, SMOKE, TREMOVE, GAINS model etc.

Source Apportionment and Trend Analysis – Qiao et al (2018) used the CAMQ modelling suite to undertake source apportionment of $PM_{2.5}$ for 25 Chinese provincial capitals and municipalities. The study explored seasonal trends and variations and identified the largest source contributors (industrial, residential). Squizzato et al (2016) explored local and long-range contributions to the composition of $PM_{2.5}$ in the Po Valley, Italy. Henschel et al (2013) studied SO_2 patterns in 6 EU cities (Athens, Barcelona, Brussels, London, Paris and Vienna) and stated that a limitation of the study was not being able to get a detailed emission inventory of the different emissions sources in each city thereby limiting their understanding of the influence of each source type on observed diurnal variations.

Longitudinal studies – Diapouli et al (2017) assessed the evolution of source contributions over a decade for two metropolitan urban areas in Greece (Athens and Thessaloniki). The findings demonstrated reduction in emissions due to control measures and technological development while also acknowledging the effects of the financial crisis in Greece, which has led to decreased economic activities and the adoption of more polluting practices by the local population in an effort to reduce living costs. Milando et al., (2016) explored trends in $PM_{2.5}$ emissions in Detroit and Chicago between 2002 and 201 using the National Emission Inventory. Gianelle et al, (2013) used an emission inventory to understand the sources contributing to B(a)P pollution in the Lombardy Region of Italy.

Management Strategies – Thunis et al., (2016) used an integrated assessment modelling tool (SHERPA) in London to assess $PM_{2.5}$ emissions and concentrations and the impact of hypothetical mitigation strategies. Mitchell et al., (2005) used an inventory and dispersion model in Leeds, UK to determine the impact of five road pricing schemes

Information provision – Jensen et al., (2017) undertook a high-resolution multi-scale air quality modelling exercise for annual concentrations of NO_2, PM_{10} and $PM_{2.5}$ for all 2.4 million addresses in Denmark. Bringing together several emission inventories and a suite of chemistry-transport models, the study generated an air quality map provided on a WebGIS platform called AirStreet[24] to provide information to the public on air pollution.

[24] http://luftenpaadinvej.au.dk

3.4.5 What makes an affective inventory?

A number of studies have put forward suggestions of what makes a good inventory methodology. Gulia et al (2015) undertook a review of urban air quality management approaches considering practices in various international countries including approaches to emissions inventories. They found that the practices employed were specific to the countries needs and requirements within existing regulatory management frameworks. In the developed countries, these practices allowed for the provision of trends and evidence related to PM_{10}, O_3, NO_2, SO_2, CO, and VOCs emissions and concentrations data. Gulia et al (2013) concluded that the key components to a successful urban air quality management process included air quality objectives, monitoring, emissions inventory, prediction and forecasting tools, control strategies and public participation. Conversely, for developing countries they concluded that the effective and efficient implementation of an air quality management plan still remains a challenging task due to lack of government commitment and stakeholder participation, weaknesses in policies, standards and regulations, lack of real–time air quality data and emission inventories (KEI, 2002; ADB, 2006; Naiker et al (2012).

Another study by Kura et al (2013) analysed urban air pollution problems in China, India and Brazil at a macro urban scale. They propose a system based methodology that includes the identification of critical pollutants and their sources; the establishment of an air quality monitoring network; development of an emission inventory; source prioritization; control strategies, and the development of decision support system.

In 2012, the European Environment Agency and the European Commission (DG-Environment) established the Air Implementation Pilot Project, which, among other objectives, assessed the status of local emission inventories, and how well they inform the development of local action plans to improve air quality (EEA, 2013)[25]. The study assesses air quality and greenhouse gas emission data from twelve European cities. The conclusions identify that good quality input data is essential but can be very challenging for local authorities to obtain. There are significant differences in the comparability and consistency between city inventories with respect to method, emission factors, sources, source definitions, updates and data storage. There is also a need for guidance on estimation of fugitive and diffuse emissions, for quality assurance and for the establishment of local inventories in general. Interestingly, greenhouse gas estimates at a local scale performed better and several cities actively explored the synergies in integrated air quality and GHG inventories (EEA, 2013).

[25] EEA, 2013, Understanding pollutant emissions from Europe's cities: Highlights from the EU Air Implementation Pilot Project, EEA, Copenhagen, 2013 doi:10.2800/51246

3.5 City initiatives, trans-national municipal networks and climate change governance

City initiatives are justified as facilitators of problem solving and decision making around environmental problems. There are a large number of city initiatives at national, European/Continental and International level. This section reviews the existing academic evidence on cities' engagement with initiatives to reduce carbon emissions and networks that are set up to support them in. This section aims to answer the following research questions:

- Why do cities and cities' leaders decide to engage with local initiatives and networks?
- What are the benefits?
- Under what conditions these initiatives are likely to be effective and what are the challenges?
- What are the benefits of stakeholder and citizen engagement with emission inventory reporting according to the literature, and is effective citizen engagement considered an indicator of successful city action.

There is an established literature that explored the role of cities and local authorities in dealing with carbon emissions. For example, Betsill, 2001; A.T. Chatfield & Reddick, 2016; Chebbi & Nouri, 2016; Grondys, Kott, & Sukiennik, 2016; Heyvaert, 2013; Hoppe, van der Vegt, & Stegmaier, 2016; Krause, Yi, & Feiock, 2016). A comprehensive review of the literature is beyond the scope of this document; instead, the review will look at:

1) City initiatives and carbon management
2) Trans-national municipal networks
3) Success factors, challenges and criticisms of city initiatives and networks
4) Smart city approaches to carbon management
5) Engagement with communities and citizen

3.5.1 City initiatives and carbon management

When dealing with city-level carbon management, the literature and practice on city initiatives report that cities' monitoring, reporting and verification of greenhouse gas emissions has been overwhelmingly voluntary (Cochran, 2015). There are a number of reasons for the voluntary nature of city inventories, including the fact that local governments cannot control all the emissions under their jurisdiction (boundary and ownership issues) and therefore they are unlikely to accept mandatory requirements (Cochran, 2015). Nevertheless, as this review has shown in section 3.3, there has been a proliferation of voluntary reporting frameworks and protocols aiming to harmonize the local carbon monitoring process across countries, and some of these have been promoted by city initiatives. As an example, the Covenant of Mayor promoted the Sustainable Energy Action Plan (SEAP) to reduce fossil fuel consumption and carbon emissions under the provision of the Kyoto protocol. Recent research has tested its efficacy, its strengths and weaknesses (Delponte, Pittaluga, & Schenone, 2017). In particular considering aspects such as cost-

benefit analysis, bankability, peer review and participatory processes as essential for an effective monitoring framework (Delponte et al., 2017).

Carbon management initiatives have other spin-off benefits in addition to facilitating the carbon inventory process, such as creating within-city partnerships and wider network. In this regard, White and Holpuch (2014) describe how the City of Bloomington, Indiana (US), produced its first "Global Reporting Initiative"[26] sustainability report through a close collaboration with two Indiana university, a local sustainability company and the city council. The research highlighted the wider benefits for students and the community that these type of initiatives can bring about, beyond the carbon reporting itself.

3.5.2 Trans-national municipal networks

Individual city initiatives and the delegation of powers from central governments to lower levels can encourage sub-national actors, and particularly cities, to interact horizontally between them, thus fostering the creation of trans-national municipal networks (Coen & Thatcher, 2008). The phenomenon of trans-national municipal networks steered the hopes of many scholars and practitioners as these networks seemed to represent an important supporting mechanism for local authorities against the backdrop of governments' lack of action (Fünfgeld, 2015). As Fünfgeld points out, trans-national municipal network cannot impose regulation or enforcing respomsibilities on their members, other than in relation to membership conditions (2015, p. 68). Nonetheless, they influence members' priorities and actions thorugh knowledge sharing, best practice, opportunities to bid for projects, innovation spreading etc. (Hakelberg, 2014). In this regards, Fünfgeld reports that trans-national municipal networks have been supporting local authorities in implementing the Carbonn Climate Registry[27], a framework for reporting actions and achievements in the field of climate change (2015, p. 70).

Trans-national municipal networks can also play an important advocacy role internationally, thus contributing to raise the local authorities' profile in global climate change governance. In this regard, Rashidi and Patt (2017) argue that in the absence of national and international commitments, city networks 'can contribute to the generation of global strategies, which in turn can translate into climate mitigation benefits', provided that cities become members of those networks that provide 'sets of tailor-made policies that meet their actual requirements' (2017, p. 14). Interestingly, in contrast to previous studies (Zahran et al 2008), Rashidi and Patt's paper found a positive correlation between GHG emissions and the adoption of climate policies and explain that the underlying reason for this might be that cities are becoming more concerned about the effects of climate change and their own, increasing, carbon footprint (Rashidi and Patt, 2017, p.13). Moreover, with regards to the relationship between participation in a network and cities' mitigation policies, Lee and Koski (2014) (p

[26] https://www.globalreporting.org/Pages/default.aspx
[27] http://carbonn.org/initiatives

490) looked at 57 C40 member cities and their results point towards a growing recognition of these networks:

> *"membership in the network is important, but the network's existence has important spillover effects in reaching policy goals…even non-members fo the CCP program are attempting to address climate change and there is a variation among C40 member cities in climate mitigation policy"*

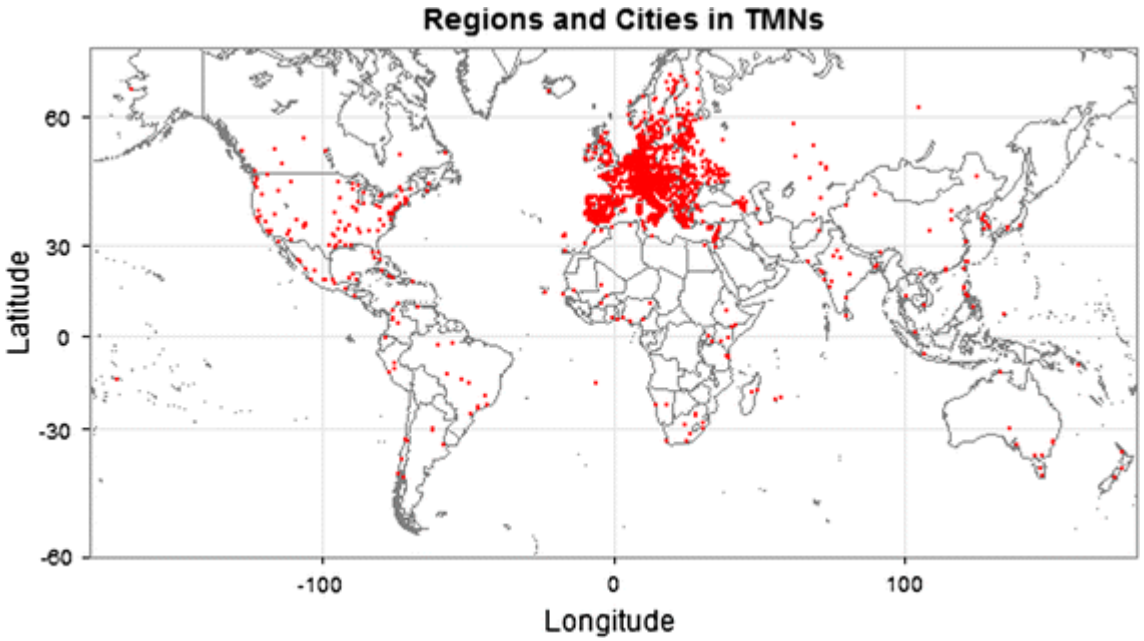
Having said this, some scholars argue that membership of trans-national municipal networks tends to be a prerogative of proactive local governments or, in Kern and Bulkeley's words, they tend to be 'networks of pioneers for pioneers' (2009, p. 311). Howevert, membership does not necessarily translate into a set of actions and initiatives, i.e. many cities that do not actively engage with the networks do not end up enjoying the added value of being part of them (Kern and Bulkeley, 2009, p. 311). For example, Kern and Bulkeley (2009) report that, particularly in larger networks such as the Climate Alliance, many cities are passive: 'membership in this case may be only symbolic – for instance, a city may have joined the network only after or because neighbouring cities, similar cities or sister cities did so' (2009, p. 316).

Furthermore, Bansard et al. (2017) analysed the proliferation of trans-national municipal networks from a geographical perspective. They analysed thirteen networks[28], focussing on climate mitigation actions and including subnational authorities in at least two states, and plotted the distribution of local authorities in the sample. As Figure 1 shows, there is a high concentration of cities in Europe and the US, while countries from the Global South are underrepresented[29] (2017, p. 235):

[28] The networks analysed are: Climate Alliance; Covenant of Mayors; Eurocities; C40; EnergyCities; UBC; R20; NEG/ECP; WMCCC; TCG-SR; NA2050; ISCI;WCI.

[29] The authors acknowledge that the map does not differentiate between larger and smaller cities; that some large networks (like ICLEI) are not included in the sample as they are not focussed solely on mitigation; that some cities can be proactive in tackling climate change without being members of any network (Bansard et al. 2017, p. 235).

Figure 1: Regions and Cities in TMNs (Bansard et al. 2017, p. 235)



In summary, decentralization and multilevel governance can foster horizontal interactions between local authorities, thus creating transnational networks. However, Bache et al.'s research highlighted the importance of cities' political commitment against the backdrop of complex governance structures that can create accountability gaps or weakened statutory duties. Furthermore, this section highlighted that, while it is true that local authorities can rely on trans-national municipal networks to supplement the lack of central governments' engagement with climate change issues, their membership can be only symbolic and may not necessarily lead to more actions and initiatives. In light of this, the following section explores the literature on cities' green leadership and political commitment as a driver for engaging with climate policy-related initiatives and transnational networks.

3.5.3 Success factors, challenges and criticisms: green leadership and political commitment

There are a number of benefits to membership of city initiatives highlighted in the literature (Mejia-Dugand et al, 2016; Christoforidis et al, 2013):

- Access to members around the globe
- Leads to knowledge sharing and exchange of urban policies, technology implementation and best practice;
- Can build legitimacy around actions by increasing social acceptance and meeting informal and external expectations
- Provides a unique platform for two-way information sharing
- Can help facilitate the diffusion process of gathering and disseminating market information .
- Can provide benchmarks of excellence, exchange of good practice and experiences, access to funding and financial tools

However, despite the widespread availability of green technologies, planning and environmental assessment methodologies and strategies for public engagements, the progress towards low-carbon cities has been slow. This indicates that the challenges of local carbon management are still affecting cities' green performance (Cam, 2013). In particular, progress has been fragmented and affected by funding constraints, short-termism and lack of political commitment (Dixon & Wilson, 2013).

The literature has identified some barriers and success factors that characterise both individual city initiatives and trans-national municipal networks, but overall what is needed for cities to successfully engage with initiatives is green leadership and political commitment. As highlighted, the effectiveness of cities' initiatives and of trans-national networks relies on "pioneer cities" that are proactive in tackling climate change, particularly where regional or national policies can constrain climate actions. Bartling (2017) analysed the role of leadership in tackling climate change at the local level and found that proactive political commitment can contribute to political support for action and to developing technical skills for carbon accounting. At the same time, they acknowledge that higher-level planning and regulations can limit the effectiveness of climate actions.

In this regard, Bache et al claim that 'at the heart of the politics of climate change is less an issue of institutions and structures and more of an issue of political will' (2015, p. 3). Affolderback and Schulz (2017) analysed the City of Vancouver's Greenest City 2020 Action Plan (GCAP) to reduce carbon emissions and evaluated the role of green leadership in shaping urban climate change policies. The aim of the strategy was to use a pluralistic and participatory planning to make Vancouver a world green leader city (2017). The characteristic of this initiative is its focus on public participation and engagement that informed the plan. As the authors explain (p. 680):

> *The planning process was accompanied by public engagement. The earlier phases involved open forums, while a wider public engagement process was launched following the presentation of the first draft of the Greenest City Action Plan in 2010. According to estimations by the City, a total of 35,000 people from around the world actively participated through various formats including face-to face workshops, idea slams, web-based tools involving also 60 city staff, 120 organizations and thousands of individuals.*

While the GCAP introduced quantifiable objectives to be implemented according to an ambitious timeframe, the core aim of the initiative was to brand the city as a world green leader, to gain citizens' support through public engagement (Ambrosch & Leihs, 2016). In addition the initiative aimed to foster 'friendly competition' and collaboration with peer cities, such as San Francisco, Portland, Toronto, Boston, New York (ibid. p. 683). The cooperation was facilitated by common membership of networks such as the Urban Sustainability Directors' Network, C40, Renewable Cities Networks (Robertson, 2016). However, there are limitations to Vancouver's "competitive positioning" and green leadership. From a social issues and citizens' perspective, some critics point to the lack of a social justice lens to the Plan. Vancouver's model of green development has made the city more attractive for middleclass residents, possibly exacerbating rising housing prices and adding to the housing

crisis that the city has been facing (Affolderbach and Schultz, 2017, p. 684; McKendry, 2016).

Political commitment and leadership is important not only in terms of being a proactive member, but also when it comes to decide whether to stay in the network or not. Although much has been written about the benefits of membership, little research has gone into exploring the reasons why a city decides to abandon a network. Krause et al. (2016) have applied policy termination theory to explain why one of the biggest climate change networks, ICLEI, managed to increase its membership for nearly a decade, reaching a peak in 2010 with 565 members and over the next 2 years, this number dropped by 20%. While it is still not clear whether cities that withdrew from ICLEI decreased their sustainability initiative, this data opens questions about the real role of networks and the reasons for withdrawal. In this regard, Krause et al. (2016) concluded that political ideology and programmatic effectiveness of the networks themselves (i.e. the perceptions that programs are effective), play a more meaningful role than financial conditions.

3.5.4 Governance complexities

As stated in section 3.2.1, cities can the most important level from which to tackle issues such as climate change and carbon emissions (Egger 2006; McEvoy et al. 1998; Giardet 1999). Nonetheless, cities have to comply with policies and directives coming from higher institutional level, i.e. regional, national and international. This is particularly the case of climate and environmental issues, where the scale of the problems that have to be tackled does not necessarily fall within traditional administrative and political boundaries. Most environmental policies are, in other words, multilevel (Wälti, 2010, p. 411; Huisingh, Zhang, Moore, Qiao, & Li, 2015).

The previous section explained how the level of political leadership and commitment can determine a gap between goals and outcomes. However, the complexities of climate governance that requires the involvement of different sectors and different institutional levels also needs to be considered. A tension between different institutions or departments can hamper the effectiveness of climate action, especially if this is not compensated for by a strong political commitment.

Chapman et al (2017) explored Wellington and Auckland's commitments to reducing their carbon emissions while fostering economic development. They found that behind the high aspirations, the implementation of climate change mitigation has been unambitious (pp 104-105). In analysing Wellington's performance the authors note that while Wellington City Council had set an ambitious goal of reducing emissions to 30 per cent below 2001 levels by 2020, a commitment renewed in 2013, the actual reduction by 2013 was 0.7 per cent (2017, p. 105). The authors note that the city focussed on a limited set of policies such as housing energy efficiency retrofits, or encouraging cycling. Moreover, they explain that: 'a concerning feature of WCC's thinking is that its transport and land use policies appear only weakly connected to its mitigation goals' (p. 105). They argue that 'analysis of some recent important land use planning decisions by WCC suggests that road-related interests, supported by the national New Zealand Transport Agency, tend to trump city-level

sustainable redevelopment interests (Chapman et al, 2017, p. 106. A similar approach to climate change mitigation goals was found in relation to the city of Auckland.

In line with this, Giest and Howlett (2013) pointed out that, because cities are subject to national and regional provisions, they might not be able to enjoy the full benefits of memberships as their actions can be restrained by higher institutional level priorities. This issue has been explored by Emelianoff (2014), which used Hanover and Växjö as case studies to look at the political dimension of cities initiatives. In this regard, Marsden and Groer (2016) conducted a cross-national comparison of urban carbon reduction policies in Germany and the UK and found that the political environment is more important than institutional structures in ensuring the success of these policies, particularly in a policy landscape dominated by pro-growth narrative. In line with this, Dixon and Wilson (2013) examined UK city officers' opinions about the effectiveness of climate change plans and actions and concluded that the UK 2010-2015 voluntary approach to low-carbon plans promoted by the Coalition Government hampered the ability of cities to deliver. As the authors note 'many cities also feel that the removal of the requirement for central government to monitor local authority emissions has weakened their ability to respond to the low-carbon agenda' (Dixon and Wilson, 2013, p. 677).

Furthermore, while it has been argued that cities should be in charge to reduce carbon emissions (Fünfgeld, 2015), the multilevel nature of environmental issues and governance creates an additional layer of complexity, which can potentially lead to a weakening of cities' initiatives to tackle climate change. In this regard Bache et al. (2015) investigated the issue of accountability in the context of the UK transport policies and carbon emissions reduction policies. They argued that there is an *accountability vacuum* in UK multilevel environmental governance that means that 'although there is a *top-down* delegation of responsibility for transport emissions management to local authorities there are no *bottom-up* systems of accountability anywhere in the UK for interventions in transport governance that are explicitly connected to a national target' (p. 1). In Bache et al.'s view, the accountability gap created by decentralization of powers in the UK caused a weakening of control and reporting mechanisms. This effect became more visible when the 2010-2015 coalition government introduced its 2011 Localism Act, which abolished national indicators for carbon emissions reduction and did not require local authorities to set their own carbon emissions targets (ibid. p. 19). The absence of implementation mechanisms, together with a reduction in revenue funding during those years (Dixon and Wilson, 2013), and an encouragement to cap council tax, caused a weakening of local authorities' initiatives and actions to reduce emissions (Bache et al, 2015). In other words, the governance and accountability vacuum contributed to shifting local authorities' priorities from carbon management to economic growth and jobs (Bache et al. 2015).

3.5.5 Representativeness

As previously discussed in this section, in the field of carbon management and climate change initiatives and networks, the Global South is underrepresented (Bansard et al., 2017). Unsurprisingly, academic studies that analyse how local authorities manage their carbon emissions in lower-income countries are scarce. Romero Lankao (2007) attempted to

fill this gap and looked at how local authorities in Mexico City manage carbon emissions and the challenges that decision makers face. Romero Lankao showed that while membership of ICLEI played a key role in shaping a local agenda for carbon emissions management and facilitated a learning process, 'this influence has not been enough to push real and effective policy strategies and actions (Romero Lankao, 2007, p. 531). In this case, problems with institutional fragmentation, complex legal mechanisms, institutional capacity and weak social participation, and problems with corruption, hampered the city's opportunity to put an effective system in place.

In addition, Valente de Macedo et al (2016) examined São Paulo's engagement in transnational networks for climate protection, specifically ICLEI and C40, and found that this engagement has been pivotal in fostering local initiatives to protect global climate. However, they found that these networks have little influence over the implementation of these initiatives and the city's reduction target has not been achieved (p. 42).

These papers show once again that while networks can be pivotal in launching a local climate change agenda, this is not enough to ensure that the initiatives are properly implemented, effective and maintained in the longer term. To conclude, the literature is conclusive in emphasising the importance of local capacity in ensuring that climate policy actions are effective (Hoppe et al., 2016). Gouldson et al. (2016) argued that in the developing world, the lack of co-ordinated, multilevel, effective governance it will likely be the case that cities will miss out even on the economic benefits of low-carbon opportunities and become locked in to more expensive and carbon intensive paths. This is particularly concerning, giving the growing size and importance of cities in the developing world, particularly in Asia (Gouldson et al., 2016).

3.5.6 Smart city approaches to carbon management

In recent years, environmental concerns and slow progress towards reducing emissions led many cities to rely on technological solutions to pave the way for sustainable communities. These approaches focussed on designing 'citizen-centric environmental sustainable information systems' (Brauer & Kolbe, 2016). Against this backdrop, the concept of *smart cities* has become a popular way to describe cities that invest in technological and infrastructural innovations, but some scholars have investigated also the contribution that *smart cities* approaches can provide to city-level carbon management. In this context, 'smart communities have a strong bond to governmental instruments and policies and aim for generating knowledge and creativity and information technology plays a vital role in supplementing the required processes and underlying infrastructure (Brauer and Kolbe, 2016, p. 1). Alternatively, a smart city represents 'a community of average technology size, interconnected and sustainable, comfortable, attractive and secure' (Lazaroiu & Roscia, 2012). However, while they are theoretically appealing, smart city approaches are difficult to implement. In particular, Chatfield et al. (2016) have highlighted that a successful implementation process requires 'shared vision of social innovation owned by diverse stakeholders with conflicting values and adaptive use of informal social governance mechanisms for effective smart city implementation' (2016, p. 757).

This research suggests that smart city approaches can be quite focussed on individual initiatives (for example, introducing driverless electric vehicles, see Chebbi and Nouri 2016), or can involve wider societal and cultural change. Indeed, even technological changes alone can require deeper regulatory and concerted institutional efforts. For example Giest (2017) studied the use of big data in smart cities in the context of carbon emission reduction in Copenhagen (Denmark), Vienna (Austria), Malmö (Sweden) and London (UK) and pointed to the institutional complexities as a constraining factors: 'big data forces city governments to include additional stakeholders into the decision-making process. This has to do with the technical capacities of data collection and analysis as well as the ownership of data' (Giest, 2017, p. 946). However, the author points out that the increased efforts in gathering and handling data has usually negative repercussions on building policy capacity: 'once the data architecture is set up, it alone cannot overcome emission problems. It requires regulatory and behavioural changes by consumers to reduce emissions with the help of data analytics' (Giest, 2017, p. 946). In summary, while promising and theoretically appealing, smart city approaches' success can only be part of the solutions, and must be accompanied by a wider process of social and political capacity building.

3.5.7 Engagement with community and citizens

Is a criticism of city initiatives that they don't (or don't effectively) engage with the citizens who are both contributing to environmental problems and also suffering from the impacts (for instance the health impacts of poor air quality)? Is the focus on networking and knowledge exchange between government, business and academic stakeholders rather than with citizens? The evidence of the literature seems to suggest that this is the case and is a key factor to consider in city case studies.

The benefits of engaging in emission disclosure projects and building frameworks to encourage stakeholder dialogue have been discussed in, for example, White and Holpuch (2014). The example of the City of Bloomington, Indiana (US) shows that urban climate change planning methods can engage in different forms of partnership including with civil society. The literature also highlights some examples of cities that engaged directly with citizens in carbon management, for example the city of Vancouver that successfully experimented different methods of pubic engagement. In addition, in this specific regard, there is also an extensive literature on citizen science and community-based environmental monitoring (see Conrad and Hilchey's review article (2011)). In particular, the literature conclusively states that citizens in communities with community based monitoring (CBM) 'tend to be more engaged in local issues, participate more in community development and have more influence on policy-makers' (Conrad and Hilchey, 2011, p. 280).

However, the literature review has identified a gap of evidence with regards to networks' engagement with citizens or experimental approaches (Broto and Bulkeley, 2013), particularly in light of shrinking memberships (Krause et al, 2016). Similarly, the review of carbon inventory and footprinting methodologies found a similar gap. The role of citizens as both sources of emissions through their energy using activities as well as casualties of environmental issues such as poor air quality is not thoroughly considered within inventory frameworks and reporting mechanisms, especially top-down approaches that consider scope

1 and 2 emissions only. This is a critical factor to consider in city case studies: what is the role of citizens in carbon and air quality management and how to city initiatives and networks help facilitate any engagement beyond business and policy stakeholders?

3.6 Summary of findings

The literature on carbon management, emission inventories and carbon footprints identifies some important themes that are relevant to both the city case studies (presented in Section 4) and the wider ClairCity project. Firstly, development of an internationally agreed methodology for city-level carbon inventories is commonly recommended as necessary with the requirement for inventories to be relevant, complete, consistent, transparent and accurate. These requirements, though necessary for inventories to be comparable with other cities and able to contribute to national inventories and reporting, place a large burden on local authorities with limited resources. In order to inform the development of carbon and air pollutant inventory frameworks that provide useful and accurate data but are not too resource intensive or complex for local authority analysts requires a greater understanding of cities' decision making process in regards to inventory methodologies and data requirements. The main question is why cities choose particular frameworks and methodologies?

It can also be argued from the literature that standard inventory processes do not allow cities to develop the best local policy options as the focus can be on production-based emission sources, sometimes outside of the control of local governments. The wider consumption behaviour of a city's citizens and businesses may also be ignored in approaches that do not include some aspect of Scope 3 emissions reporting, perhaps though lifecycle analysis or input-output analysis. This has the potential for local policy actions on carbon reduction to be misdirected, and as a result ineffectual.

Both the literature on carbon inventories and that on air-pollution identify a lack of consideration of citizen behaviour in current methodologies. Recommendations for inventories identify greater inclusion of activity data as necessary but a standard/bottom-up approach for including, for example, housing energy end-use data in emission inventories does not exist.

The literature review has also identified a knowledge gap around engaging citizens (and to a lesser extent businesses) in the process of compiling and reporting carbon emission and air pollutant inventories. The benefits of doing this to develop a more-bottom up approach for city-level inventories is not explored in the literature, and hence it is unclear whether cities have considered this as a potential route to both raise the awareness of citizens and improve the effectiveness of local policy options.

In analysing the literature on city initiatives, trans-national municipal networks and smart cities, it is possible to identify some common themes. First of all, it is important to acknowledge the role of pioneer cities that are at the forefront of climate change mitigation policies and can work as 'test cases' of new ambitious approaches and methodologies, like the example of Vancouver in planning for sustainability or cities like Copenhagen and

London in the application of big data for carbon management. Moreover, pioneer cities can start trans-national municipal networks that foster cooperation between cities, and can also inspire peer cities or neighbourhood cities to follow their example and adopt more ambitious policies.

Some challenges emerged consistently in the literature: political commitment and the coherence of national and international provisions with city-level policies. On the one hand, a change in local governments can determine a withdrawal from existing commitments, thus indicating how maintaining green leadership is important to implement climate change policies that are by nature longer-term. On the other hand, inconsistencies between local and national policies can hamper city leaders' ability to ensure a more substantial progress in managing their carbon emissions. In addition, the literature seems to suggest that more investment of time and resources in local capacity building is a prerequisite for future success, as technological innovation alone is not enough to ensure longer and more radical changes.

Finally, the literature review has highlighted two important gaps, both in academia and in practice. First of all, there is a lack of initiatives and networks that focus on pollution and air quality issues – as the overwhelming majority of initiatives and networks focus on carbon management issues. Air quality and carbon management within local authorities is largely siloed, as are Local, National and European policies. This siloing continues within inventory processes. A more in-depth exploration is needed of the potential trade-offs between air-quality and carbon but there are undoubtedly examples within the UK and Europe where consideration of one without the other has led to policy gaps or mistakes. Firstly, the incentivisation of diesel car purchasing because of lower carbon emissions, despite higher levels of air pollutants, Secondly, the ongoing incentivisation of biomass burners in homes at the national level as 'renewable heat' despite them also leading to higher levels of ambient air pollution.

Secondly, further research should look at the extent to which trans-municipal networks have adopted or might adopt experimental approaches to engage more effectively with citizens, given the general consensus that this is beneficial both for society and for policy-making. Further research is needed to both identify evolving best practice and to trial approoaches with cities and regions.

4 Survey and City Case Studies

4.1 Survey reponses

In total there were 27 responses to the survey. The survey was completed by local authority representatives in Europe, North America, Asia and Africa and Australasia

	Full survey	Part survey
Europe	6 (22%)	12 (44%)
North	2 (7%)	
Asia	2 (7%)	1 (4%)
Africa	1 (4%)	1 (4%)
Australasia	1 (4%)	
Unknown		1 (4%)

Given the low response rate, comprehensive statistical analysis of the responses was determined to not be valueable. However, the results were used to provide support for a qualitative assessment of the subject. The qualitiative analysis of the survey responses will largely focus on the 12 fully complete responses but all full and partical responses can be found in Appendix 1.

4.1.1 Carbon and greenhouse gas inventories

The results from the survey indicated some of the methods used for carbon inventories by respondants. Durban, South Africa, and Seattle, US both use the GPC, Bristol, UK uses Carbonn, whilst Baguio City, Phillipines, City of Berkeley, US and Seattle use ICLEI inventory methodologies. The Aveiro Region in Portugal stated that they used a national inventory method. Six respondants did not specify a particular methodology. All respondants identified that they recorded CO_2 or CO_2e emissions in their city inventories with Seattle and Wellington stating that they recorded the full range of greenhouse gases identified in the survey question (see Appendix 1).

The majority of cities (83%) recorded scope 1 emission for the Residential, Business, Energy Supply, Industry and Road sectors with 3 respondants, Bristol, Wellington and Noida, Uttar Pradesh, India recording that they include scope 1 emissions for all sectors in their inventories. A smaller number of respondants identified recording scope 2 emissions for sectors other than Energy Supply in their region. Most respondants did not record scope 3 emissions other than in the Waste sector (42%). Durban and Wellington both use input-

output analysis. In particular Wellington uses input-output analysis to calculate scope 3 emissions. For transport they primarily use fuel sales within the region instead, and for waste weighbridge numbers from one specific landfill. In Seattle, with reference to the aviation sector, they calculate a share of the regional airport's emissions based on population, whereas for waste they use a waste commitment approach.

The boundaries of carbon/greenhouse gas emission reporting were largely defined by the administrative boundaries of the city/region or by national governments 75%. Durban stated that they were partly defined by the inventory methodology and Tatabanya, Hungary stated they were defined on a sector by sector basis.

Most respondents stated that they use inventories to support the council in policymaking in different sectors, to track ongoing progress in reducing both greenhouse gas and conventional air pollutant emissions and to target policies at particular sectors/areas of the city. Inventories are also seen as part of an ongoing accountability and transparency process both locally and internationally (Durban, Bristol). Inventories were also used to educate and engage the public and some specific sectors about carbon footprints (City of Berkeley, Baguio). As an example, City of Berkeley stated that "we reach out to green business districts, as well as part of our outreach for green requirements in the City to explain how sustainability aspects are a good investment on their part, and help the City reach its Climate Action Goals" in response to how they engage the business sector. Seatle identified that they "use GHG inventory data to inform conversations with stakeholders as we develop climate actions/policies".

4.1.2 Conventional air pollutant inventories

Of the respondants to the survey who completed it fully, 5 (42%) stated that they had an air pollution emission inventory process or preferred methodology that they were aware of. These were Amsterdam, Baguio City, Aveiro and Estarreja, Portugal and Durban. Apart from Durban all stated that they recorded a range of pollutants including nitrogen oxides, sulphur dioxide, particulate matter ($PM_{2.5}$ and PM_{10}) and carbon monoxide.

Use of air pollutant inventory process was linked to transport policy by a number of respondants (Baguio City and Aveiro Region) but otherwise specific mention of how air pollution inventories were used in policy and in engaging with citizens and organisations was limited. This highlights a general bias in the survey reponses towards carbon/greenhouse gas emission inventories and also shows the lack of integration or common thinking around carbon and air quality management in cities, identified in the literature review. It was challenging to find respondants to the survey who could comment on both carbon inventories and air pollutnat reporting methodologies, demonstrating how these two areas of often siloed within city/regional administrations.

4.1.3 Engagement with city initiatives

The final part of the city looked at which inititives city and regions engage with on climate change/carbon and air quality. Of the full survey respondants, 8 (67%) named national and transnational initiatives they engage with. City of Berkeley, Bristol, Wellington and Seattle were all engaged with either the Compact or Covenant of Mayors initiative. City of Berkeley, Tatbanya, Bristol and Baguio City were also member of ICLEI. Again the focus was on climate change/carbon reduction focussed initiatives and those with associated inventory methodologies and standards. Wellington for example was also part of the Carbon Discolsure Project. Only one place, Baguio City, identified being a member of an air quality initiative: Cities for Clean Air Certification.

In the survey, participants mentioned some examples of the benefits of being part of initiatives or networks. These include concrete support in reducing GHG emissions and Air pollutants by tackling citizens' behaviours (Tatabanya); to access international resources and technical expertise in project planning, inventories and forecasting (Berkeley), information exchange (Bristol), learning opportunities from leading cities and being part of a global climate conversation (Seattle), providing a framework for an holistic approach to improving air quality and reducing carbon emissions and support to policy making (Baguio).

4.2 City Case Study 1: Wellington, New Zealand

4.2.1 Case study city description

Wellington city has set targets to reduce emissions by 30% from the 2001 baseline by 2020 and by 80% from their 2001 baseline by 2050. These targets are not as ambitious as other cities' but are supported by tools and mechanisms to facilitate their achievement. One of these tools is the 2050 Climate Calculator based off the city's inventories that allow stakeholders (business and citizens) 'to develop their own pathways to meet our targets' (survey response).

4.2.2 Carbon Inventories

With regards to the inventory, Wellington use the GPC protocol, primarily because this is what is used by the cities that are signatories of the Global Covenant of Mayors. The city currently keeps the GHG emission inventories and reporting separate from conventional air pollutant reporting, as the outcome of those pollutants are different. According to the participant 'GHG emissions primarily result in long-term threats through changes in the climate system while conventional pollutants result in long-term threats to individuals'.

4.2.3 City initiatives and benefits

Wellington is member of:

- The Covenant of Mayors (joined in 2014), which provides the city with an international accountability framework;
- CEMARS (joined in 2014), which is used as an audited framework for tracking emissions;
- Carbon Disclosure Project, which is the methods that Wellington uses to report to the Covenant of Mayors. It also offers a platform for open data and disclosure of results.
- NZ Local Government Declaration on Climate Change (2015 & 2017)
- 100 Resilient Cities (joined in 2014), which supports the City in building resilience.
- Wellington stopped being part of ICLEI, but the reasons for the interruption of the membership are not clear.

Why joining: Memberships of networks are considered pivotal to building accountability locally and internationally, particularly because they often provide evaluation and assessment frameworks

Benefits: membership of these networks can foster engagement with the wider community and region (for example, the 100RC). Moreover, in particular, according to the participant, CEMARS and CDP 'were instrumental in our target-setting, which is substantively more ambitious than Central Government targets'. This leads also to a more effective action towards influencing central government's policies. A strong element also concerns mutual learning. As the participant put it, 'CEMARS facilitated learning about our overall organization's footprint, which has redirected our attention into the key areas of emissions for project attention'.

Challenges: No particular challenges were highlighted in relationship to memberships, although there was a recognition that some networks are more effective than others in facilitating knowledge exchange and supporting the city in meeting its targets.

4.3 City Case Study 2: Durban, South Africa

4.3.1 Case study city description

The critical issues of Durban's transition to a low carbon city are high levels of unemployment and the need for economic development, which emphasise the need to shift to a green economy (Assaf, 2011). The city of Durban has been a leader in South Africa with regards to both climate change mitigation and adaptation initiatives (it is a coastal city). Transportation and industry are the largest contributors to Durban's GHG emissions (37% and 32% respectively in 2012). The high level of transportation GHG emissions in Durban mean that air pollution is also a significant problem.

Durban is a signatory of the covenant of mayors and therefore is obliged to use the Global Protocol for Community-Scale Greenhouse Gas Emission protocol (GPC) for compliance.

The city is also a member of ICLEI Local Governments for Sustainability, Rockefeller 100 Resilient Cities and the Carbon Climate registry. The city of Durban forms the eThekwini Municipality, which is the largest city in the province and the third largest in South Africa. As a result Durban has a leading role in provincial and national networks

4.3.2 Carbon inventories

The city of Durban uses the GPC emission protocol as they are a signatory of the Covenant of Mayors, and report carbon dioxide, methane and nitrous oxide emissions as carbon dioxide equivalent (CO_2e). Previously the municipality used a methodology provided by ICLEI. The transition to the new methodology was not difficult. Durban sees benefits in using the GPC methodology. It makes it easier to report on an international platform and to compare emissions with other cities.

Currently carbon and air quality management in the city is carried out in separate departments and inventories are carried out separately. There is an aim to stop this siloed working in the future with the two departments working much more closely together and hopefully producing just one emission inventory.

4.3.3 City Initiatives and benefits

The City of Durban is very positive about its membership of initiatives such as the Covenant of mayors and the benefits for their local carbon management. They are members of a number of different initiatives as the city is committed to climate change actions on both mitigation and adaptation and emission reporting. The main benefit of membership is knowledge sharing; seeing what other cities are doing and all working together. Because Durban is the main municipality in the area they are able to gain knowledge from international networks and forums which they can there with other provinces nationally and regionally. Though Durban has to align with national targets on emission reductions, membership of international city initiatives means that if they see an approach other cities are using that helps to fill national policy gaps they can “go for it”.

City initiative membership help them to engage with local businesses and communities. Something that is considered very important to the City of Durban. They engage with industries and businesses to get the information they need for their GHG inventory, but to do this successfully they have to explain what they are doing and why, and then present their results back to industry and to citizens. The city considers explaining what they are doing to be an important part of the carbon management process. Membership of city initiatives has helped them to develop community focussed programmes for sharing information based on projects done in other cities. The City of Durban also engages with businesses through a regional Compact on Climate Change as well as through the local labour unions.

4.4 City Case Study 3: Glasgow UK

Ambitious targets and international networks drive Glasgow's emissions reduction plans and transformation from an industrial city towards a more resilient city.

4.4.1 Case study city description

Glasgow is on a trajectory to move on from its industrial past towards meeting ambitious low-carbon targets becoming a sustainable city. Glasgow's Energy and Carbon Masterplan stated that the total CO_2 emissions produced in Glasgow in 2006 were 4,094,327 tCO_2, which dropped by 13% by 2012. Glasgow's mitigation agenda provides for a 30% reduction target by 2020 from a 2005-2006 baseline and the city has currently almost met the targets (90% progress made towards the target by 2017). The city expects not only to meet the targets but also to exceed them, and have set further ambitious reduction goals to be met by 2025 and 2030.

In addition to several local initiatives (it is now set to introduce Scotland's first low-emission zones), Glasgow is part of several national and international networks, including the 100 Resilient Cities, the Covenant of Mayors and Mayors Adapt, Eurocities, and the UK Core Cities Group, a self-selected and collaborative group of large cities in the UK outside Greater London. In engaging with these initiatives, the sustainability and low-carbon focus has expanded to include also aspects of poverty and social inequalities.

4.4.2 City initiatives and benefits

Why joining – Glasgow's engagement with transnational and national municipal networks stems from a strong political drive by the Scottish Government and the local authority to make sure that Glasgow is ready to meet the future climate change challenges. Despite the fact that Glasgow is not a capital and is not a big city by world standards, the city is characterized by a desire to play at a global stage, supported by a political vision that aims to position Glasgow as a post-industrial city that has overcome its sustainability and climate-change related challenges by working with other cities.

Level of engagement – Glasgow has never stopped being a member of any organization or network. However, the level of activities carried out within each network varies from year to year. For example, Glasgow level of engagement with Eurocities tends to go up and down based on the projects that are undergoing and also based on politicians' interests.

Benefits: the benefits of membership of networks are perceived at different level. First of all, these memberships facilitate learning and mutual sharing. They are perceived to be particularly effective to building partnerships and friendships. As the city's Resilience officer put it: 'you can always learn a new lesson about how to engage with people and communities, you always learn new ways of doing something different around the world these initiatives are very helpful in terms of helping each other out'. Membership of this networks can also create a constructive competitive environment between cities, which is considered conducive to innovation and stronger bids for funding. Networks also support

cities in bringing a unified voice before the national Government. For example, the experience of the UK Core Cities Group, which includes the 10 biggest UK cities outside London gives strengths to the cities' positions and governments tend to respect these cities for being part of these networks. Moreover, the cities' voice is strengthened for example when representatives from these networks visit the city and can also connect with representatives from the central Government. This is particularly relevant when cities' priorities are at odds with central governments' priorities and help them to fill a policy gap and be proactive against the backdrop of a slacking central government. For the City of Glasgow this aspect is less significant given that the current Scottish Government's priority are in line with the local authority's sustainability goals. In addition, networks can sometime foster the city's engagement with the local community and citizens. However, this was perceived as the weaker aspect of networks. Finally, in terms of more practical benefits, the fact that some networks require carrying out annual reporting activities is perceived as useful because it forces the city's officers to reflect on progress and things to change.

Challenges: Diary pressures are perceived as a challenge to engaging more with city-level initiatives and networks. Sometimes meetings and events are held far away from the local authorities and a political judgment has to be made about the best use of time and resources. This can affect the level of engagement with cities and determine 'quieter' periods. In addition, there is also somewhat skepticism about the value of projects in terms of delivery of concrete and long-lasting benefits for the community. Beyond the relationships developed across Europe and internationally, sometimes the legacy on the ground can be more difficult to evaluate. Another criticism related to the way the networks communicate with members. In particular, while regular updates and newsletters are welcome, more substantive policy reports and policy recommendations would be more helpful for city officers.

4.5 Summary of findings

The case studies and survey data highlight that it is important for cities to have an international framework that can help strengthening cities' accountability, allows for cross-cities comparisons and grant cities credibility internationally and locally. With regards to cities' engagement with initiatives and networks, participants have strongly stressed the importance of being part of these networks, which support them in learning new approaches and in building partnerships. Moreover, the case of Glasgow is exemplificative of the benefits of being active in international networks for a relatively small city (by world standards) in order to have a role at the global stage. In this regard, it is paramount that cities that want to lead the way and be pioneers in fighting pollution and setting ambitious climate change mitigation targets are active in transnational networks. Furthermore, networks help councils to have a stronger and more unified voice when national governments' priorities are at odds with local needs and support councils in setting more ambitious targets than the central governments'.

The evidence from the case studies indicates that these networks are more effective in building partnerships than in delivering projects with a long-term legacy on the ground. This

may be indicative of the fact that more work needs to be done in terms of engaging directly citizens and local communities and in encouraging city officers in experimenting and finding new ways to make community engagement more effective.

Overall, responses to both the survey and case study interviews highlighted that air quality and climate change/carbon reduction reporting processes are often not integrated within cities. Responses to the section of the survey on greenhouse gas emissions were generally more fullsome and achknowledge membership of clean air & air quality inititiatives was very limited. The views of Wellington and Durban highlight a difference of opinion on this with Wellington thinking air quality and carbon reporting should be kept separate and Durban seeing the benfits of considering both in a more holistic approach.

5 Conclusions and recommendations

Considering the findings from a systematic literature review, survey of cities and city case studies this report draws the following conclusions:

On inventory processes:

- The literature review and case studies both support the need for internationally agreed carbon inventory frameworks that allow inventories to be comparable between cities and form part of the international response to climate change mitigation.
- There is a need for greater inclusion of bottom-up, activity data related to citizen and business behaviour in both air pollutant and carbon emission inventories. This could support the development of more effective policy strategies at the local level which consider the choices, decisions and activities of citizens made within the city.
- Development of an integrated inventory process that can include both air pollutants and carbon emissions is an area that requires further exploration, with a particular focus on including more bottom-up, local activity data. Initial case studies suggest this would be of benefit to some cities though some see them as two separate issues due to the local versus global impacts.
- Further research is required to identify the trade-offs between air quality and carbon policies at the city-level across Europe. Two conflicts within the UK are identified in terms of historical incentivisation of diesel cars and current incentivisation of biomass burners in homes.
- There is very little evidence in the literature of the potential benefits of greater engagement with citizens on both air pollutant and carbon emission inventories. This appears to be a research/knowledge gap: it is missing from the literature rather than previously explored and dismissed.
- In developing an emission inventory methodology greater consideration needs to be given to the time and resource constraint of local governments. A potentially role of initiatives is to help facilitate this process.

On city initiatives and networks

- Pioneer cities at the forefront of climate change mitigation policies can work as test cases of new ambitious approaches and methodologies. They can play an important role in ensuring the dissemination of knowledge to other cities and regions.
- Inconsistencies between local and national policies can hamper cities' progress on emission reductions. City initiatives have a role to play in facilitating greater progress but there should be more of a focus on capacity building rather than just technological innovation.
- There are a lack of initiatives focussing on air pollution and air quality issues, even as a co-benefit of addressing climate change mitigation.
- Citizen engagement is not consistently apart of city initiatives and networks, who could adopt a greater number of approaches to engage more effectively with citizens.

It is recognised that the city case studies reported in this study are part of an ongoing process that will continue through the length of the project to gain a greater understanding of cities' engagement with both inventories frameworks and city initiatives. The ongoing process will allow for a strengthening of these conclusions and can begin to address some of the research/knowledge gaps identified.

This study makes the following recommendations for the ClairCity project (the work package in () indicates which ClairCity work package this recommendation is most relevant for):

- ClairCity should investigate how to include more behavioural, bottom-up elements in city level emission inventories for both air pollutants and carbon emissions and consider how this feeds into the ClairCity toolkit structure and outputs. To do this ClairCity should:
    - Explore how cities integrate behavioural/bottom-up elements through a review of the city-level grey literature and policy documents for identified cities (WP6.2).
    - Identify other sectors where behavioural, bottom-up elements are included in quantitative reporting and benchmarking to guide policy, perhaps through a strategic review of the literature on systems approaches (WP3 and WP6.2).
    - Build recommendations through the research and knowledge generated in ClairCity especially related to the practice-activity and micro-simulation work and how this can feed into bottom-up inventories (WP3).
- There is a need to investigate the barriers and challenges of integrating air pollutant and carbon emission inventories. An assessment of the ClairCity case study cities and regions should ascertain whether there is any desire to do this from a local authority inventory users point of view (WP5).
- The project should keep a watchful eye on carbon, air quality and environmental management practices, particularly in China and other Asian countries where increasing urbanisation and creation of mega-cities presents challenges for inventories. With this in mind, ClairCity should consider connecting into other work in this area (WP6 and WP2).
- The citizen engagement approach of ClairCity is currently missing from both inventory methodologies and city initiative processes. The project should seek opportunities to engage with cities through dissemination and communication activities to pilot their activities, share the projects policy-messages and approaches to engagement (WP2 , WP4 and WP5). This may be achieved by:
    - Reviewing the processes of transnational city initiatives such as Covenant of Mayors and C40 to identify any changes to their practices or innovative attempts to engage citizens with inventory processes (WP6.2).
    - Working with the ClairCity city/regions to trial increasing citizen engagement with carbon and air quality emission inventories and reporting (WP4 and WP5).
    - Build on the relationships created in this work package to identify opportunities to engage citizens in trial processes with city/regions outside of the project consortium, for example, Glasgow in the UK (WP2).

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Appendix 1: Survey Questions and Responses

Background

ClairCity is an innovative project involving thousands of people in cities across Europe, enabling us all to decide the best local options for a future with clean air and lower carbon emissions. This survey will take 10 - 15 minutes to complete and should be completed by a person with knowledge of local GHG and conventional air pollutant emission inventories and reporting. The data from the survey will be used to inform city emission inventory reporting and improve transparency and accuracy. It is up to you to decide whether or not to take part in this survey. By proceeding and completing the questionnaire you consent to the data you provide being used in the following way: Your answers will not be identifiable to you and will be grouped thematically with other respondents. ClairCity will treat your information in accordance with the terms and conditions of the 1995 EU Data Protection Directive. Overall outcomes from the research will be published in reports to the European Commission, on our website www.claircity.eu and through wider media.

This study was given ethics consent by the Research Ethics Committee of the Faculty of Environment and Technology, University of the West of England, UK researchethics@uwe.ac.uk.

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If you have any comments or queries about this survey, please contact us.

Background Questions

Q1 Which city/region do you work for?

Q2 In which country?

Q3 What is your role in your city/region's government?

GHG Emission Inventory Questions

Question 4: Does your city/region use a GHG emissions inventory framework or standard?

Yes = 14; No = 7; Blank = 4

Question 4a: If yes, which inventory framework or standard do you use?Please provide a brief description if you use a regional or country specific framework/standard.

Response Id	Answer
R1	Previously, we had an in-house model created for our inventory, but in the past year have switched to an online ICLEI tool called ClearPath, and adheres to the basic requirements of GPC, as we report to the Covenant of Mayors.

R3	Carbon considering C40
R8	country http://okolje.arso.gov.si/onesnazevanje_zraka/vsebine/toplogredni-plini local https://www.ljubljana.si/sl/moja-ljubljana/varstvo-okolja/stanje-okolja/ see "zrak"
R11	I don't know which one
R14	Based on information on the Orography, Land Use, Population Density and Air Quality Monitoring Campaigns carried out at the national level, three Central Zones and two Agglomerations were delimited in the Central Region: Interior Center, Coastal Center and Coastal Northwest Coast Vouga (former Estarreja Influence Zone); Agglomerations of Coimbra and Aveiro / Ãlhavo. For a systematic measurement of some pollutants in the Region, it was essential to define an air quality monitoring network, consisting of several measuring stations. The location of the stations is always intended to monitor areas where pollution is presumed to be highest and where average concentrations are representative of local conditions. The stations are equipped with automatic analyzers that enable continuous monitoring of various pollutants. In the Estarreja Influence Zone there is an Industrial (Teixugueira / Estarreja) air quality measurement station, located south of the Estarreja Industrial Complex, integrated in the monitoring network of the central region, which is managed by CCDRC (Commission for Coordination and Regional Development of the Center).
R15	We follow both the GPC and the ICLEI US Community protocol
R16	Anadia signed a commitment to reduce CO2 emissions of its territory, with the Covenant of Mayors. The monitoring of sustainability actions is based on the continuous evaluation of indicators to monitor the implementation of the SEAP. These indicators were defined according to the Joint Research Center and the Covenant of Mayors recommendations for the development of the SEAP implementation reports and considering the specific sustainability measures presented in the municipality's SEAP.
R19	The inventory was conducted under an ICLEI project (Cleaner Mobility) using WHO standard
R20	Inventario nacional divulgado pela AgÃªncia Portuguesa do Ambiente
R23	Global Protocol for Community-Scale Greenhouse Gas Emission protocol (GPC). As a signatory to the Compact of Mayors, the city is obliged to adopt the GPC for its compliance.

Question 4b: If no, please can you briefly describe your city/region's emissions inventory process

Response Id	Answer
R2	Calculating the city's CO_2 emission in line with the Hungarian Ministry Decree No. 7 of 2006 (24 of Mai) on the Determination of Buildings Energetic Features (7/2006) (V.24)

Question 5: Which greenhouse gas emissions do you report in your city/region's inventory? Tick all that apply. - Selected Choice

1. Carbon Dioxide (CO_2) = 14
2. Methane (CH_4) = 9
3. Nitrous oxide (N_2O) = 11
4. Hydrofluorocarbon (HFCs) = 4
5. Perfluorocarbons (PFCs) = 3
6. Sulphur hexafluoride (SF_6) =3
7. Other = 3

Response Id	Answer
R1	Carbon dioxide (CO_2),Methane (CH_4),Nitrous oxide (N_2O)
R2	Carbon dioxide (CO_2)
R3	Other
R4	Carbon dioxide (CO_2),Methane (CH_4),Nitrous oxide (N_2O)
R5	Carbon dioxide (CO_2),Methane (CH_4),Nitrous oxide (N_2O),Hydrofluorocarbon (HFCs),Perfluorocarbons (PFCs),Sulphur hexafluoride (SF_6),Other (please state):
R7	Carbon dioxide (CO_2),Methane (CH_4),Nitrous oxide (N_2O)
R8	Carbon dioxide (CO_2),Methane (CH_4),Nitrous oxide (N_2O),Hydrofluorocarbon (HFCs),Perfluorocarbons (PFCs),Sulphur hexafluoride (SF_6)
R9	Carbon dioxide (CO_2)
R11	Carbon dioxide (CO_2)
R12	Perfluorocarbons (PFCs)
R13	Nitrous oxide (N_2O)
R14	Other
R15	Carbon dioxide (CO_2),Methane (CH_4),Nitrous oxide (N_2O),Hydrofluorocarbon (HFCs),Sulphur hexafluoride (SF_6)
R16	Carbon dioxide (CO_2)
R19	Carbon dioxide (CO_2),Methane (CH_4),Nitrous oxide (N_2O),Hydrofluorocarbon (HFCs)
R20	Carbon dioxide (CO_2),Methane (CH_4),Nitrous oxide (N_2O),Other
R23	Carbon dioxide (CO_2),Methane (CH_4),Nitrous oxide (N_2O)
R25	Carbon dioxide (CO_2),Nitrous oxide (N_2O)

Question 5_7_TEXT: Which greenhouse gas emissions do you report in your city/region's inventory? Tick all that apply. - Other (please state):

Response Id	Answer
R3	Will be reporting all but to date only CO_2 and CO_2e
R5	NF_3
R14	O_3, NO_2, NO, SO_2, PM_{10}, $PM_{2.5}$, NOx
R20	SOx; NOx; NH_3;PM_{10}; Pb; Cd; Hg

Question Q5a: How do you report your GHG emissions data?

1. As individual pollutants = 6
2. As carbon dioxide equivalent (CO2e) =10
3. Don't know = 2

Response Id	Answer
R1	As carbon dioxide equivalent (CO_2e)
R2	As individual pollutants
R3	As carbon dioxide equivalent (CO_2e)
R4	As carbon dioxide equivalent (CO_2e)
R5	As carbon dioxide equivalent (CO_2e)
R6	As carbon dioxide equivalent (CO_2e)
R7	As individual pollutants
R8	As individual pollutants
R9	Don't know
R11	As individual pollutants
R12	As carbon dioxide equivalent (CO_2e)
R14	As individual pollutants
R15	As carbon dioxide equivalent (CO_2e)
R16	As carbon dioxide equivalent (CO_2e)
R19	As carbon dioxide equivalent (CO_2e)
R20	As individual pollutants
R22	Don't know
R23	As carbon dioxide equivalent (CO_2e)

Question 5b: Do you report your emissions per capita?

Yes = 8, No = 6, Blank = 11

Question 5c: If no, what units do you use?

Response Id	Answer
R1	metric tons CO_2e, per capita is a separate metric we report as well
R2	whole city
R14	ug/m^3
R19	$kgCO_2$ per litre
R20	Km2

Question 6: Which emission Scopes do you report and across which sectors? Tick all that apply.

Scope	All sectors	Agriculture	Aviation	Business	Energy Supply	Industry	Land use change
1	3	3	1	6	6	6	1
2	2	0	0	4	3	3	0
3	2	2	3	1	1	0	1

Scope	Public	Residential	Road Transport	Shipping	Waste management	Water	None		Other
1	5	7	6	3	4	4	3	2	Forestry; Industrial processes
2	4	3	1	0	0	2	2	0	-
3	0	1	2	1	4	2	3	1	Wastewater treatment

Q7: Which method do you use to calculate your Scope 3 emissions?

Response Id	Answer
R1	For wastewater, a simple emissions factor was provided, and applied to our population, for lack of better data. For waste, emissions are included even though landfill is outside City boundaries, based on tons of waste landfilled and a waste characterization factor set. For water, it is simply amount of water consumption multiplied by an emissions factor provided.
R3	We are currently investigating which method to use, e.g. DPSC vs CB
R5	We use input-output analysis primarily to calculate scope 3 emissions. For transport this is primarily fuel sales within the region, and for waste this is primarily weighbridge numbers from one specific landfill.
R11	I don't know
R15	For aviation, we calculate a share of the regional airport's emissions based on our population. For waste, we use a waste commitment approach
R19	Not applicable
R20	We do not know. The competency is determined by the Ministry of Environment
R23	Input-output analysis

Question 8: If you report some Scope 3 emissions, can you briefly describe what information you include? For example, "upstream" emissions from fossil fuel extraction for industry sector, emissions from transport food and goods purchased in business sector, emissions associated with water supply industry.

Response Id	Answer
R1	Water supply emissions, wastewater treatment emissions, and emissions from land filled waste.
R3	Residential buildings, Commercial and institutional buildings and facilities, Manufacturing industries and construction, Energy industries (Emissions from transmission losses etc) Agriculture, forestry and fishing activities Fugitive emissions from mining, processing, storage, and transportation of coal On-road transportation (Emissions from portion of transboundary journeys occurring outside the city, and transmission and distribution losses from grid-supplied energy consumption) Aviation, railways and waterborne (ditto) Solid waste disposal (Emissions from solid waste generated in the city but disposed in landfills or open dumps outside the city)

	Biological treatment of waste Incineration and open burning= Wastewater treatment and discharge Other Scope 3
R5	We include aviation - domestic and international, road transport for all fuels, and waste to an out-of-boundary landfill on a weight basis.
R11	I don't know
R19	Not applicable
R20	Emissiones totais, incluindo fontes naturais Emissiones totais, excluindo fontes naturais
R23	Fuel consumption for contracted buses. For flights is distance travelled per municipal employee.

Question 9: How do you determine the spatial and sectoral boundaries for emission reporting in your city/region? Tick all that apply. - Selected Choice

1. The boundaries align with the city/regional administrative boundaries = 8
2. The boundaries are determined on a sector by sector basis = 1
3. The boundaries are determined at a national government level = 4
4. The methodology for determining boundaries is part of our adopted inventory= 1
5. Other = 2 → specify:
    a. (R1) We do exclude two entities within our boundaries that the City does not have jurisdiction over (a state university and a national lab).
    b. (R15) We use a geographic plus approach based on the areas the city has policy influence. For example waste is disposed outside of the city boundaries but the solid waste utility is a city agency giving us significant policy influence.

Response Id	Answer
R1	The boundaries align with the city/regional administrative boundaries; Other (please give more detail): We do exclude two entities within our boundaries that the City does not have jurisdiction over (a state university and a national lab).
R2	The boundaries are determined on a sector by sector basis
R3	The boundaries align with the city/regional administrative boundaries
R5	The boundaries align with the city/regional administrative boundaries
R6	The boundaries align with the city/regional administrative boundaries
R11	The boundaries align with the city/regional administrative boundaries
R12	The boundaries are determined at a national government level
R14	The boundaries are determined at a national government level
R15	Other (please give more detail):
R16	The boundaries align with the city/regional administrative boundaries
R18	The boundaries are determined at a national government level
R19	The boundaries align with the city/regional administrative boundaries
R20	The boundaries are determined at a national government level
R23	The methodology for determining boundaries is part of our adopted inventory framework/standard. The boundaries align with the city/regional administrative boundaries

Q10: Do you have an air pollutants emission inventory reporting process or preferred methodology?

Yes= 7, No = 8, Don't know = 2, Blank = 8

Question 10a: If yes, which conventional air pollutants do you record in your city/region's inventory? Tick all that apply

Air pollutants		Respondents
Nitrogen oxides (NOx/NO_2)		6
Non-methane volatile organic compounds (NMVOC)		1
Sulphur dioxide (SOx/SO_2)		4
Particulate matter ($PM_{2.5}$)		5
Particulate matter (PM_{10})		5
Carbon monoxide (CO)		3
Black carbon (BC)		1
Total suspended particulates (TSP)		1
Other	Ozone (O_3)	2
	Nitric Oxide (NO)	1
	Benzene (C_6H_6)	1
(Blank)		19

Q11: Do you report citizens' transport behaviours, practices and/or activities in your GHG and/or air pollutants inventory? For example, apportioning road transport emissions by commuting to work, study, shopping, recreational etc

No = 12, Yes = 3, Don't know = 1, Blank = 9

Q11a: if yes, please give more detail

Response Id	Answer
R1	The commercial traffic model (used by cities throughout the Bay Area region for inventories) only goes to a County level. We use census data about % of jobs associated with heavy vehicles in order to proportion a certain amount of County emissions to the City level. For passenger traffic, we simply use the modelled data, as it is City-specific.
R19	Vehicle count performed in selected intersections within the city

Q12: Do you report on the sources of emissions from different energy end-uses in your GHG and/or air pollutant inventory?

Yes = 4, No = 9, Don't know = 3, Blank = 9

Q12a: If yes, please give more detail

Response Id	Answer
R19	Commercial building electricity consumption and street lighting considered in GHG inventory
R20	Existem 3 locais de medio distintos: (i) EstaÃo de medio de referencia (fundo); (ii) Estao de medio urbana (duas);

Question 13: What value/benefit does your city/region get from producing an emissions inventory? Please give up to 5 examples of what you use the information for and why it is valuable to your city/region

Response Id	Answer
R1	• Educates public about reducing carbon footprints • Identifies areas Council should support policy within Identifies sectors we need to focus on to achieve emissions reductions goals • Identifies potential policy focus areas or technology focus areas • Encourages public to take action
R2	• Public buildings energetic development • Connection to the national inventory
R3	• Benchmarking viz relative progress • Progress reporting viz progress to targets • Policy pointers • Global reporting sharing of progress • Allows access to networks and tools and exchange
R5	• We use the information from our inventories to generate our strategic plan for addressing emissions • We use the information from our inventories as part of our accountability process as our targets are based off these numbers • We use the information from our inventories to target interventions • We use the information in our inventories to develop tools like our Wellington calculator to enhance understanding among stakeholders including business
R11	• For policies • Insight in emissions
R14	• Eco XXI
R15	• Inform planning and policy decisions • Track our progress • Compare to other cities to identify successful strategies in other cities that we can learn from
R11	• For policies
R14	• Eco XXI
R15	• Inform planning and policy decisions
R19	• Transport identified as the dominant source of GHG and air pollutants in the city This sector was made priority and data used as basis for pushing implementation of vehicle testing and apprehension program • Halogen lamps replaced sodium lamps for street lighting to improve energy efficiency • Fluorescent replaced incandescent lamps for street lighting to improve energy efficiency

R20	• Implementação de ciclovias • Implementação de zonas de velocidade controlada • Implementação de Areas pedonais • Promoção do transporte publico
R23	• Decision making in climate actions in the city • Advising relevant departments on their emissions and how to reduce • Benchmarking the city with others in terms of reporting to international platforms • Increase awareness programmes for the community • Reducing the overall emissions in the municipal area

Q14: Do you use GHG and air pollution emissions inventory data in citizen and community engagement activities?

Yes = 7, No = 5, Don't Know = 2, Blank = 11

Question 14a: If yes, please can you give some examples of how you do this?

Response Id	Answer
R1	We annually update our emissions inventory and present it to Council, which is a public meeting we encourage interested parties to attend. This gives an opportunity to explain our methodology, our progress against our baseline emissions, and our policy focus areas moving forward. At various event, we usually give context to the particular program we are promoting or educating, to show how it fits into meeting our Climate Action Plan goals. The inventory data allows us to cite specific statistics to support those programs.
R5	We developed a Wellington 2050 calculator based off our inventory to allow stakeholders - business and individual alike - to develop their own pathways to meet our targets. We also use the information from our targets in consultations around our Low Carbon Capital Plan.
R14	https://www.pacopar.org/images/stories/revistas/RevistaPacopar2016_PT.pdf
R15	Our current emissions and progress to goal inform our community conversations on climate action planning.
R19	GHG inventory data used in information and educational campaign activities, specific messaging for consumers included use of more efficient lighting such as florescent lights
R20	Para melhorar a mobilidade urbana
R23	By community outreach programmes, presentations in schools and tertiary institutions, dispatching posters with info on reducing the emissions

Q15: Do you use GHG and air pollution emissions inventory data in business engagement activities?

Yes = 5, No = 5, Don't know= 5, Blank = 11

Q15a: If yes, please can you give some examples of how you do this?

Response Id	Answer
R1	We reach out to green business districts, as well as part of our outreach for green requirements in the City to explain how sustainability aspects are a good investment on their part, and help the City reach its Climate Action Goals.
R15	We use GHG inventory data to inform conversations with stakeholders as we develop climate actions/policies
R19	Data used in information and education campaigns for small businesses and private sector
R23	When advising on using renewable energy and energy efficient technologies to reduce the ghg emissions

Q16: How important are the following factors in your city's efforts to reduce GHG and air pollutant emissions: (On a scale of 0 - 10, with 0 being not important and 10 being very important)

Response Id	Infrastructure (e.g. New cycle lanes, road closures, building retrofits etc.)	Services (e.g. New public transport routes)	Technical (e.g. cleaner cars and buses)	Behavioural (e.g. trying to change the way citizens go about their daily lives)
R1	8	3	8	4
R2	10	10	10	10
R3	10	10	9	8
R5	7	5	10	9
R11	8	8	9	6
R12	1	3	1	6
R14	4	9	7	9
R15	10	10	10	10
R19	10	10	10	10
R20	9	9	4	5
R23	10	10	10	10

Question 16_1: Please consider up to 5 initiatives/networks that your city is a member of. What are the main benefits of each?

Response ID	Initiative 1	Benefits
R1	Covenant of Mayors	Reporting to the Covenant of Mayors not only gives visibility to the progress the City has made thus far, but also allowed us to transition our inventory into a regionally agreed upon model, making our data more accurate and consistent with other cities we partner with often.

R2	ICLEI	To reduce GHG and air pollutant emissions, trying to change citizens consumption and energy use behavior
R3	Compact and Covenant	progress monitoring and reporting
R5	Covenant of Mayors	International accountability
R14	Pacto de Autarcas	-
R15	Carbon Neutral Cities Alliance	Learn from leading cities, collaborative projects
R19	Cities for Clean Air Certification	Address challenges in improving air quality through a holistic approach to improve air quality management capacity. Provides international for actions taken by the city to address air pollution
R20	Ciclovias	Melhorar a mobilidade urbana e a qualidade urbana das cidades

Response ID	Initiative 2	Benefits
R1	ICLEI	ICLEI membership allows us access to technical expertise in inventories and forecasting, allowing for an inventory that aligns with the regional approach and follows a similar methodology between cities.
R2	Association of Climate Friendly Municipalities (Hungarian)	To reduce GHG and air pollutant emissions, trying to change citizens consumption and energy use behavior, climate friendly and environmental education
R3	ICLEI	information and exchange
R5	CEMARS	Internal accountability
R14	Mayors Adapt	
R15	Global Covenant of Mayors	Lift the voice of cities in the global climate conversation
R19	USAID	Supported formulation of city policies that would serve as legal basis for taking action on air pollution; Provided financial and training support for enactment of policy (vehicle testing and roadside apprehension)
R20	Requalifição de Ãreas/centros urbanos	Melhorar a mobilidade urbana e a qualidade urbana das cidades

Response ID	Initiative 3	Benefits
R1	USDN	Being a member of USDN opens up a world of resources and networks, allowing us to collaborate extensively on new policy areas and effective planning and evaluation of programs & technologies.

R3	EGC network	information and exchange
R5	CDP	Time series of data, global comparators
R14	ECO XXI	-
R15	C40	Lift the voice of cities in the global climate conversations, Mayor to Mayor engagement, peer learning networks, research
R19	ICLEI	Performed GHG inventory to identify major sources; Conducted study on impacts of climate change and local adaptation strategies
R20	Introdução de transporte publico especfica para as periferias das cidades	Melhorar a mobilidade urbana e a qualidade urbana das cidades

Response ID	Initiative 4	Benefits
R5	NZ Local government declaration on climate change	Local community motivation
R20	Implementação de estaçãde monitorização de qualidade do ar	Detalhar o nível vel de informação sobre a qualidade do ar no concelho

Response ID	Initiative 5	Benefits
R5	100 Resilient cities	International network building

Question 16_1: Please consider up to 5 initiatives/networks that your city is a member of. What are the main benefits of each?

Initiative	Benefits
Covenant of Mayors	• Reporting to the Covenant of Mayors not only gives visibility to the progress the City has made thus far, but also allowed us to transition our inventory into a regionally agreed upon model, making our data more accurate and consistent with other cities we partner with often (R1) • Progress monitoring and reporting (R3) • International accountability (R5) • Lift the voice of cities in the global climate conversation (R15)
Compact	• Progress monitoring and reporting (R3)
ICLEI	• To reduce GHG and air pollutant emissions, trying to change citizens consumption and energy use behaviour (R2) • ICLEI membership allows us access to technical expertise in inventories and forecasting, allowing for an inventory that aligns with the regional approach and follows a similar methodology between cities. (R1) • Information exchange (R3)

	• Performed GHG inventory to identify major sources (R19) • Conducted study on impacts of climate change and local adaptation strategies (R19)
Pacto de Autarcas	(R14)
Carbon Neutral Cities Alliance	• Learn from leading cities (R15) • Collaborative projects (R15)
Cities for Clean Air Certification	• Address challenges in improving air quality through a holistic approach to improve air quality management capacity (R19) • Provides international for actions taken by the city to address air pollution (R19)
Ciclovias	• Melhorar a mobilidade urbana e a qualidade urbana das cidades (R20)
Association of Climate Friendly Municipalities (Hungarian)	• To reduce GHG and air pollutant emissions, trying to change citizens consumption and energy use behavior, climate friendly and environmental education (R2)
CEMARS	• Internal accountability (R5)
Mayors Adapt	(R14)
USAID	• Supported formulation of city policies that would serve as legal basis for taking action on air pollution (R19) • Provided financial and training support for enactment of policy (vehicle testing and roadside apprehension) (R19)
Requalifição de Ãreas/centros urbanos	• Melhorar a mobilidade urbana e a qualidade urbana das cidades (R20)
USDN	• Being a member of USDN opens up a world of resources and networks, allowing us to collaborate extensively on new policy areas and effective planning and evaluation of programs & technologies. (R1)
EGC network	• Information and exchange (R3)
CDP	• Time series of data (R5) • Global comparators (R5)
ECO XXI	(R14)
C40	• Lift the voice of cities in the global climate conversations (R15) • Mayor to Mayor engagement (R15) • Peer learning networks (R15) • Research (R15)
Introdução de transporte publico especfica para as periferias das cidades	• Melhorar a mobilidade urbana e a qualidade urbana das cidades (R20)
NZ Local government declaration on climate change	• Local community motivation (R5)
Implementação de estaçãde monitorização de qualidade do ar	• Detalhar o nível vel de informação sobre a qualidade do ar no concelho (R20)
100 Resilient Cities	• International networking building

Q17: City initiatives and networks can provide a lot of advantages and benefits through membership. Please rate these benefits for your city/region on a scale of 0 - 10 with 1 - not important and 10 very important.

Response Id	Increased networking	Access to funding	Access to research/knowledge sharing
R1	4	10	8
R2	2	7	10
R3	8	10	9
R5	9	-	9
R7	5	-	-
R14	4	4	9
R15	10	10	10
R19	8	8	10
R20	7	9	8
R23	0	-	-

Response Id	Influencing policy	Raising awareness through citizen and stakeholder engagement	Other (please state):
R1	8	5	8
R2	5	8	5
R3	10	2	1
R5	10	9	-
R11	-	-	-
R12	8	9	8
R14	9	10	9
R15	10	10	10
R19	8	9	8
R20	-	-	-
R23	8	5	8

Q17_9: City initiatives and networks can provide a lot of advantages and benefits through membership. Please rate these benefits for your city/region on a scale of 0 - 10 with 1 - not important and 10 very important.

No responses available for this question

Appendix 2: Case study interview questions

On carbon/GHG inventories
Why do you use the carbon/GHG inventory framework/tool/method you use? What are the benefits of this approach? Are there are any disadvantages to this approach? To what extent are decisions around which emissions to include in the inventory decided by the method or by local decision-making
On conventional air pollutants:
Do you see any need to integrate conventional air pollutant reporting with GHG emission inventories and reporting at the city level?
On city initiatives:
When did you join the city initiatives you listed in your survey response? Why are you a member of these initiatives - what are the benefits of your membership? Do you anticipate a continuation of your membership for the foreseeable future? Has your city ever stopped being a member of any city initiative/network? Why
Do the city initiatives/networks facilitate engagement with the wider city region on carbon emission reduction? For instance, through providing activities or processes for engaging citizens or the business sector? Is this something you see as part of the role of city initiatives/networks?
Does you membership of these initiatives help in developing local policy around emission (GHG and/or air pollutants) reduction, or does it help fill any policy gap, if, for example, national government are not engaged or active in the sector. One example could be helping set local emission reduction targets that go further than national targets.
Does your membership of these initiatives help your city to engage with or influence national or international priorities/choices/agendas (e.g. in policy, research, innovation or funding).
Does your membership of these initiatives facilitate learning or opportunities to develop projects? If yes, can you give some examples?
In your opinion, could city initiatives improve their internal processes/operations in any areas. For example, communication, knowledge exchange, or administration? How?