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# Co-benefits of urban climate action: A framework for cities

A working paper by the [Economics of Green Cities Programme](#),  
LSE Cities, London School of Economics and Political Science

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## LSE Cities and C40 Cities Climate Leadership Group

LSE Cities is an international centre that carries out research, education and outreach activities in London and abroad. Its mission is to study how people and cities interact in a rapidly urbanising world, focusing on how the design of cities impacts on society, culture and the environment. With the support of Deutsche Bank's Alfred Herrhausen Gesellschaft, the centre builds on the interdisciplinary work of the Urban Age Programme, an international investigation of cities around the world that since 2005 has studied the social and spatial dynamics of metropolitan areas such as Istanbul, São Paulo, Mumbai, Johannesburg, Shanghai, New York City and London.

This Report forms part of a wider research programme at the LSE on the Economics of Green Cities (EGC). The EGC is a global collaborative programme chaired by Lord Stern at the LSE. The Programme was set up with the aim of examining the risk-adjusted costs and benefits of green policy frameworks on the sustainable economic growth of cities in different parts of the world. The purpose is to provide robust, evidence-based recommendations for city and national policy leaders and other stakeholders. The LSE is also the cities research partner for the Global Commission on the Economy and Climate, leading the research for the Global Commission's flagship project, the New Climate Economy.

The C40 Cities Climate Leadership Group (C40), now in its 10th year, connects more than 80 of the world's greatest cities, representing 600+ million people and one quarter of the global economy. Created and led by cities, C40 is focused on tackling climate change and driving urban action that reduces greenhouse gas emissions and climate risks, while increasing the health, wellbeing and economic opportunities of urban citizens.

C40's international staff works with the C40 network under the leadership of city governments to deliver this mission. Using a data-driven approach, the C40 team identifies and promotes the exchange of proven programmes and policies developed by cities; provides world-class research, technical expertise and access to key partners to deliver new programmes and policies with cities; and communicates cities' individual achievements and collective leadership. C40's research team performs cutting edge analysis on urban sustainability and serves as the leading authority on the impact the world's cities have on global climate change.

## Executive Summary

### Why do climate co-benefits matter for cities?

- The evidence suggests that citizens are more likely to take action on climate change, or more likely to support governments that take action on climate change, if the wider co-benefits of those actions are emphasised.
- At the same time, policies that are aimed at supporting innovation, delivering economic benefits and enhancing the quality of life of citizens can potentially lead to major climate co-benefits (e.g. reduced greenhouse gas emissions) which would be more challenging to achieve if climate action were the primary objective.
- At the city level, the potential of co-benefits is particularly great as citizens can often witness the results of policy actions more directly on their daily lives.

### Definition and taxonomy of co-benefits

- The term co-benefits has a wide range of definitions in the climate literature, with over 20 terms identified in the literature that are used synonymously or in a similar context.
- The term co-benefits varies in intentionality (e.g. is climate the primary or secondary objective, or simply an unintentional benefit?), scope (e.g. does it include mitigation benefits, adaptation benefits or both?), and scale (e.g. are the benefits short term and local, or long term and global?).
- Co-benefits may be (1) secondary benefits from climate policy action, (2) secondary climate benefits from other policy actions, or (3) the combination of climate and non-climate benefits; both of which are targeted under an integrated policy programme.
- The wide range of established definitions of co-benefits used by authoritative organisations means that formulating a taxonomy of co-benefits with broad buy-in from policy makers is challenging.

### Results of literature review

- Health, Land Use and Transport were the top three sectors for the number of co-benefits, with over 40 co-benefits identified in each.
- Waste, Air Quality, Transport and Energy had particularly high numbers of mitigation co-benefits in the literature reviewed. Adaptation co-benefits were particularly strong for Disaster and Emergency, Food Security and Tourism, Culture and Sport. Land Use, Health, Water and Education tended to be strong for both mitigation and adaptation co-benefits.

## Co-benefits frameworks

- Current co-benefits frameworks tend to be focused on three areas: (1) the green economy, (2) benefit-cost approaches, and (3) resilience frameworks. In many of these frameworks, the term co-benefits is not explicitly used. However, none of these frameworks are sufficient to capture the full landscape of co-benefits comprehensively.
- Furthermore, none of the existing frameworks are designed to identify and measure specific co-benefits in a city.
- This report suggests a new potential framework for city co-benefits based on five strategic sectors: Health, Mobility, Buildings, Resources and Economy.
- These strategic sectors are central to the strategy of many cities, including those in developed, emerging and developing countries.
- The strategic sectors can be subdivided into city goals and associated policy actions.
- Alternative policy actions can be assessed based on their climate and non-climate impacts.
- Five promising areas where co-benefits are potentially high include: 1. Traffic pollution; 2. Healthy lifestyles; 3. Smart transport systems (including Bus Rapid Transit); 4. Flooding and building damage; 5. Valuing the size of the environmental goods market.

## Urban indicators and data

- Cities need robust data and standard indicators to measure and monitor the impact of policy actions on co-benefits.
- The review identified three types of data source with potential to quantify co-benefits: data, case studies and models. However, much of the data contained in these sources is of little value to individual cities.
- The evidence suggests that currently few cities have benchmark indicators against which authorities can measure and monitor policy impacts on co-benefits. Where these do exist, they are not standardised across different cities.
- The evidence from the literature suggests that many cities do not collect the primary data to estimate such indicators. Other cities may hold relevant data, but are currently not using it either due to lack of capacity or the lack of a co-benefits framework.
- Gaps in data and technical capacity for analysing data are major barriers to implementing policy actions that maximise co-benefits.

## Recommendations

### Recommendation 1. Develop a co-benefits framework based on five strategic sectors; Health, Mobility, Resources, Buildings and Economy.

- Initiate a **global level collaboration** to develop a co-benefits framework.
- Build on and extend the **LSE/C40 co-benefits framework** (Annex 1 and 2) for the five strategic sectors, to provide a more comprehensive landscape of co-benefits, linking them to C40's Climate Action in Megacities.
- Develop a methodology for **measuring the green economy** and related co-benefits.
- Upgrade existing methods for measuring economic, social and environmental co-benefits and adjust to a **climate resilience framework**.
- **Using pilot studies, develop an integrated accounting framework** for municipal governments that includes climate, economic, social and environmental indicators and data.

### Recommendation 2. Improve the collection and analysis of climate co-benefits data.

- **Using pilot cities, build a detailed database of co-benefits data and indicators** beginning with the following areas: 1. Traffic pollution; 2. Healthy lifestyles; 3. Smart transport systems (including Bus Rapid Transit); 4. Flooding and building damage; 5. Valuing the size of the environmental goods market.
- Support a **data capacity building** programme for cities by sharing best practices on data and indicators.

### Recommendation 3. Implement a research programme on governance and finance required for delivering co-benefits.

- Develop best practice guidance for departmental and multi-level **governance** to deliver cross-departmental co-benefits through integrated policy.
- Develop action plans for allocating **public finance** more effectively and efficiently to deliver cross-departmental co-benefits and leverage private finance.
- Develop **planning frameworks** capable of integrating considerations across sectoral, spatial and temporal scales.
- Develop a **tool for prioritising policy programmes** that maximise climate impacts and co-benefits.

### Recommendation 4. Develop a communication strategy for taking action based on co-benefits.

Develop an evidence base for **best practice to communicate co-benefits to mayors, senior city officials, business, citizens and NGOs.**

## Part 1: Introduction

### Why do climate co-benefits matter for cities?

The evidence suggests that citizens are more likely to take action on climate change, or more likely to support governments that take action on climate change, if the wider co-benefits of those actions are emphasised (Bain et al. 2015). At the same time, policies that are aimed at supporting innovation, delivering economic benefits and enhancing the quality of life of citizens can potentially lead to major climate co-benefits (e.g. reduced greenhouse gas emissions) which would be more challenging to achieve if climate action were the primary objective.

At the city level, the potential of co-benefits is particularly great as citizens can often witness the results of policy actions more directly on their daily lives. One example is urban air quality. The major source of both outdoor air pollution and greenhouse gas emissions is the burning of fossil fuels. Consequently, targeted policy actions to improve air quality can lead to substantial climate co-benefits and vice versa. As air pollution leads to 7 million premature deaths a year, the health impacts of improved air quality represent a potentially powerful driver to reduce carbon emissions at the same time (WHO 2014).

Despite the potential for making a more robust economic, social and environmental case for climate action, combined with the potential for mainstreaming climate objectives into integrated municipal policy programmes, governments have not developed comprehensive co-benefits frameworks for policy decision making. Part of the reason is the lack of clarity on the definition of co-benefits. At the same time, where co-benefits are well-defined (e.g. policies that simultaneously reduce GHG emissions and urban air pollution levels), the benefits are most often unquantified and uncoded.

### Objectives of this report

C40 aims to support cities to “understand value and then make the case for individual climate actions based on the environmental, economic and social costs and benefits” of those actions. To support this overall aim, this report - a scoping study on co-benefits by the Economics of Green Cities Programme at the London School of Economics - has three key objectives:

- Undertake a review of the literature and data on urban co-benefits to climate action in order to map the current landscape of understanding, use and availability of data.
- Produce a co-benefit framework to support a shared language for, and common understanding and measurement of, co-benefits.
- Produce recommendations to inform further work on co-benefits.

## Methodology

### Review of literature by sector

The literature on climate co-benefits was examined across 13 key sectors. In order to define the scope for collecting the evidence on co-benefits, the project team initially identified 20 urban policy areas based on city and national departmental policy responsibilities. These were derived from the structures of a generic national government and a city's policy departments, and complemented by examining the overall strategies of a range of cities in developed, emerging and developing countries. For example, the digital policy area covers digital inclusion strategies as well as the digital infrastructure for business growth.

The policy areas were refined and organised into coherent sectors to reduce substantial overlaps. Given the overlap in the initial search results across Tourism, Culture and Sport, these were amalgamated. Similarly, Buildings and Housing were amalgamated. An initial examination of the Police and Security search results found little or no relevant co-benefits in the literature and this sector was excluded from the main analysis. Finally, Economy and Economic Development, Social Inclusion and Environment were not included as sectors as the co-benefits identified across the other remaining sectors were themselves grouped into economic, social and environmental. Combined, these co-benefits also cover the quality of life of citizens. However, given the importance of Air Quality as an environmental sector in the co-benefits literature, this was included as a specific sector in its own right. The process of refining and amalgamating the 20 initial areas resulted in 13 key sectors.

Many of the 13 key sectors were then divided into broad sub-sectors, reflecting the key areas of government responsibilities in each sector. This was particularly the case for sectors that covered a broad range of issues (e.g. Transport) or where the precise policy area was unclear using the sector keyword alone (e.g. Land use planning). The inclusion of sub-sectors was designed to extend the search to cover more potential co-benefits than might be apparent from sector headings only. This exercise resulted in 13 key sectors and 55 sub-sectors (see Box 1.1).

The literature was reviewed for each sector, using two search engines: scholar.google.co.uk and www.google.co.uk so that relevant grey literature was captured as well as academic studies. The searches were carried out for each sector and sub-sector in both Google and Google Scholar with identical keywords in standardised order. The total number of search results was recorded and the first 20 relevant articles for each sector and sub-sector search were reviewed in detail.

It should be noted that the literature search was conducted using English keywords and with the UK version of Google. Consequently, articles on co-benefits in other languages and in other countries are probably under-represented in the sampling. However, case studies found in the search were broadly international in scope. At the same time, certain urban challenges were particularly concentrated in certain regions, countries or cities. For example, many of the searches related to air quality co-benefits mentioned case studies from China and India, reflecting the significant air pollution challenges that these countries currently face.

The literature review was supplemented by additional key articles that were referenced in the articles reviewed as well as specific literature suggested by C40 (New Climate Economy research publications, LSE research, Carbon Disclosure Project) and LSE experts. For each of the 13 sectors, benefits identified in the literature were categorised into adaptation, mitigation, economic, social or environmental benefits.

**Box 1.1 List of 13 key sectors examined in the co-benefits literature**

Overall, 13 key sectors and 55 sub-sectors were reviewed for co-benefits. Economy & Development, Social Inclusion and Environment were not included as sectors, but were instead captured as co-benefits across the 13 sectors.

- |  |   |   |
|--|---|---|
| <p>1. Health</p> <ul style="list-style-type: none"> <li>• Health efficiency</li> <li>• Children</li> <li>• Elderly</li> <li>• Care services</li> <li>• Pharmaceuticals</li> <li>• Malnutrition</li> </ul>  | <p>4. Water</p> <ul style="list-style-type: none"> <li>• Water quality</li> <li>• Water pollution</li> <li>• Water distribution</li> <li>• Flood protection</li> <li>• Sewerage</li> </ul>                                    | <p>9. Tourism, Culture and Sport</p> <ul style="list-style-type: none"> <li>• Tourism</li> <li>• Culture</li> <li>• Sport</li> </ul>  |
| <p>2. Land use planning</p> <ul style="list-style-type: none"> <li>• Planning rules</li> <li>• Infrastructure planning</li> <li>• Regeneration</li> <li>• Green spaces</li> </ul>  | <p>5. Buildings</p> <ul style="list-style-type: none"> <li>• Energy efficiency</li> <li>• Building standards</li> <li>• New technology</li> </ul>   | <p>10. Food security</p> <ul style="list-style-type: none"> <li>• Food distribution</li> <li>• Food safety</li> </ul>   |
| <p>3. Transport</p> <ul style="list-style-type: none"> <li>• Rail</li> <li>• Metro</li> <li>• Roads</li> <li>• Parking</li> <li>• Road safety</li> <li>• Cycling</li> <li>• Walking</li> <li>• E-mobility</li> <li>• Shared mobility</li> <li>• Multimodality</li> <li>• Airports</li> <li>• River transport</li> <li>• Freight</li> <li>• New technology</li> </ul> | <p>6. Digital</p>   | <p>11. Air quality</p> <ul style="list-style-type: none"> <li>• Carbon emissions</li> <li>• Air pollution</li> </ul>  |
|  | <p>7. Energy</p> <ul style="list-style-type: none"> <li>• Energy security</li> <li>• Low carbon energy</li> <li>• Energy regulation</li> <li>• Smart grids &amp; energy distribution</li> <li>• Distributed energy</li> </ul> | <p>12. Waste</p> <ul style="list-style-type: none"> <li>• Household waste</li> <li>• Industrial waste</li> <li>• Recycling</li> <li>• Landfill</li> <li>• Incineration</li> </ul>         |
|  | <p>8. Education</p> <ul style="list-style-type: none"> <li>• Childcare</li> <li>• Schools</li> <li>• Higher education</li> </ul>  | <p>13. Disaster &amp; emergency</p> <ul style="list-style-type: none"> <li>• Contingency planning</li> <li>• Resilient infrastructure</li> <li>• Fire &amp; emergency services</li> </ul> |

Different sectors had different numbers of sub-sectors, leading to a higher number of articles being reviewed in some sectors than in others. Transport had the highest number of sub-sectors (14), followed by Health (6). This tended to reflect the abundance of co-benefits literature for these sectors. The Digital sector was not divided into sub-sectors as it was more specialised than many of the other sectors, and many co-benefits with a digital association were picked up in “New Technology” searches (under Transport and Buildings). The total number of articles found for each sector may also depend on the search engines’ algorithms. For these reasons, sectors were compared in terms of relative numbers (e.g. percentage of articles with mitigation co-benefits) rather than absolute numbers.

The literature review represents one of the most extensive reviews on climate co-benefits across urban sectors yet undertaken. Nevertheless, as a scoping study, it should not be regarded as exhaustive. Some sectors had a large range of research on co-benefits that could not be examined in detail within the scope of this review. By focusing on the first 20 relevant articles in each sub-sector search, the majority of co-benefits were probably identified in each sector. Indeed, few new co-benefits were captured successively after around 15-20 articles. Nonetheless, further research efforts could be directed to a number of sectors that are particularly rich in co-benefits literature; these include health, land use planning and transport.

In some of the less represented sectors, the keywords used in the literature review may not have picked up articles that examine co-benefits but do not explicitly use the term co-benefits. The concept of co-benefits is not as established in certain sectors, and this may have influenced the number of relevant articles in these sectors. Sectors where more research would seem promising include education, water and tourism.

### **Review of co-benefits frameworks**

In parallel to the literature review on co-benefits by sector, the project team conducted a review of co-benefits definitions and frameworks. A large range of definitions were already identified in the sectoral review, and this review was supplemented with detailed searches for definitions by major organisations with climate co-benefits programmes or research publications. These included the Intergovernmental Panel on Climate Change (IPCC), the United States Environmental Protection Agency (EPA), the Organisation for Economic Co-operation and Development (OECD), the Asian Co-benefits Partnership (ACP), the Japanese Ministry of Environment, the United Nations, and the World Bank.

A review of co-benefits frameworks identified three important general approaches in the literature. These were (1) the green economy, focusing on mitigation and economic benefits, (2) benefit-cost approaches, which provide an insight into how governments assess multiple benefits and costs, and (3) resilience frameworks, which focus on climate adaptation and potential co-benefits. The report examines each of these three approaches along with their potential and limitations.

### **Five strategic sectors**

The co-benefits identified in the sectoral literature review were grouped into five strategic sectors: Health, Mobility, Resources, Buildings, and Economy. These strategic sectors were then divided into city goals, policy actions and co-benefits.

The strategic sectors were created using two main criteria. First, the strategic sectors are collectively exhaustive, with all the co-benefits identified in the review assigned to one of the strategic sectors. The strategic sectors are not mutually exclusive, and in many cases, a judgement was made over which strategic sector a co-benefit should be assigned to, when strong arguments could be made for assigning the co-benefit to another strategic sector. Given that this is a scoping report, the assignment of co-benefits may be refined in future research.

Second, the strategic sectors were based on policy areas where many city governments already have strategic goals that resonate with urban citizens. All five strategic sectors include an element of improving quality of life, with perceived benefits for citizens that are both direct and tangible. The evidence for this was drawn from a previous LSE Cities survey of policy makers in 100 cities worldwide along with evidence on mayoral city powers by C40 (Rode and Floater 2013; C40 2015).

The five strategic sectors encompass the co-benefits in the 13 sectors described above. For example, many of the co-benefits in the Air Quality sector are integrated into the strategic sector of Health. Mobility includes co-benefits in the Transport sector, but also in Land Use. Resources include Energy, Water and Waste. To reduce double counting, policy actions that initially appeared in multiple sectors were consolidated. For example, the preliminary findings included 'Increase public transport' under Land Use; and 'Increase the use of public transport (by bus rapid transit, light rail, metro or rail)' under Transport. As the policy action is the same, it appears only once in the Annex tables under the Mobility strategic sector, inclusive of all co-benefits previously identified.

While double counting of policy actions and associated co-benefits was reduced, the same or similar co-benefit may still be found more than once if it is associated with more than one strategic sector. This reduced the total number of co-benefits from 287 to 268 spread across 55 policy actions. The results are shown in Annex 1 and 2 of the report.

## Part 2: Findings

### Definition and taxonomy of co-benefits

#### Definitions used in the literature

The term *co-benefits* is defined in many different ways in both the academic and policy literature. There are also many terms (such as *ancillary benefits*, *secondary benefits*, etc.) that are in some cases synonymous with co-benefits but in other cases have a slightly different meaning. In our literature review, *co-benefit* was associated with over 20 different terms with a wide range of uses (see Box 1.2). In addition, various studies have highlighted the existence of co-impacts that have a net cost or are neither positive nor negative in their impact.

#### Box 1.2 List of terms used interchangeably with “co-benefits”

The term *co-benefits* is used in many different ways. As part of the C40/LSE project, our literature review uncovered the following list of over 20 terms that are used interchangeably with *co-benefits*:

- Win-win situations
- Life-cycle benefits
- Triple-win scenarios
- Consequential benefits
- Ancillary benefits
- Mutual benefits
- Consequential life cycle impacts
- Secondary benefits
- Induced changes
- Collateral benefits
- Side benefits
- Associated benefits
- Spill-over benefits
- Alignment of incentives/objectives
- Mainstreaming
- No-regret strategies
- Co-priorities
- Co-control
- Synergistic objectives
- Leverage points
- Co-incidence of agendas
- Externalities
- Coupled systems

In addition to these terms for co-benefits, a number of studies have highlighted the existence of co-impacts that have a net cost or are neither positive nor negative in their impact. Examples include:

- Co-effects
- Co-impacts
- Co-costs
- Life cycle impacts
- Ancillary impacts

## Definitions used by major organisations

The IPCC Third and Fourth Assessment Reports (AR3 and AR4) distinguish between *co-benefits* (benefits that are intended by the policy maker) and *ancillary benefits* (unintended benefits). Under this definition, co-benefits are the benefits from policy options implemented for various reasons at the same time (see Box 1.3; (IPCC Climate Change 2001: Working Group III: Mitigation)).

Consequently, AR3 suggests an integrated policy approach in which multiple policy objectives are intended, including climate and non-climate objectives (illustrated in diagram (c) in Fig. 1.1). In contrast, single-objective policies result in *direct benefits* in the stated sphere, and unintentional *ancillary benefits* in other spheres as a result of the policy action.<sup>1</sup> However, in the Fifth Assessment Report (AR5), the IPCC has shifted its definition, and acknowledges that co-benefits are often referred to as ancillary benefits.

Programmes and research such as those of the **US EPA** Integrated Environmental Strategies, the Clean Air Initiative for Asian Cities (CAI-Asia) and the **OECD** focus particularly on air quality and GHG emissions. They are open to different interpretations of intentionality (Bollen et al. 2009). Co-benefits relate to GHG emission reductions along with health, agricultural and economic benefits from addressing local air pollution. In the EPA's formulation, benefits can be generated unintentionally when decision makers implement a policy with a single aim and then later discover that the policy resulted in additional co-benefits. **CAI-Asia** suggest potential value in de-emphasising the intentional climate objective, "considering that many of the Asian countries do not have climate change policies in place, nor are they expected to have detailed policies in the next years" (Castillo et al. 2007).

The **Asian Co-benefits Partnership** suggests that climate co-benefits can represent a secondary benefit to development objectives but are integrated into the policy making process. This means promoting "policies, programmes or projects designed to meet immediate development priorities such as improving urban air quality, water quality, and waste management while taking into account longer term climate concerns." In the case of air quality, climate considerations may be better placed as a secondary consideration as "direct local air pollution control policies appear to be typically cheaper than indirect action via greenhouse gases emissions mitigation" (Bollen et al. 2009).

**The World Bank** analysis shows the scoping possibilities when co-benefits are treated as 'win-win-win' scenarios in developing policies which "create environmental benefits while simultaneously contributing to development, adaptation, and mitigation" (Hamilton and Akbar 2010).

As for scale, GHG reductions in a city are aimed to support collective action to reduce the damaging impacts of climate change globally. This can be achieved while delivering a range of benefits (e.g. improved air quality, waste management, energy security) at the local scale for the city itself. Climate mitigation benefits also tend to be long-term; actions taken today will support the reduction of climate impacts decades into the future. At the same time, non-climate co-benefits tend to offer relatively near-term benefits which are also locally felt, affecting the communities relatively close to the sources of the emissions changes (IPCC Climate Change 2001: Working Group III: Mitigation). The opportunity for cities to pursue co-benefit policies thus offers an analytical framework through which individual action on GHG reductions which have singular minimal impact (but significant collective impact if pursued by large numbers of cities) can be aligned with local policy objectives.

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<sup>1</sup> Note as consistent with the objectives of the IPCC, the policy focus is always climate action. Thus the distinction lies in whether the policy actions are simultaneously and explicitly designed for climate and non-climate co-benefits; or offer delivery of non-climate ancillary benefits (e.g. resource efficiency).

**Box 1.3 Definitions of co-benefits used by major organisations****Intergovernmental Panel on Climate Change (IPCC) 2001, 2007**

*“Co-benefits” are the benefits from policy options implemented for various reasons at the same time, acknowledging that most policies resulting in GHG mitigation also have other, often at least equally important, rationales. “Ancillary benefits” are the monetized secondary or side benefits of mitigation policies on problems such as reductions in local air pollution associated with the reduction of fossil fuels, and possibly indirect effects on congestion, land quality, employment, and fuel security.*

**IPCC 2014**

*The positive effects that a policy or measure aimed at one objective might have on other objectives, without yet evaluating the net effect on overall social welfare. Co-benefits are often referred to as ancillary benefits.*

**United States Environmental Protection Agency (EPA) 2004**

*Co-benefits is used to refer to two or more benefits that are derived together from a single measure or set of measures. Benefits can be generated unintentionally when decision makers implement a policy with a single aim and then later discover that the policy resulted in additional co-benefits. This document... considers any positive benefit derived from a policy measure or scenario to be a co-benefit of the policy, provided that one of the benefits achieved is reduced GHG emissions.*

**Organisation for Economic Co-operation and Development (OECD) 2015**

*For GHG mitigation policies, co-benefits can best be defined as effects that are additional to direct reductions of GHG and impacts of climate change and have estimated to be large, relative to the costs of mitigation (e.g. anywhere from 30% to over 100% of abatement costs).*

**The Asian Co-benefits Partnership (ACP)**

*[Co-benefits are] those derived from the intentional decision to address air pollution, energy demand, and climate change in an integrated manner, but also considers the other unspecified benefits that may arise such as improved transport and urban planning, reduced health and agricultural impacts, improved economy or reduced overall policy implementation cost. This enables sector managers to utilize the co-benefit approach without doing so in the context of a specific climate change policy.*

**Ministry of Environment, Japan 2009**

*Co-benefits refers to multiple benefits in different fields resulting from one policy, strategy, or action plan.*

**United Nations IAS 2013**

*Co-benefits approach refers to the development and implementation of policies and strategies that simultaneously contribute to tackling climate change whilst addressing local environmental and developmental problems.*

**World Bank, Background Paper 2010**

*Co-benefits are defined as the benefits for the local environment as a result of (mitigation/adaptation) actions that are targeted at addressing global climate change.*

## Taxonomy of co-benefits

As part of the scope of the LSE co-benefits review, C40 requested an examination of a potential taxonomy of co-benefits. A taxonomy can be defined in at least two ways. The strictest definition of a taxonomy, based on its original biological definition, is a hierarchical classification in which objects or groups in one level are aggregated into groups at the level above. A broader definition of taxonomy is simply any type of classification of objects.

In order to classify co-benefits into a taxonomy it is necessary to have a clear definition of co-benefits themselves. As discussed in the sections above, the term co-benefits is used in a wide range of different ways. This makes a single taxonomy of co-benefits based on the literature impossible. However, while the term co-benefits has a wide range of uses, the literature reveals three main elements that policy makers should consider when classifying the term for policy purposes: intentionality, scope and scale.

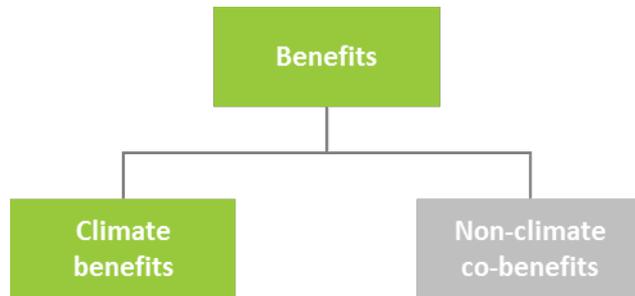
1. **Intentionality:** does the design and implementation of policy actions intentionally seek climate change benefits or are these benefits incidental; and where climate action is intentional, is it pursued as the primary objective, the secondary objective, or as one of several simultaneous objectives through an integrated policy approach?
2. **Scope:** do climate benefits capture mitigation, adaptation, or both; and do the benefits include a range of sustainable development considerations including economic, social and environmental net benefits?
3. **Scale:** are co-benefits realised at the same or different temporal or geographical scales (e.g. GHG reductions that support global climate action and improved air quality locally)?

A classification based on these three elements could be termed a taxonomy in the broadest sense of the term.

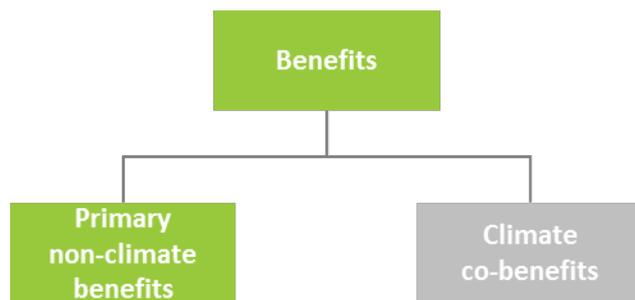
The type of intentionality used by a policy maker may depend on the circumstances of the policy in question. For example, a city may aim to reduce vehicle use based on the objective of reducing greenhouse gases (Fig. 1.1a). Another city may also aim to reduce vehicle use – even using the same policy instrument – but based on the objective of reducing congestion (Fig. 1.1b). Ideally, both climate and non-climate benefits will be assessed as part of a comprehensive risk-adjusted cost-benefit analysis (Fig. 1.1c) as discussed in the section on frameworks in this report.

**Fig. 1.1 Intentionality and directionality of co-benefits. (a) Climate benefits are the primary objective of the policy which results in other non-climate co-benefits, (b) Non-climate benefits are the primary objective of the policy which results in climate co-benefits, (c) An integrated policy approach targets climate and non-climate benefits simultaneously.**

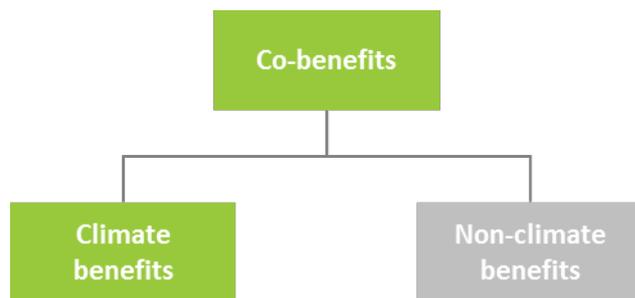
**Primary climate benefits**



**Secondary climate benefits**



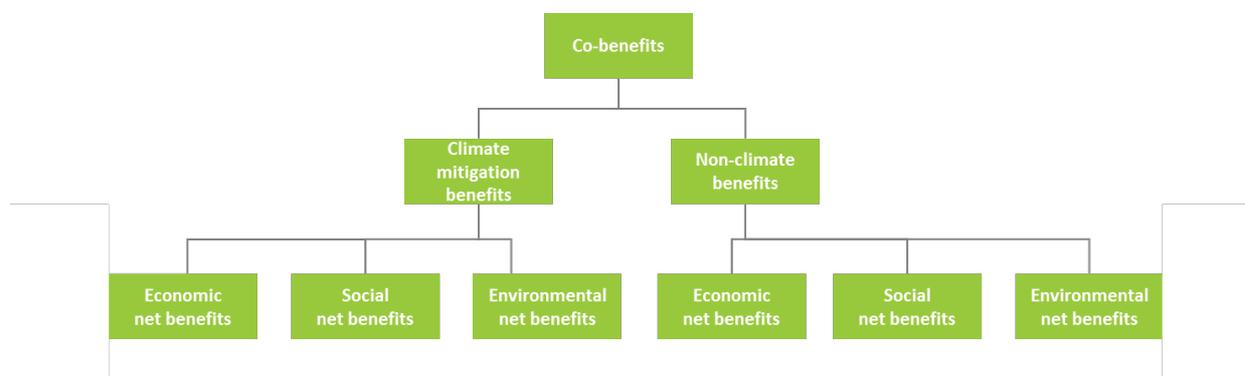
**Integrated policy**



A number of organisations define co-benefits in such a way as to allow a taxonomy based on a hierarchical classification (e.g. the US Environmental Protection Agency described in the previous section). These hierarchical classifications first differentiate between climate mitigation and non-climate benefits. Co-benefits then refers to the existence of at least one climate mitigation benefit and one non-climate benefit associated with a policy action.

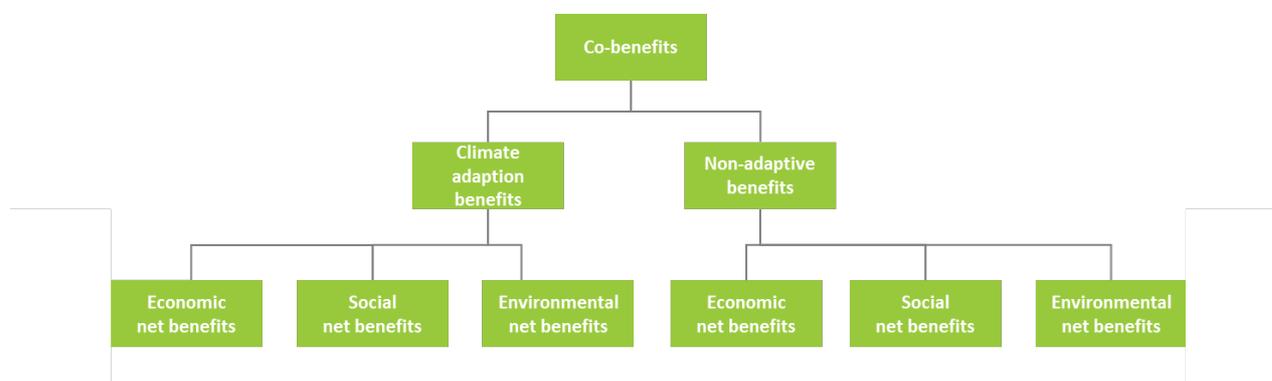
These climate mitigation and non-climate groupings can then be sub-divided into different types of groups. For example, Fig. 1.2 shows non-climate benefits sub-divided into the familiar groupings of sustainable development: economic, social and environmental benefits. Mitigation benefits are also sub-divided into economic, social and environmental net benefits that may result from reduced climate change.

**Fig. 1.2 Example of a taxonomy of mitigation co-benefits based on a hierarchical classification.**



Organisations have devoted less attention to definitions of climate adaptation co-benefits. However, a similar taxonomy can be used, based on sustainable development net benefits (Fig. 1.3). It should be noted that many organisations define non-climate benefits as shorter term, local benefits, rather than, for example, the reduction in longer term global economic losses due to reductions in greenhouse gases. Under these definitions, economic net benefits can be classified as being either climate mitigation benefits or non-climate benefits. However, under other definitions, no distinction is made between climate and non-climate groups of economic net benefits.

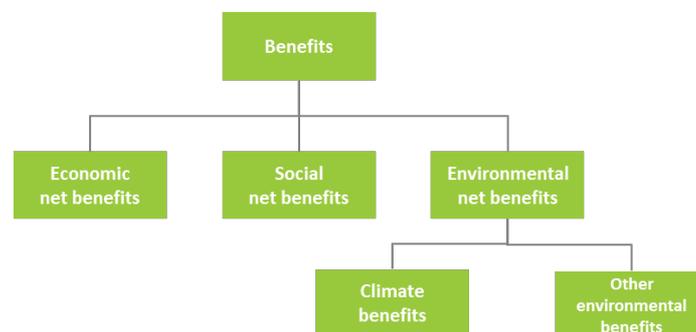
**Fig. 1.3 Example of a taxonomy of adaptation co-benefits based on a hierarchical classification.**



C40 reported that for many of their cities, climate change, whilst acknowledged as important, is not among the most immediate or urgent priorities – especially for rapidly urbanising cities in developing countries where basic services, e.g. potable water and sewerage, are still lacking for a significant proportion of citizens. This led to discussions about a taxonomy that might better represent city priorities and the reality that they face. In addition, the principle of integrated decision making was felt to be important; that cities assess policy options based on overall net benefit across not only climate, but also economic, social and environmental benefits.

This led C40 to suggest an alternative classification of policy benefits that is not based on the co-benefits literature or on existing definitions of co-benefits used by major international organisations. The classification structure is illustrated in Fig. 1.4. First, the classification uses the term benefits rather than co-benefits. Second, the classification is based on a standard sustainable development classification of economic, social and environmental net benefits. Third, this type of classification goes back to the traditional theoretical framework commonly used before the Stern Review, which defined climate action as an environmental policy, rather than a socio-economic policy. From a C40 perspective, the advantage of this approach is that as per above (i) it reflects the reality in cities, i.e. that climate change is not their top priority, and (ii) it encourages integrated decision making based on overall net benefit. In addition, policy makers are often more familiar with it. However, the risk of this approach is that climate change is not prioritised as clearly or strongly, being regarded primarily as an environmental issue rather than a socio-economic issue.

**Fig. 1.4 Example of a taxonomy of climate benefits based on a hierarchical classification.**



The results of this scoping exercise show the extensive confusion in defining and classifying co-benefits in the literature. One approach to this confusion is to provide a comprehensive taxonomy of co-benefits. An advantage of this approach is that it may attempt to bring clarity to a growing area of policy interest. However, given the wide range of international organisations with their own classifications, it is unlikely that a comprehensive taxonomy would be accepted by all. A second approach is to abandon the co-benefits concept altogether. However, given the interest shown by policy makers, and the strong potential for multiple benefits of particular policy actions, the co-benefits agenda is likely to grow at the city and national levels.

A third approach is to develop a framework for co-benefits that is not based on a taxonomic classification, but on strategic sectors that encompass particularly promising policy actions with climate and non-climate co-benefits. This approach is discussed in the section of this report on frameworks.

## Co-benefits landscape

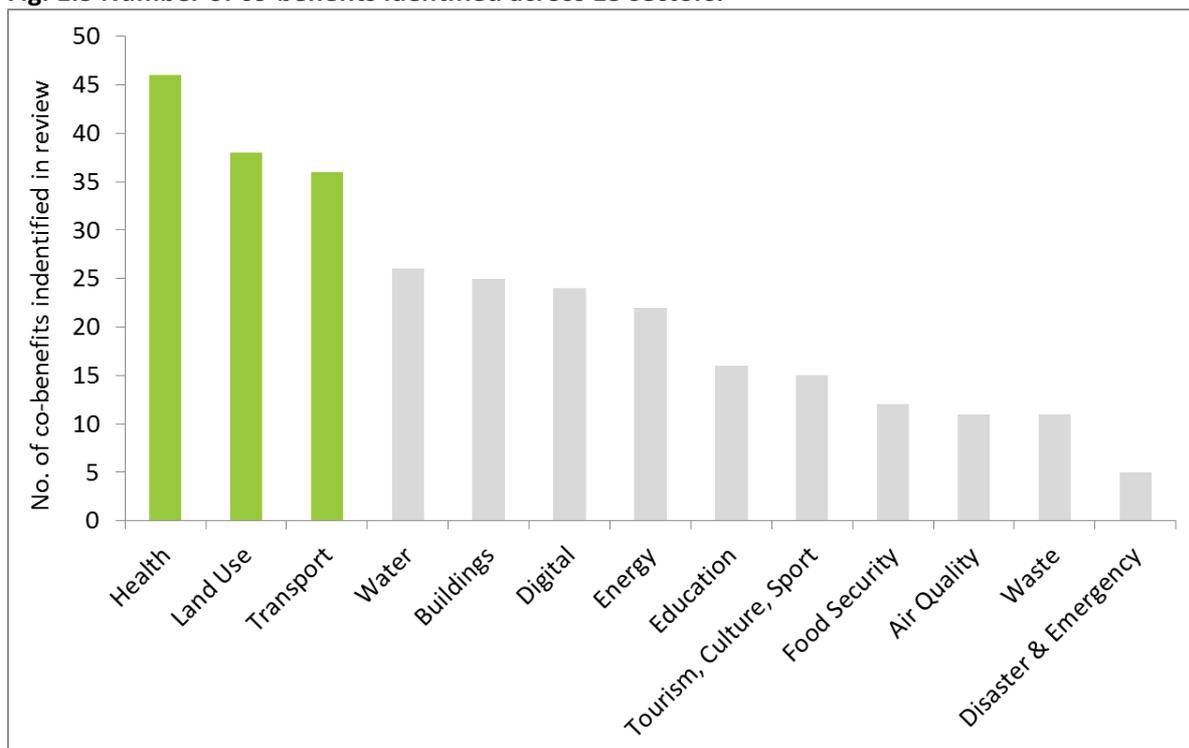
### Literature review

The review identified 287 co-benefits for 76 policy actions with climate-related impacts across 13 sectors. Some of these co-benefits and policy actions were recorded in more than one sector. The co-benefits listed are only those that can be drawn from the studies and reports reviewed. Nevertheless, while the results should not be considered comprehensive outside of the sources referenced, they do capture the leading research on co-benefits as described in the Methodology. This approach has some limitations in that broader co-benefits from policy choices that are not strictly climate related have been excluded<sup>2</sup>. Further research on discerning these otherwise established co-benefits for their mitigation and adaptation potential should be considered.

### Key sectors for climate co-benefits

Health, Land Use and Transport were the top three sectors for the number of co-benefits, with over 40 co-benefits identified in each (Fig. 1.5). Water, Buildings, Digital and Energy policy also scored relatively highly with around 30 co-benefits in each. Over 20 co-benefits were identified for Education. Disaster & Emergency had the lowest number of identified co-benefits.

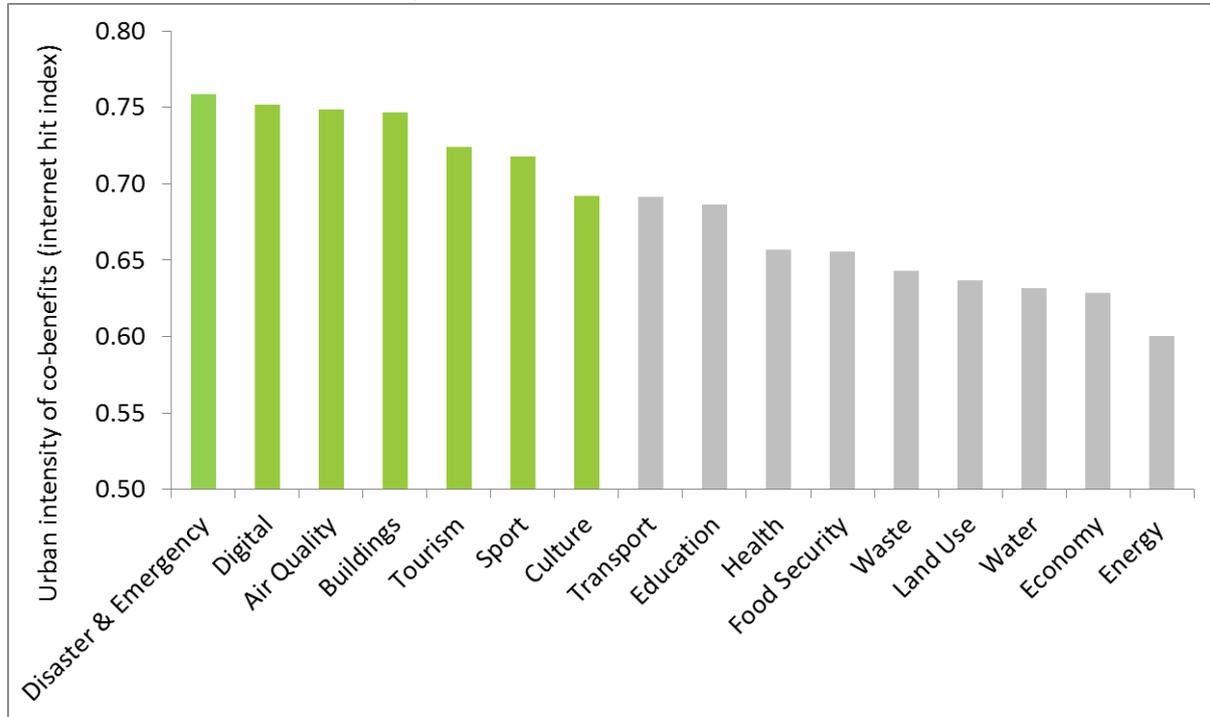
Fig. 1.5 Number of co-benefits identified across 13 sectors.



<sup>2</sup> For example, transport policies that decrease GHG emissions through mode shifting away from private cars (e.g., investments in mass transit or non-motorised mobility) are likely to have social inclusion and personal health co-benefits, but this has not been assessed/linked in the literature.

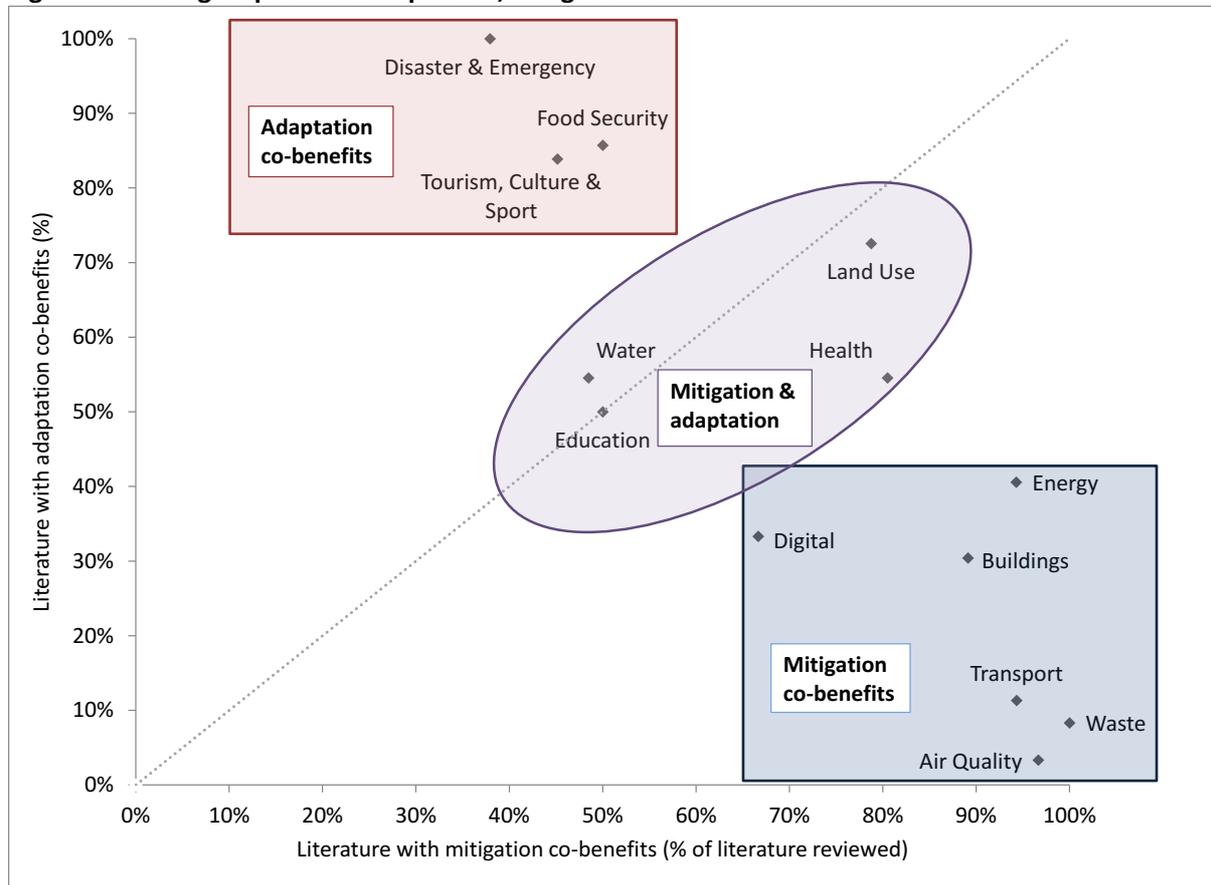
While the Disaster & Emergency sector had the lowest number of co-benefits in the literature, these co-benefits were associated more strongly with urban areas than those of other sectors (Fig. 1.6). Digital, Air Quality, Buildings, Tourism, Culture and Sport also scored highly for their urban focus.

**Fig. 1.6 Sectors with high urban co-benefits. Bars represent the proportion of co-benefits papers in the literature that contain the keyword “urban”.**



Co-benefits can be divided broadly into three groups of sectors: predominantly mitigation, predominantly adaptation, and a combination of both (Fig. 1.7). Waste, Air Quality, Transport and Energy had particularly high numbers of mitigation co-benefits in the literature reviewed. Adaptation co-benefits were particularly strong for Disaster & Emergency, Food Security and Tourism, Culture & Sport. Land Use, Health, Water and Education tended to be strong for both mitigation and adaptation co-benefits.

**Fig. 1.7 Sectors grouped into adaptation, mitigation and combined co-benefits.**



**Key sectors for climate mitigation and other co-benefits**

The review identified 171 economic, social and environmental co-benefits for 42 policy actions with a climate mitigation benefit, across 12 sectors. In almost all cases, the climate mitigation benefit was related to reduced GHG emissions. Other mitigation benefits include carbon sequestration. No co-benefits were identified in the literature reviewed for Disaster & Emergency policies with a mitigation impact. Transport, Health and Digital were the top three sectors for the number of mitigation-related co-benefits, with 20 to 30 co-benefits identified in each (Fig. 1.8a).

Health, Digital, Transport and Buildings recorded the highest number of mitigation-related economic co-benefits, ranging between 8 and 12 for each (Fig. 1.8b). Transport recorded 14 mitigation-related social co-benefits, considerably higher than any other sector. Social co-benefits were also prominent in the Health sector (Fig. 1.8c). Health, Transport, Waste and Energy recorded the highest number of mitigation-related environmental co-benefits, ranging between 6 and 7 for each (Fig. 1.8d).

These results suggest that the Transport and Health sectors are particularly rich in mitigation-related co-benefits. It should be noted that both of these sectors had a relatively large number of sub-sectors which may have biased the results to some degree. However, the inclusion of these sub-sectors reflected in part the importance of both sectors in the literature.

Of the top 10 policy actions for mitigation co-benefits, five are transport-related (Fig 1.9).

**Fig. 1.8a Total number of co-benefits of mitigation-related policies, by sector.**

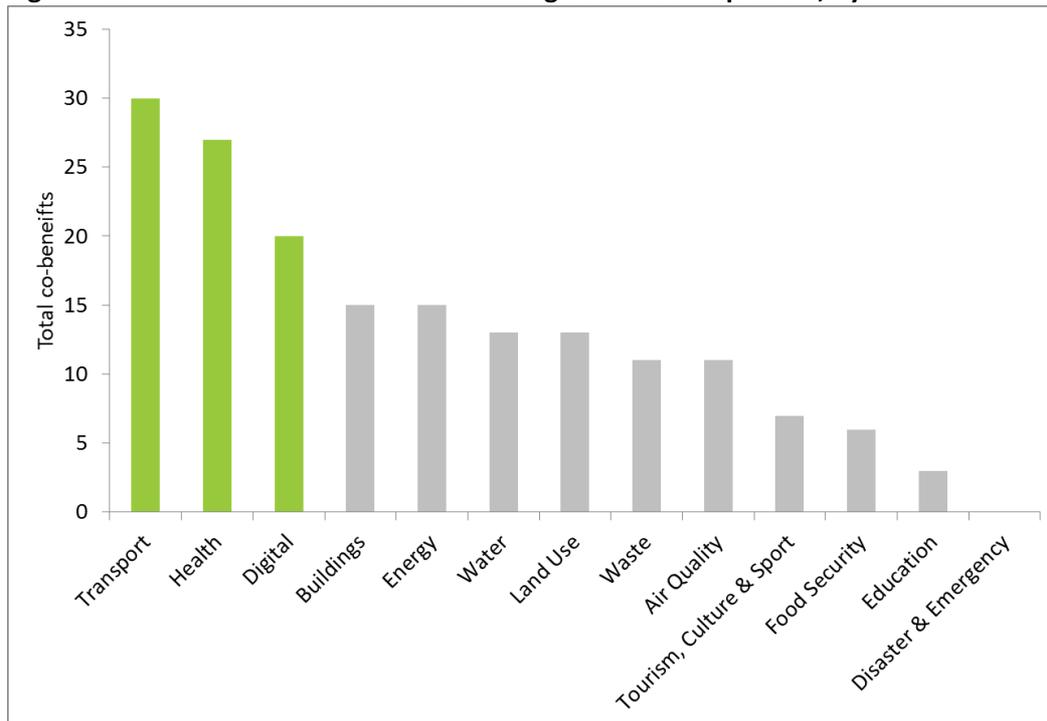


Fig. 1.8b Economic co-benefits of mitigation-related policies, by sector.

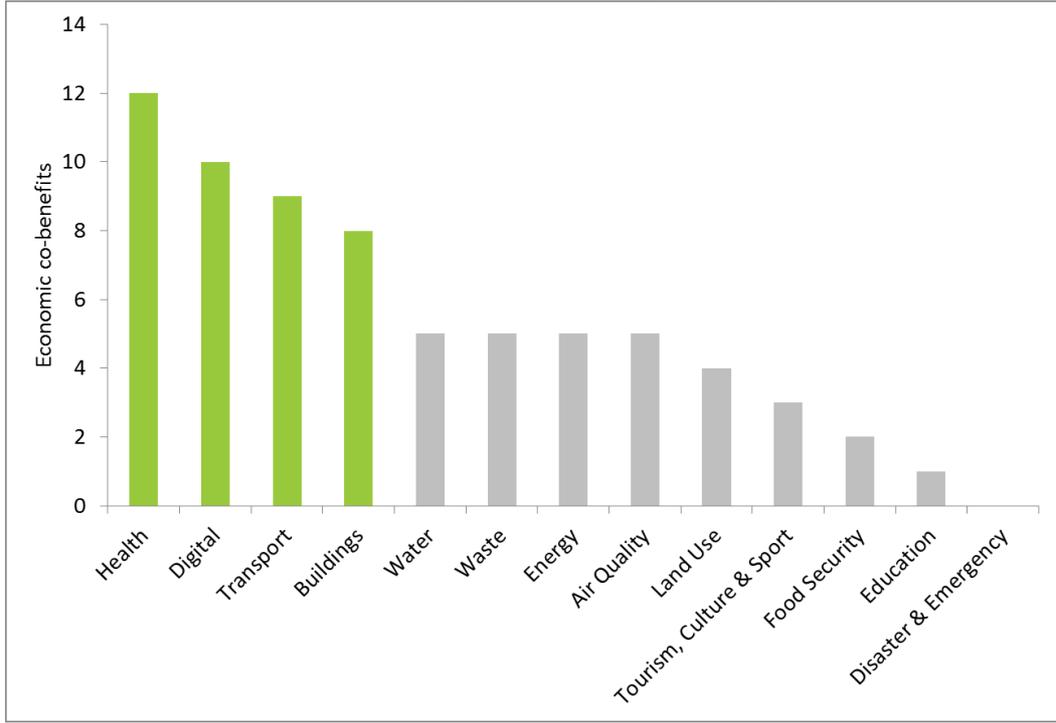


Fig. 1.8c Social co-benefits of mitigation-related policies, by sector.

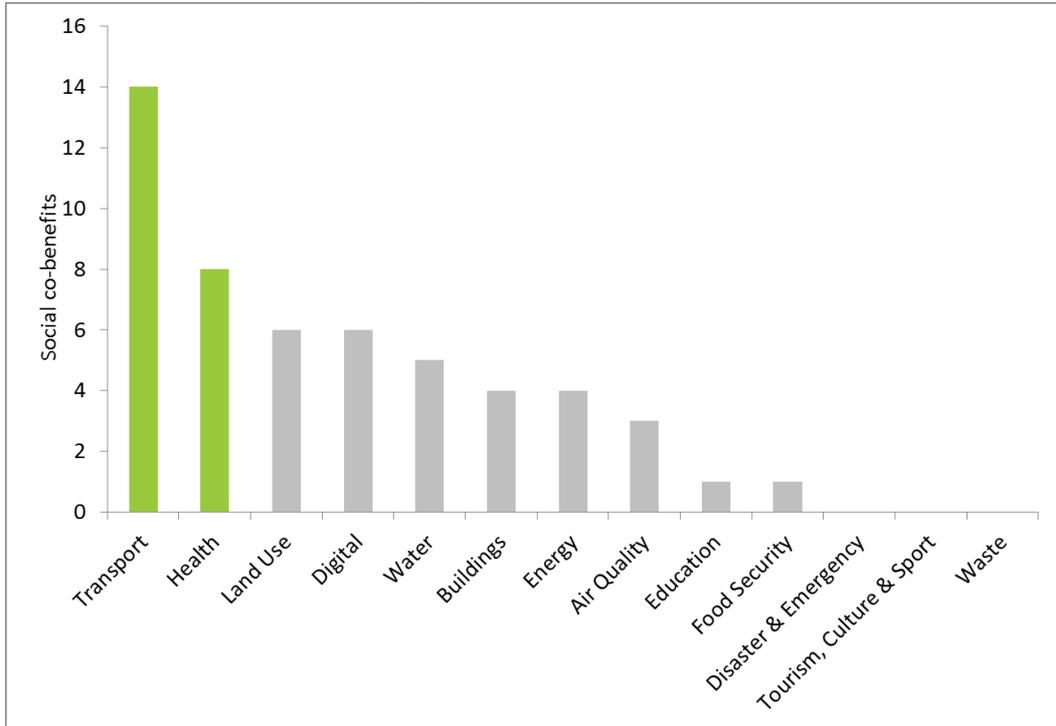


Fig. 1.8d Environmental co-benefits of mitigation-related policies, by sector.

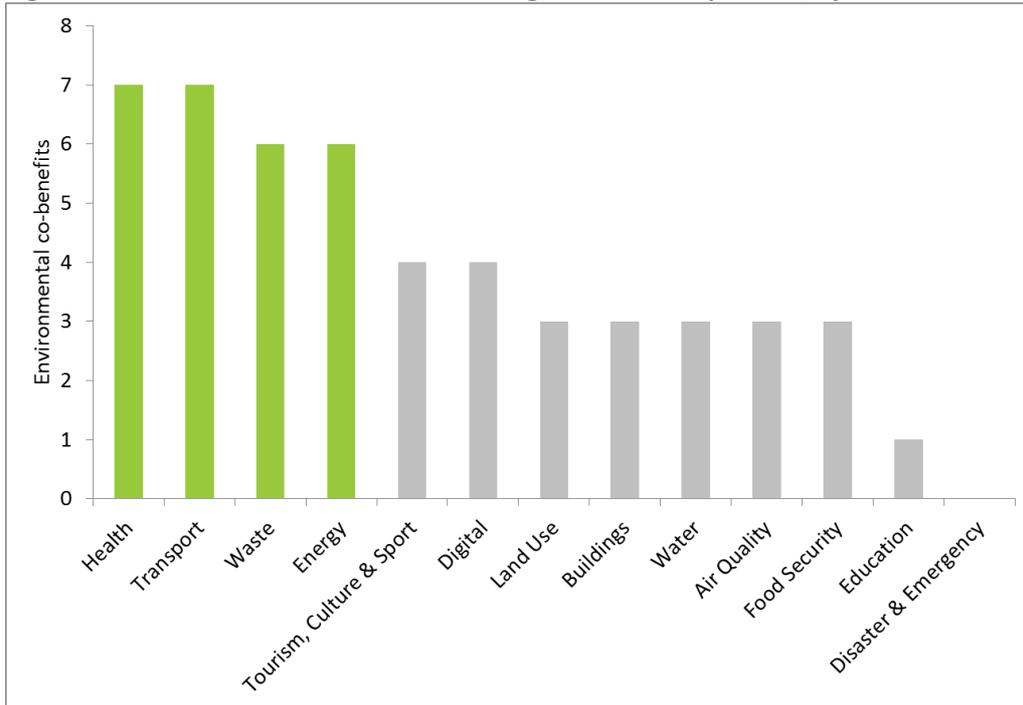
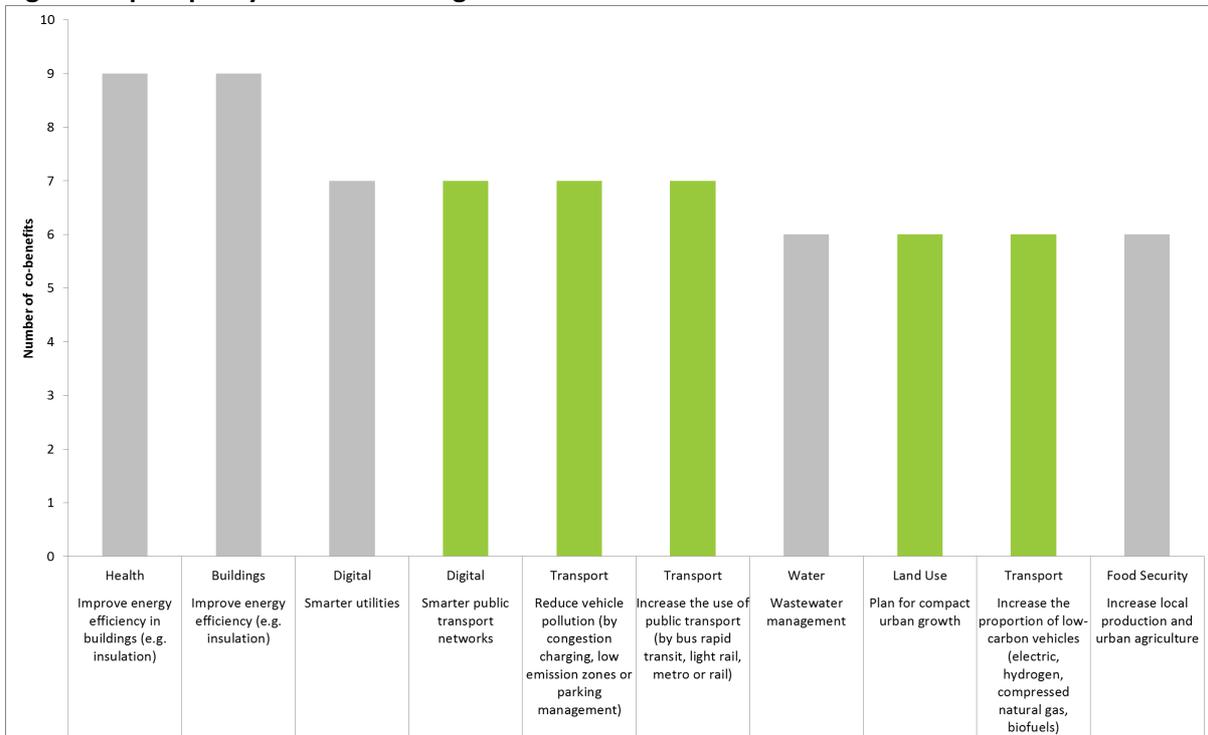


Fig. 1.9 Top 10 policy actions for mitigation-related co-benefits.



**Key sectors for climate adaptation and co-benefits**

The review identified 116 economic, social and environmental co-benefits for 34 policy actions with a climate adaptation benefit, across 11 sectors. No co-benefits were identified in the literature reviewed for Air Quality and Waste policies with an adaptation impact. Land Use and Health were the top two sectors for the number of adaptation-related co-benefits, with 19 to 25 co-benefits identified in each (Fig. 1.10a).

The sectors Health, Land Use and Buildings held the highest number of adaptation-related economic co-benefits, ranging between 7 and 9 for each (Fig. 1.10b). Land Use, Health and Education recorded the highest number of adaptation-related social co-benefits, ranging between 7 and 11 for each (Fig. 1.10c). Land Use, Water and Food Security documented the highest number of adaptation-related environmental co-benefits, ranging between 3 and 5 for each (Fig. 1.10d).

These results suggest that the Land Use and Health sectors are particularly rich in adaptation-related co-benefits. As noted in the mitigation section, these are sectors that had a relatively large number of sub-sectors in the review which may have biased the results in terms of higher numbers of co-benefits. However, the inclusion of these sub-sectors reflected in part the importance of both sectors in the literature.

Of the top 10 policy actions for adaptation co-benefits, four are related to flood defence (Fig. 1.11).

**Fig. 1.10a Total number of co-benefits of adaptation-related policies, by sector.**

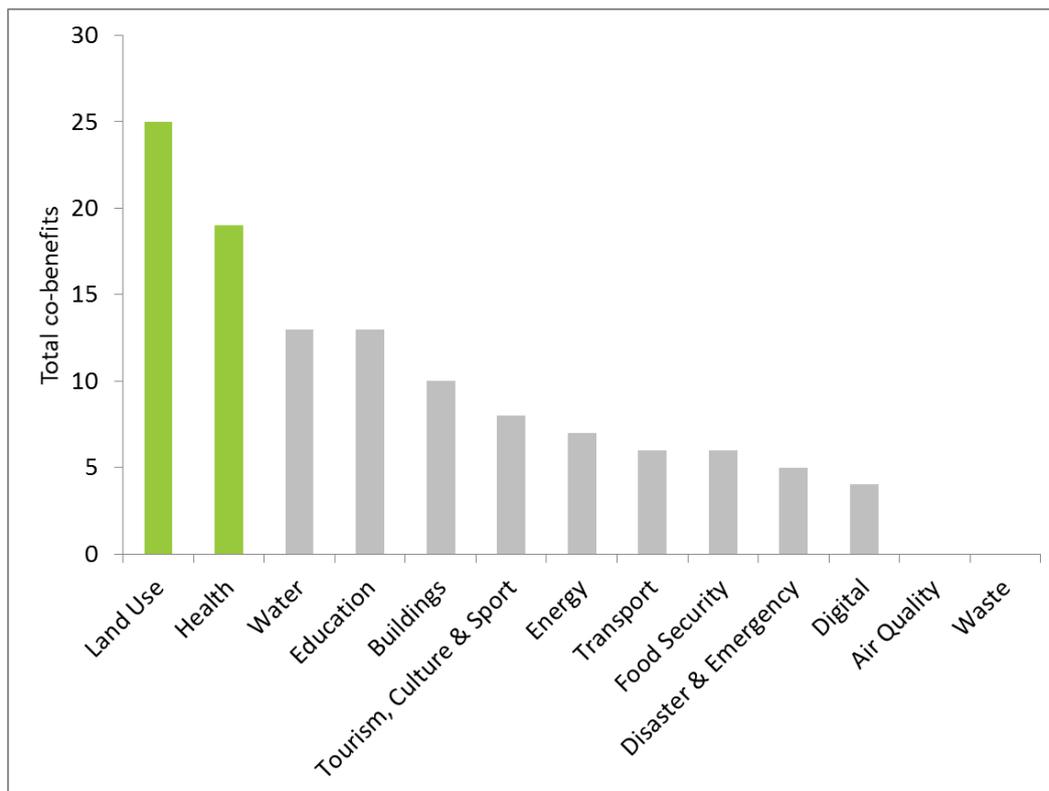


Fig. 1.10b Economic co-benefits of adaptation-related policies, by sector.

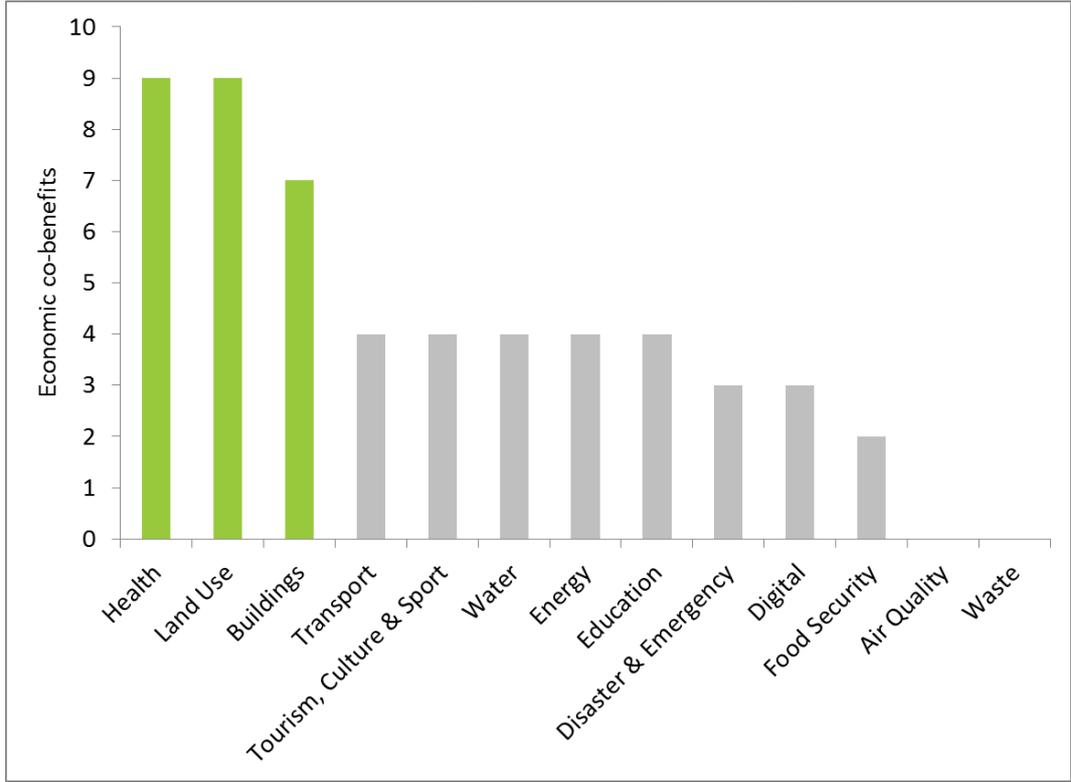


Fig. 1.10c Social co-benefits of adaptation-related policies, by sector.

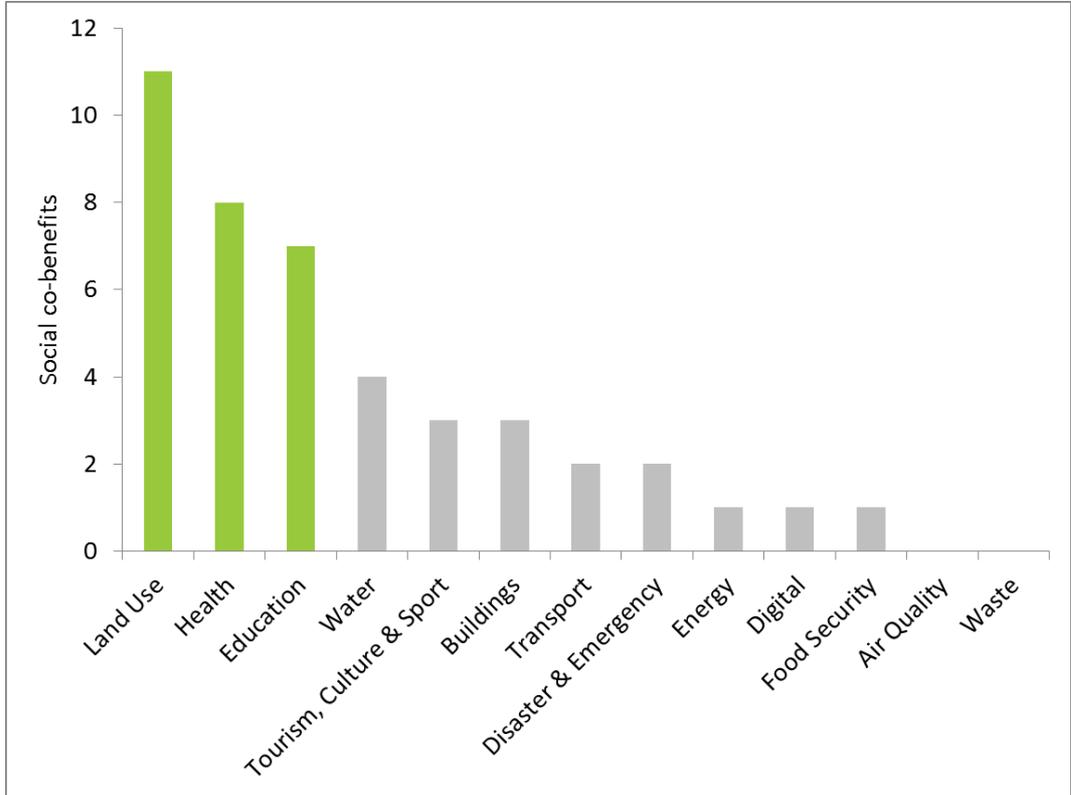


Fig. 1.10d Environmental co-benefits of adaptation-related policies, by sector.

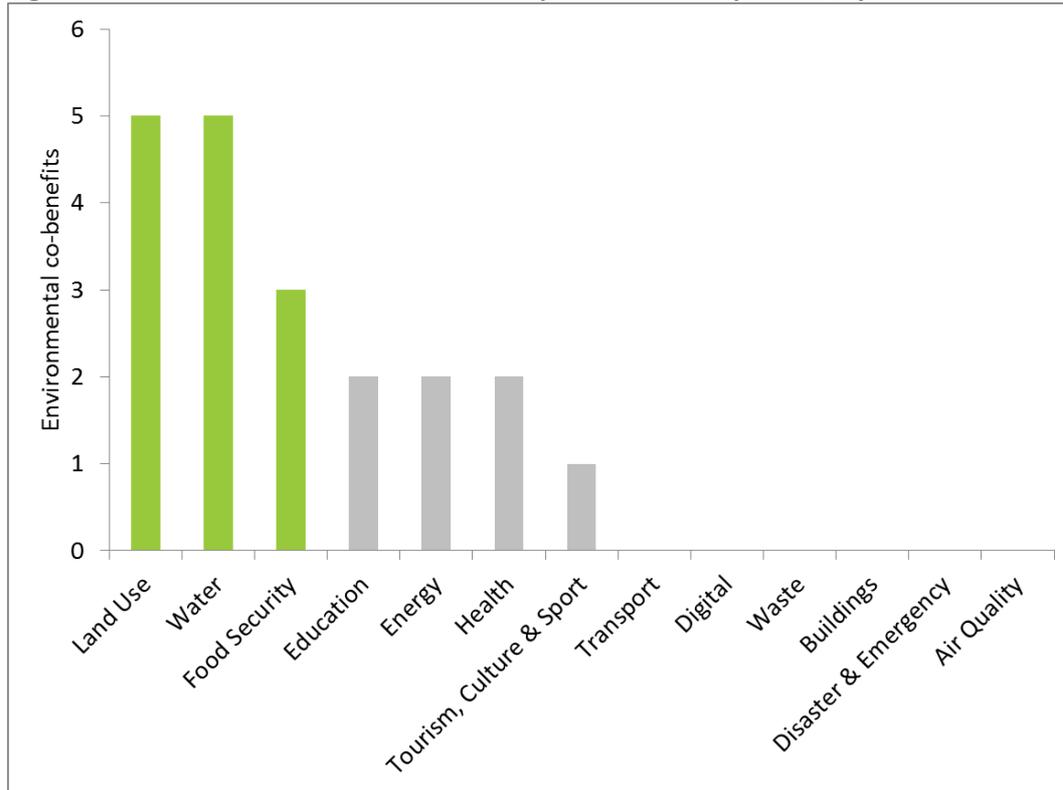
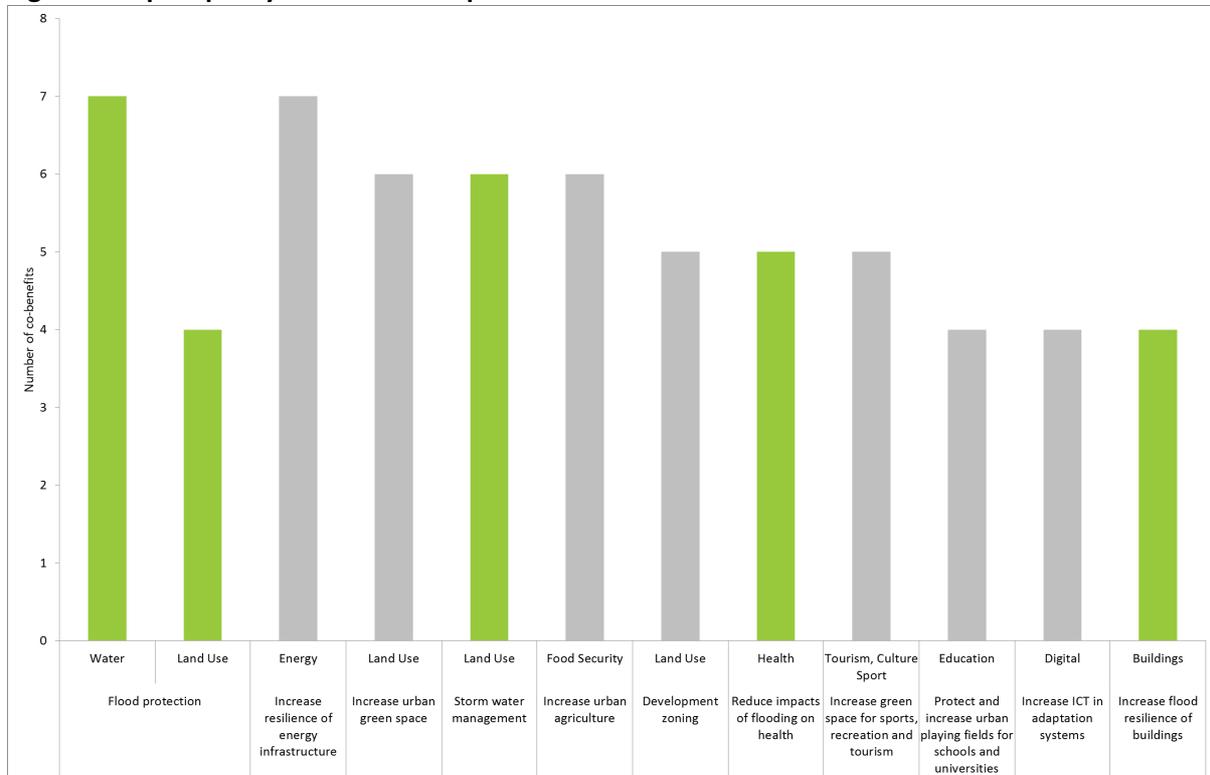


Fig. 1.11 Top 10 policy actions for adaptation-related co-benefits.



## City interviews

C40 consulted a sample of member cities on their approach to co-benefits in a policy-making environment. The aim of the consultation was to establish: (1) why and how cities currently measure co-benefits and use this data; (2) how cities would like to measure co-benefits and use co-benefit data; (3) how future C40 and partner research can best support cities to achieve this; and (4) importantly, to check that findings from the literature and data review were broadly consistent with city feedback. Semi-structured interviews were undertaken with 14 cities, two from each region in order to give global coverage.

The interviews supported the findings from the literature and data review: cities were expressing a requirement for co-benefits data, but that currently there was very limited data available. Below is a summary of the key findings from the interviews.

Different cities do use co-benefits to make the case for action on climate change; yet, climate change mitigation or adaptation benefits are often presented as secondary benefits after economic development or health priorities. The key co-benefits that cities cited were cost savings and economic development, followed by health, quality of life and equity issues. Cities felt it was important to quantify the co-benefits, even if the level and detail presented would depend on the stakeholder.

Many cities considered that events directly impacting the lives of urban citizens, such as floods, blackouts, droughts or congestion are major drivers of policy action and as such constitute the most impactful co-benefits of climate change policies. Any current or recent direct experience has a strong impact on the perception of the climate threat. In this way, citizens' concerns on climate change direct the priorities of municipal politicians.

Whether climate change has high awareness in a city has an effect on how the co-benefits are presented; in some cases, it is citizens making the case to the city government rather than vice versa. However leadership does have a major impact on whether climate change is a priority and many cities pointed out the need for political capital to be invested in order for change to occur. Strong governance or citizen awareness makes it easier to make the case for climate change policies but a robust case for action is still required. The visibility of the co-benefits case to citizens is essential as it creates a more positive voter-response.

The view from C40 cities was that the audience for making the case on climate change co-benefits affects how that case was assessed. In most cases, the first step is to convince internal municipal government, such as senior politicians and their staff; this is done on the basis of the city strategy, the personal priorities of leaders, voting-impact and visibility, and cost and practicality.

Cities made the point that making the case for climate action is most effective when linked to the direct impact on the life and work of citizens, combined with the impact on basic services, security and employment. Cities perceive that the private sector judges the climate case on the basis of finance and competitiveness. Some cities mentioned other stakeholders, ranging from universities, national governments, NGOs, labour organisations and transport authorities (such as ports or airports). In general, the importance of different stakeholders depends on the policy issue.

The need for consistent data was supported by all cities consulted. Many cities requested standardised data for benchmarking and monitoring in order to capture the benefits more consistently, although comparisons were most meaningful if they were with similar cities. In some locations, local data was thought to have more impact than global data, or comparisons with dissimilar cities.

Some cities felt they were lacking the methods to convert data into scenarios and policy decisions, along with the means of assessing 'difficult' data, such as quality of life or climate awareness. Furthermore some cities felt that they were lacking the capacity to collect and analyse the data. Many cities considered effective marketing was essential, some citing the need for tools like infographics. Other material requested included case studies and examples of where solutions had worked, ideally coming from similar cities in order to maximise the impact. In terms of assessing the impact of certain policies, some cities are using tools such as Marginal Abatement Curves, Business as Usual vs Action scenarios, or assessing CO<sub>2</sub> intensity as a proportion of GDP.

## A framework for climate co-benefits

One way to support policy goals that deliver climate co-benefits is to use frameworks: sets of principles, focus areas, and processes related to long-term goals that create a basis for actions and interventions. They are conceptual policy tools that help identify the array of possible co-benefits of policy choices. They support decision-making through a consistent, analytical approach to achieve the highest net-benefit with regard to climate, economic and social developmental, and local environmental dimensions.

Frameworks establish principles, boundaries, and desired results, without prescribing actions. Discerning appropriate actions relies on a range of methodologies and tools to: understand existing conditions and capacities; set baselines and targets, and measures and indicators in support of these; identify possible pathways/realms for intervention; reconcile scale, temporal, and data quality misalignments; and qualify and quantify inputs and outputs/outcomes.

The existing literature is rich with examples of methodologies and tools for climate change policy analysis and policy-making at the city scale. Many of these were not created as city-specific but are appropriate for that level nonetheless. However, the literature is far less rich in climate co-benefit frameworks that are sufficiently broad and comprehensive to capture the complexities and interdependencies of city systems.

The project team reviewed existing frameworks and identified three important general approaches in the literature for assessing and delivering co-benefits. These were (1) the green economy, focused on integrating climate mitigation and economic benefits, (2) benefit-cost approaches, which provide an insight into how governments may assess multiple benefits and costs effectively, efficiently and equitably, and (3) resilience frameworks, which focus on climate adaptation and potential co-benefits.

### Green economy frameworks

Green growth, or the green economy, is an overarching principle for delivering economic growth and development while reducing the environmental impact, for example: low air pollution and CO<sub>2</sub> emissions; low consumption of natural resources including water, energy and undeveloped land; and the protection of ecological services (Floater et al. 2013, 2014a, 2014b, 2014c; OECD 2013). Linking economic growth to environmental/low-carbon outcomes as complementary, even interdependent, is clearly consistent with co-benefit objectives.

Moreover, countries and cities are promoting green growth as an explicit economic development strategy by targeting green goods and services as growth sectors that create a virtuous cycle of innovation, new technology development and deployment, jobs and skills, and improved environmental conditions. One example is the Korean government, which has made green growth part of national policy, outlined through three objectives (below), which in turn are supported by ten specific strategies (see Cho 2009):

1. paradigm shift to a low-carbon society with lower greenhouse gas emissions and enhanced environmental protection;
2. green technologies as future growth engines; and
3. enhanced corporate competitiveness, as a new exporter of green industries.

At the city level, urban development which is poorly managed results in market failures that hinder productivity and economic growth, and negatively impact the quality of life of citizens. These market failures include urban sprawl, congestion and longer travel times, negative externalities of pollution and carbon emissions, network externalities, reduced agglomeration effects on innovation and skills matching, and imperfect and asymmetric information (Floater et al. 2014a).

World Bank literature promotes green growth as a generalised method for reducing market failures that prevent optimal economic and environmental outcomes. Correcting these market failures can increase efficiency and boost short-term growth, and thus yield benefits that go beyond the environment. For this, green growth policies may include: increasing natural capital through environmental management; increasing labour productivity through improved health; increasing physical capital through asset protection from extreme events; improved resource efficiency; and stimulus through public investment in green infrastructure (World Bank 2012).

Effective climate mitigation and green growth are ideally delivered through policy alignment from national to local levels. Green growth policies benefit from these policy complementarities and can thus be more effective when applied at a local scale (Hammer, S. et al. 2011). The OECD framework for urban green growth offers a structured approach to formulating pro-growth policies within various policy instruments available to city governments (ranging from the regulatory to the persuasive) for multiple targeted outcomes of job creation, green supply and consumption, and urban attractiveness.

The OECD framework recognises that local government levels of control and responsibility in sectors and assets that can be policy targets for climate change and co-benefits does vary, and that actions and collaborations will need to be generated to suit local circumstances. Generally, modes of city governance can be characterised as:

- Self-governing: a high degree of control over city-owned assets, decision-making and use of resources, with minimal governing input required from other actors.
- Governing by authority: reliance on regulation and sanctions, which can be used to incorporate climate policy goals into the strategic planning of key sectors such as transport, energy, and land use planning.
- Governing by provision: multi-stakeholder environments where the city is one of several key agents in the delivery of services to the public (e.g., development and operation of urban infrastructure such as energy, water, waste, and road and rail networks).
- Governing by enabling: a less direct role for city government that relies on coordinating and facilitating climate action through partnerships and collaborations with private and civil society actors, and through engagement with affected communities.

Cities can be highly effective agents for addressing climate change and green growth all along this continuum (C40 2015). Power to own and operate assets and functions is beneficial. But in the absence of this, cities are using innovative approaches in collaboration and partnerships, target-setting, and influencing to steer public and private investment toward green growth and to improve organisational capacity to plan and respond to climate challenges.

Research by LSE Cities for the New Climate Economy has resulted in a model for urban development and well-managed growth that promotes the co-benefits of urban form, productivity and growth, improved health and reduced GHG emissions called the '3C model' which stands for *Compact, Connected and Coordinated* (Floater et al. 2014a, 2014b). This model offers a set of institutional and organising elements to lock in pathways with economic, climate and other benefits for cities:

- Compact urban growth is based on expansion and/or retrofitting that encourages higher densities, contiguous development and mixed neighbourhoods. It focuses on how urban expansion is managed in order to develop dense, transit-oriented urban forms.
- Connected infrastructure is achieved through investment in innovative urban infrastructure and technology such as Bus Rapid Transit systems, cycle superhighways, electric vehicles, smart grids, energy efficient buildings and essential water, sanitation and waste services.
- Coordinated governance is implemented through effective and accountable institutions that support the coordinated planning and implementation of programmes of activity and investment across public and private sectors and civil society, particularly for land use change and transport.

Green economic growth and development necessarily requires focus across multiple issues and factors related to the built form, economy, and social welfare elements of cities. Green growth and maximising climate change co-benefits should be viewed as a process for cities to: create competitive advantages for economic productivity; deliver environmental performance which confers natural capital and quality of life benefits; and achieve sustainable growth in output and welfare over the longer term through strategic policy decisions that lock in low-carbon, high-growth pathways.

Many of these can potentially be managed through fiscal or financial interventions by government organisations so that the effects are likely to be short-term and on the whole minor when broader benefits can be captured (note, however, the tools to manage these impacts often sit at the national rather than city-level). The above suggests that equity issues need to be considered and integrated into decision making. Social equity co-benefits are clearly possible within green growth and city-level climate policies, but they require policy emphasis to be realised.

**Table 1.1 Examples of green economy frameworks.**

Framework	City goals	Climate benefits	Co-benefits		
			Economic	Social	Environmental
Urban Green Growth OECD	Increase green economic growth	Reduced GHG emissions	Job creation Economic growth	Social housing	Urban attractiveness
Green Economy Leaders, 8 Drivers Framework LSE Cities	Increase green growth	Reduced GHG emissions	Productivity and compact urban growth Innovation, investment, skills and employment, enterprise	Reduced fuel poverty through better building standards Health benefits of air quality Social inclusion and quality of life in mixed developments	Increased energy and resource efficiency Increased air and water quality Enhanced green space
3C Model of New Climate Economy LSE Cities	Increase low carbon economic growth	Reduced GHG emissions	Productivity and compact urban growth Connected infrastructure & efficient services Access to labour pools	Health benefits of air quality Social inclusion and quality of life in mixed developments Reduced road deaths	Increased energy and resource efficiency Increased air quality Enhanced green space

### Benefit-Cost approaches

In theory, policy and investment decisions should be guided by comparison between the costs of action and the value of the outcomes and co-benefits (Krupnick et al. 2000). Unlike climate mitigation, the benefits of which are dispersed globally and accrue in the long-term, co-benefits often have more local and more immediate impacts and realisation which is to cities' advantage. However, not all co-benefits can be monetised or even fully quantified. This means that some co-benefits are often not taken into account in traditional economic models and cost-benefit calculations.

Furthermore, cities have widely divergent technical capacities and standards related to the monitoring and measuring which forms the basis of benefit-cost analyses. This presents challenges for city decision-makers for understanding options and opportunities, and for quantifying costs and direct and co-benefit impacts of climate-related policies and investments.

**Box 1.4. ISO 37120 - City indicators for service delivery and quality of life**

The International Standards Organisation (ISO) has, as part of a new series of International Standards being developed for a holistic and integrated approach to sustainable development and resilience, created ISO 37120. This can help address the reality that city indicators and accounting standards are often not standardised, consistent, or comparable over time or across cities.

ISO 37120 is a set of standardised indicators and provides a uniform approach to what is measured, and how that measurement is to be undertaken to track and monitor a whole city system and city performance related to sustainability. Using the standard does not mean that sustainable/green growth outcomes have been achieved, but rather that measurements and monitoring follows verifiable best practice for those outcomes. ISO 37120 methodology applies to the following themes: Economy, Education, Energy, Environment, Recreation, Safety, Shelter, Solid waste, Telecommunications and innovation, Finance, Fire and emergency response, Governance, Health, Transportation, Urban planning, Wastewater, and Water and sanitation.

Measurement and quantification is complicated by some of the features of green growth/climate change mitigation and adaptation that go beyond simple economic use functions of environmental assets (e.g., harvesting forests for timber products), though tools do exist. Contingent valuation approaches used to estimate economic values for all kinds of ecosystem and environmental services is an available and established technique within an expanding field of accounting methodologies.

In order to assess environmental impacts and benefits, decision-makers will ideally have access to 'natural capital' accounts in the same way economic statistics are gathered and built assets are capitalised and accounted for in balance sheets. Having this information set would enumerate the natural asset base and thus allow tracking of changes in the capital balance over time. Determining the economic values for environmental assets in ways that are comparable to other economic values promotes good economic management, identifies situations in which economic growth is not wealth creating (because the growth degrades natural resources faster than it creates wealth), and assesses whether a country's economic trajectory is sustainable.

The World Bank Group leads a partnership to advance natural capital accounting internationally (principally at the national, not city, level). The Wealth Accounting and the Valuation of Ecosystem Services (WAVES) partnership aims to promote sustainable development by ensuring that natural resources are mainstreamed into development planning and national economic accounts.<sup>3</sup>

Established approaches for quantifying impacts on health and by extension morbidity and mortality, relevant for matters such as air quality and extreme weather events, also exist. These rely on assigning economic value to individuals based on their productive capacity and potential (VSL, or value of statistical life), plus other more objectively quantified factors such as the costs of treating illness. Applying discount rates (i.e. the time value of money) is also an accepted and relevant factor. Each of these do rely at least to a degree on preferences and assumptions that create a level of complexity that is greater than simple financial-based input/output accounting methods.

The Co-Benefits Risk Assessment (COBRA) Screening Model developed by the US Environmental Protection Agency (EPA) (v 2.7, revised June 2015<sup>4</sup>) is an example of a framework for air quality

<sup>3</sup> See <https://www.wavespartnership.org/> for more detail.

<sup>4</sup> See: <http://www3.epa.gov/statelocalclimate/resources/cobra.html> for more detail.

improvements that can be used to quantify changes in air quality and the resulting calculated health outcomes in both epidemiological and monetary terms. COBRA as well as other work from the US EPA<sup>5</sup> suggests that measures for producing both local air quality and associated GHG co-benefits offer compelling value for health and wellbeing that can be pursued irrespective of a climate change agenda. As understanding grows and data become more readily available, frameworks and analyses can consider additional co-benefits such as ecosystem benefits or avoided material damages, as well as potential economic opportunities to develop and deploy innovative clean technologies (US EPA 2004).

Techniques and methodologies used for the health economics evaluation and climate change impacts and adaptation have strong levels of overlap. To support health adaptation planning in EU Member States, the WHO European Regional Office created guidance and a step-by-step tool for estimating (a) the costs associated with damage to health due to climate change, (b) the costs for adaptation in various sectors to protect health from climate change and (c) the efficiency of adaptation measures, i.e. the cost of adaptation versus the expected returns, or averted health costs (World Health Organisation 2013). It attempts to quantify health damage costs related to climate change absent of adaptation actions; the costs of adaptation to minimise or prevent the health damage; and the resulting economic performance of adaptation measures, in terms of either cost-effectiveness or economic benefits versus costs. Thus it aims to characterise the positive economic contributions that may result from climate action.

Benefit-cost analyses can inform whether climate policies result in a zero-sum outcome, that is, some economic sectors or environmental indicators improve while others decline due to changes in priorities or investments (Hammer, S. et al. 2011). Managing uncertainty is another risk area. With the existing levels of uncertainties with linking changes in emissions to externalities (e.g. health impacts, extreme weather), determining if decreases in emissions result in net ancillary benefits can be modelled but will always be subject to ranges. Because models will need to be localised to match highly specific circumstances of individual cities, city-level estimates of costs and benefits will likely show great variances. Transparency in setting baseline conditions from which interventions can be analysed will go some way to creating comparability between cities.

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<sup>5</sup> For example, The Integrated Environmental Strategies (IES) Handbook (2004) includes guidance on emissions and air quality modelling for health impacts and economic benefits.

**Table 1.2 Examples of benefit-cost approaches.**

Framework	City goals	Climate benefits	Co-benefits		
			Economic	Social	Environmental
Ancillary Benefits of Climate Change Policy  Krupnick et al.	Increase welfare benefits from climate mitigation policies	Reduced GHG emissions	Economic system benefits: workplace health and safety, employment, energy security, induced technological change	Workplace health and safety  Reduced mortality and morbidity from pollution  Equity	Ecological systems improvements
Co-Benefits Risk Assessment (COBRA)  US EPA	Quantify air quality and health outcomes	Reduced GHG emissions	Economic value, illness and death avoided		Emissions reductions/air quality improvements
Climate Change and Health: A Tool to Estimate Health and Adaptation Costs  WHO Regional Office for Europe	Quantify adaptation and health outcomes	Adaptation	Economic value, illness and death avoided	Resilience to extreme heat, weather events Improved preparedness, health services delivery, disaster response	Protection, maintenance and increase in natural and man-made assets

### Resilience frameworks

Adaptation benefits differ from mitigation actions and outcomes in that they are broadly anticipatory and generally only valued following an event or when a set of climate-induced circumstances have been made apparent. The co-benefits are likely to be less immediate and more distant, and generally harder to quantify, compared to those derived from mitigation.

Furthermore, adaptation tends to be pursued through a wider range of ‘hard’ (engineered, infrastructure) and ‘soft’ (capacity building, institutional or social networks strengthening) measures. Soft measures are often measured subjectively, if measured at all, and many of these measures cannot be quantified or monetised in a meaningfully comparative way. Programmes such as the Rockefeller Foundation 100 Resilient Cities (100RC) initiative, the Asian Cities Climate Change Resilience Network (ACCCRN), and the Urban Adaptation Assessment (UAA) Framework of the University of Notre Dame Global Adaptation Index (ND-GAIN) are evidence of increasing attention and resources directed to city-scale adaptation and resiliency.

Adaptation and resilience have become generally synonymous, though are not strictly interchangeable. Adaptation is often taken to mean discrete actions, such as building flood-protection systems or mangrove restoration, developed to address specific vulnerabilities or problems. Resilience is an ongoing process as vulnerability and climate risk are constantly evolving,

as are the agents and institutions within cities that contribute to resilience (MacClune and Reed 2012). Resilience is a feature of adaptation, but can be broader than just climate change adaptation.

Adaptation or resilience is assessed and delivered through a combination of exposure to climate impacts, sensitivity to those impacts (who or what is affected), and adaptive capacity or resilience to who or what is affected. Identifying vulnerabilities (sensitivity and exposure) and developing policies to address adaptive capacity (or improve resilience) are dependent on appropriate data points, information gathering, and monitoring and surveillance at the local level. Prioritising focus areas to improve adaptive capacity can follow similar cost-benefits assessments to those described in the section above. To that end, the ND-Gain Urban Adaptation Framework Assessment (Climate-Eval.org 2015), presently in development for trial in US cities, is structured to lead cities through:

- an evaluation of baseline risks: understanding the baseline of the most likely hazards, and the baseline capabilities a city has to deal with the impacts;
- an adaptation gap analysis: the distance between targets the city sets for gains achieved or losses avoided through climate change adaptation and the present capabilities to meet those targets; and
- an analysis of adaptive capacity: city-level influence and opportunities to improve social, economic and governance capacities that help to shape a variety of specific adaptive responses.

The last point - adaptive capacity – is considerably widened in a framework developed for the 100RC, which lists eight city functions which are critical to resilience. These functions are:

1. delivers basic needs;
2. safeguards human life;
3. protects, maintains and enhances assets;
4. facilitates human relationships and identity;
5. promotes knowledge;
6. defends the rule of law, justice and equity;
7. supports livelihoods; and
8. stimulates economic prosperity.

A city's ability to perform these functions determines whether it is resilient or not (Rockefeller Foundation 2014). As these are (or arguably should be) core functions of city governments, determining co-benefits will need to quantify and characterise what the Rockefeller Foundation refers to as the 'resilience dividend' – the value-added to cities from high-performing social, institutional, and economic systems that are better enabled to manage stresses. The 100RC framework as well as that of the Institute for Social and Environmental Transition-International show the strong focus on non-financial and social/institutional inputs, the wide range of information and awareness factors, and the need for formalised assessment and collaborative action for improvement from baseline conditions.

The Economics of Climate Adaptation working group<sup>6</sup> note that adaptation assessment and economics is a new field. As such there are presently limits to quantifying risks in a way that is robust and that facilitates comparison between different hazards in different geographies. There is also a lack of support tools for decision-making to address climate risk in a systematic and resource-efficient way (ECA 2009). So as to align with accepted methods, the ECA working group suggests a

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<sup>6</sup> A partnership of organisations formed to understand climate risks and model adaptation responses formed of the ClimateWorks Foundation, European Commission, Global Environmental Facility, McKinsey & Company, Rockefeller Foundation, Standard Chartered Bank, Swiss Re, and United Nations Environment Programme.

process based on comprehensive risk management to capture all location-specific climate hazards and economic sectors, and scenario planning to help in selecting and prioritising adaptation and resilience measures based on a degree of uncertainty. The result can be an inventory of responses which can be subjected to cost-benefit analyses. While the modelling the ECA working group has undertaken shows significant risks both today and in the future, it suggests that much of the projected loss can be averted and that doing so can boost economic development.

**Table 1.3 Examples of resilience frameworks.**

Framework	City goals	Climate benefits	Co-benefits		
			Economic	Social	Environmental
Urban Adaptation Framework Assessment  University of Notre Dame	Assess vulnerability to natural disasters  Prioritise adaptation measures	Adaptation	Resilient urban areas, Infrastructure and economy	Food supply/security  Health protection  Strong social systems	Water supply/security  Protection of ecosystem services
City Resilience Index  Rockefeller Foundation	Increase city resilience to physical, social and economic challenges	Adaptation	Knowledge and learning  Job creation  Economic growth	Service delivery to meet basic needs  Human health and life protected  Human relationships and identity facilitated  Social stability (rule of law, justice and equity)	Protection, maintenance and increase in natural and man-made assets
Climate Resilience Framework  ISET (Institute for Social and Environmental Transition)	Assess vulnerability and responses to climate change	Adaptation	Flexible, diverse and redundant systems	Greater resilience of vulnerable communities	

### Why a new framework for city co-benefits is needed

The review of frameworks discussed above highlights the need for developing a new co-benefits framework for cities. A range of green economy frameworks has emerged over the last decade, which provides a rigorous foundation for assessing the co-benefits of a low carbon transition. The green economy approach has a number of advantages. In particular, the economy is a key element of every city’s strategy; impacts are quantifiable, measurable and can be monetised in a comparable way. Consequently, any new co-benefits framework for cities should include the green economy as an important pillar. However, the green economy is not sufficient as an overarching framework for

co-benefits as it does not include climate adaptation or a comprehensive coverage of social and environmental co-benefits.

The benefit-cost approach is a potentially useful tool for assessing different options for policy actions that deliver co-benefits. In many cases, traditional cost-benefit analysis fails to internalise the negative externalities of climate change, air pollution and a range of other market failures discussed in previous sections. In addition, benefits that cannot be monetised or even fully quantified are often excluded from traditional economic cost-benefit approaches. A risk-adjusted approach to costs and benefits would address these failures. However, even the risk-adjusted benefit-cost approach is not a framework of principles for assessing co-benefits. Rather, it is an assessment methodology. Furthermore, the feasibility of this approach will depend on data availability and the capacity of city governments to undertake data analysis.

The resilience frameworks are useful for assessing the averted losses from climate impacts (such as flood damages, or reduced productivity resulting from the urban heat island effect), along with the costs of adaptation measures. However, non-climate co-benefits of adaptation can be relatively small compared to the costs of resilient infrastructure measures, and a distinction needs to be made between costly adaptation measures (e.g. sea walls) with minor co-benefits (e.g. employment creation that substitutes employment creation in other sectors), and infrastructure that meets non-climate objectives (e.g. metro lines) that can be future-proofed against climate impacts (e.g. resilient metro lines).

### **A new framework**

In this section, a new framework is developed for assessing co-benefits around strategic sectors that are central to mayoral action in most cities (see Table 1.4). The five strategic sectors are: Health, Mobility, Resources, Buildings, and Economy. These strategic sectors are then divided into city goals, policy actions and co-benefits.

The strategic sectors were created using two main criteria. First, the strategic sectors are collectively exhaustive, with all the co-benefits identified in the review assigned to one of the strategic sectors. The strategic sectors are not mutually exclusive, and in many cases a judgement was made over which strategic sector a co-benefit should be assigned to, when strong arguments could be made for assigning the co-benefit to another strategic sector. Given that this is a scoping report, the assignment of co-benefits may be refined in future research.

Second, the strategic sectors were based on policy areas where many city governments already have strategic goals that resonate with urban citizens. All five strategic sectors include an element of improving quality of life, with perceived benefits for citizens that are both direct and tangible. The evidence for this was drawn from a previous LSE Cities survey of policy makers in 100 cities worldwide along with evidence on mayoral city powers by C40.

**Table 1.4 Co-benefits framework around five strategic sectors.**

Strategic sectors	City goals (examples)	Policy actions (examples)	Co-benefits	Coordinated governance
HEALTH	Improve outdoor air quality	Reduce conventional vehicle use	Reduced premature deaths and health problems	Health, Transport, Land Use, Energy, Digital, Economy, Air Quality, Buildings, Tourism
MOBILITY	Reduce congestion	Reduce vehicle use	Increased economic efficiency, quality of life, air quality	Transport, Economy, Land Use, Digital, Energy, Education, Tourism, Air Quality
RESOURCES	Improve food security	Promote agricultural production	Increased economic efficiency, quality of life, reduced health impacts	Food Security, Waste, Water, Health, Land Use, Transport, Buildings, Energy, Education, Disaster & Emergency
BUILDINGS	Reduce fuel poverty	Increase building energy efficiency	Cost savings	Buildings, Energy, Health, Education
ECONOMY	Support economic growth	Establish cleantech business clusters and incentives	Innovation, productivity, SME growth in technology sector	Economy, Education, Transport, Buildings, Digital, Water, Waste

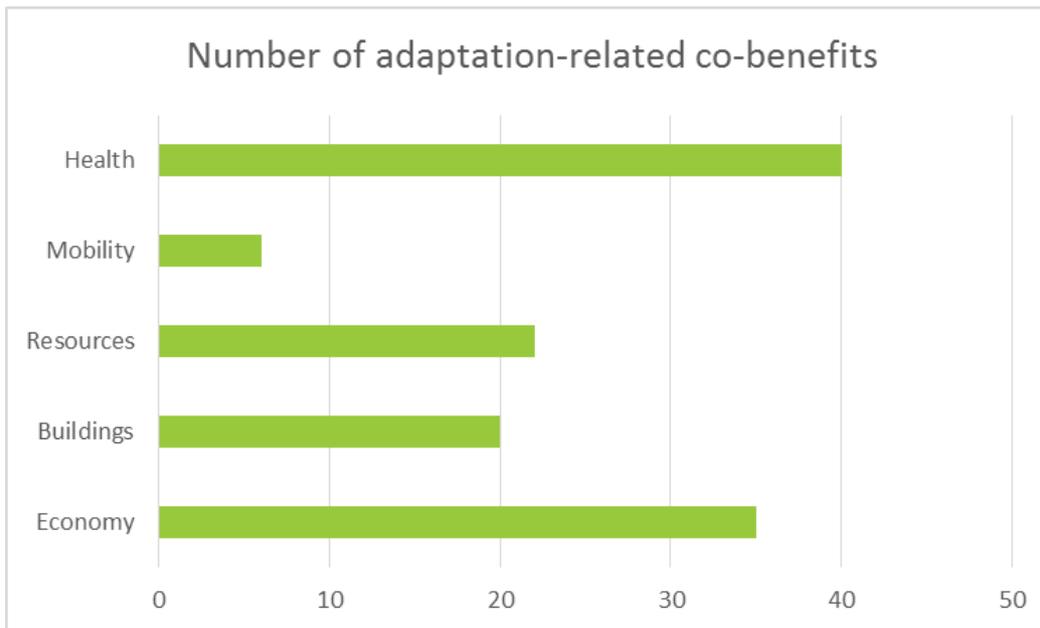
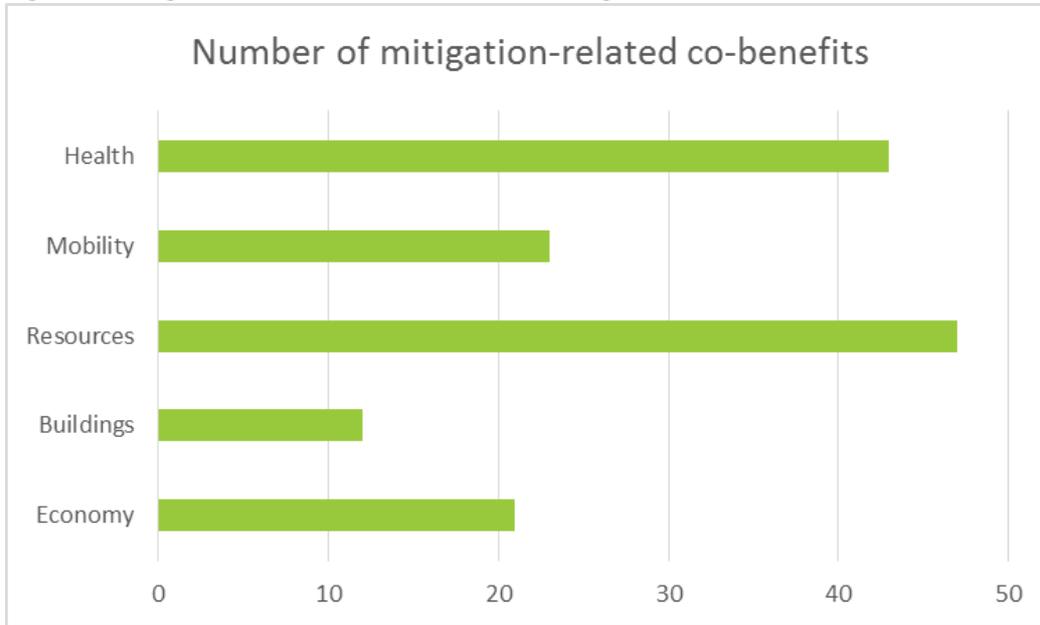
The five strategic sectors encompass the co-benefits in the 13 sectors reviewed in this report. For example, many of the co-benefits in the Air Quality sector are integrated into the strategic sector of Health. Mobility includes co-benefits in the Transport sector, but also in Land Use. Resources include Energy, Water and Waste.

Focusing on these five strategic sectors for co-benefits provides a number of advantages for city mayors: they resonate with citizens with a direct impact on their quality of life; they are already core strategic areas for many cities; they are key to cities in developed, emerging and developing countries; they are cross-cutting and require coordination across several government departments while also allowing for one city department to take the lead; they all have substantial climate mitigation and adaptation potential; and they are all rich in co-benefits.

Another advantage of this framework is that most city governments have a degree of policy responsibility over these five strategic areas. For example, the strategic sector of Health is an issue of high concern for citizens. Direct responsibility for health care is often held by central government level or by specific public bodies. However, city governments hold important policy levers that influence urban health directly (e.g. air quality) and will be held to account for how they deliver in this area.

Figure 1.12 provides a breakdown of the number of co-benefits identified in the literature review for each of the strategic sectors, with regard to both mitigation and adaptation potential.

**Fig. 1.12 Mitigation co-benefits across five strategic sectors.**



Within each strategic sector, authorities will have a range of city goals. These are goals on which the electorate are likely to judge their record. For example, the mayor of a city with high levels of air pollution may have a city goal to improve outdoor air quality (see Table 1.4). For the purposes of this framework we have characterised improving outdoor air quality as a city goal, whose ultimate objective is to support the health of the urban population (the strategic sector).

By comparing the impacts of different policy actions, city governments can make evidence-based decisions on the most effective, efficient and equitable policy actions, both for climate and non-climate objectives. The benefits of the policy action will be both the realisation of the city goal (improving air quality) and the intended impact on the climate. For example, reducing conventional car use would reduce GHG emissions as well as PM pollutants, and have a range of other co-benefits in addition.

There are likely to be a number of policy actions that could deliver a city goal. Among these actions, some will have a greater impact on climate mitigation and adaptation than others. For example, some policy actions may improve air quality but not reduce carbon emissions (e.g. reducing pollutants from vehicle exhausts, but not CO<sub>2</sub> emissions). On the other hand, some policy actions aimed primarily at reducing GHG emissions may deliver greater or lesser non-climate benefits. In the case of diesel cars, regardless of the impact on vehicle carbon emissions, the costs of air pollution may be relatively high. In these cases, the climate benefits may be outweighed by other benefits or net costs.

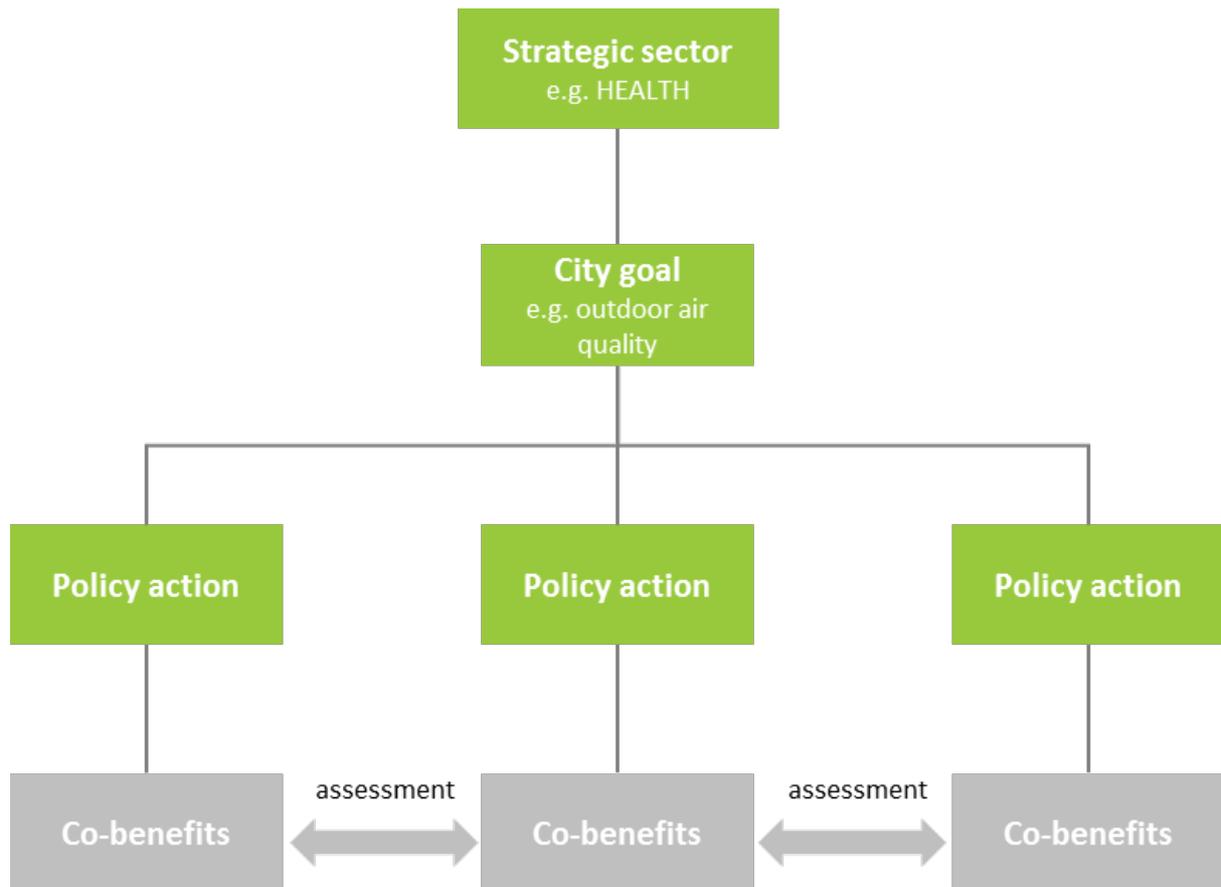
This highlights the importance of developing an assessment approach whereby the net benefits for climate action as well as non-climate net benefits can be evaluated to guide city policy makers to the most effective policy action overall – not simply the most effective in terms of climate action. The risk-adjusted benefit-cost assessment across alternative policy actions is therefore an important step in the policy decision-making process. An assessment could be used to determine which policy actions have the greatest climate benefits, and have the most significant economic, social and environmental benefits. Such information is essential for evidence-based policy decision-making when delivering on a city goal.

In our example, one of the city goals for Health may be to improve urban outdoor air quality. Consequently, the policy action could cover pollution caused by energy production, manufacturing plants or transport. The policy action example used in Table 1.4 is to reduce conventional vehicle use. In this example, the policy action can improve air quality as well as reducing carbon emissions. However, it would need to be assessed against other policy actions, and could also be part of a suite of complementary policy actions (e.g. each targeting a different carbon emissions source). Furthermore, reducing conventional vehicle use could take the form of a number of measures, including demand-side measures (e.g. congestion charges, low emission zones or parking management) and supply-side measures (e.g. mass transit service, cycle routes and cycle-share programmes).

The non-climate benefits may be economic, social or environmental. Using this categorisation of co-benefits is consistent with a standard sustainable development approach which is already used and understood by many city governments. For example, the economic benefits of reduced conventional vehicle use could include reduced congestion and reduced travel times, increased productivity of healthier workers and reduced health costs associated with air pollution. Congestion charging or parking fees could also be considered as a means of revenue raising for the government to use for public spending. The social benefits could include reduced premature deaths and health problems, such as respiratory diseases, reduced injury and mortality from road accidents and reduced noise stress and greater social inclusion. The environmental benefits could include improved air quality and reduced environmental noise.

Finally, the framework provides an opportunity to identify cross-sectoral policy objectives and the development of integrated policy programmes to maximise co-benefits across a range of sectors simultaneously. Traditionally, many policy actions are compartmentalised, consigned to specific policy departments. For example, outdoor air pollution has traditionally been regarded as an environmental policy area primarily and a transport policy secondarily. However, air pollution has a major impact on health and should arguably be a central policy in the overarching strategic sector of Health. It also has implications for land use planning, the economy, tourism, education and energy security policies (see Table 1.4).

**Fig. 1.13 Importance of assessing climate and non-climate co-benefits of alternative policy actions.**



In order to assist cities in developing strategies and tools for assessing the impact of alternative policy actions on climate and non-climate benefits, Table 1.5 provides a summary of examples of the decision-making approach for each of the five strategic sectors of the co-benefits framework.

**Table 1.5 Examples of policy actions for co-benefits in five strategic sectors.**

Strategic sectors	City goals (examples)	Policy actions (examples)	Co-benefits	Climate mitigation benefits	Climate adaptation benefits	Time horizon	Public finance required	Coordinated governance
HEALTH	Improve outdoor air quality	Reduce conventional vehicle use	Reduced premature deaths and health problems	High	Low	Short term	Low	Health, Transport, Land Use, Energy, Digital, Economy, Air Quality, Buildings, Tourism
MOBILITY	Reduce congestion	Reduce vehicle use	Increased economic efficiency, quality of life, air quality	High	Low	Medium term	Medium	Transport, Economy, Land Use, Digital, Energy, Education, Tourism, Air Quality
RESOURCES	Improve food security	Promote agricultural production	Increased economic efficiency, quality of life, reduced health impacts	High	High	Long term	Low	Food Security, Waste, Water, Health, Land Use, Transport, Buildings, Energy, Education, Disaster & Emergency
BUILDINGS	Reduce fuel poverty	Increase building energy efficiency	Cost savings	Medium	Medium	Short term	Potential pay back	Buildings, Energy, Health, Education
ECONOMY	Support economic growth	Establish cleantech business clusters and incentives	Innovation, productivity, SME growth in technology sector	Medium	Medium	Short term	Low	Economy, Education, Transport, Buildings, Digital, Water, Waste

## Urban indicators and data

### Indicators that cities can measure and monitor

Indicators are essential for measuring and monitoring the impact of policy actions. They are indicative of data points that may help assess the efficacy of policy actions and causation between the policy action and the climate co-benefits. In Table 1.6 an example is provided of an indicator that could potentially be used to measure the results of a policy action. A more detailed examination of potential indicators that may be used by cities to measure and monitor the impact of policy actions is set out in Annex 3 of the report.

**Table 1.6 Examples of potential indicators for assessing co-benefits.**

Strategic sector	City goal (example)	Policy action (example)	Indicator (example)
HEALTH	Improve outdoor air quality	Reduce conventional vehicle use	Vehicle kilometres travelled in urban core
MOBILITY	Reduce congestion	Reduce private vehicle use	Modal split (percentage of trips using public transport)
RESOURCES	Improve food security	Promote agricultural production	Volume of food produced within municipal boundary
BUILDINGS	Reduce fuel poverty	Increase building energy efficiency	Number of households in fuel poverty (after fuel costs they would be left with a residual income below the official poverty line.)
ECONOMY	Support economic growth	Establish cleantech business clusters and incentives	New firm formation annually by sector

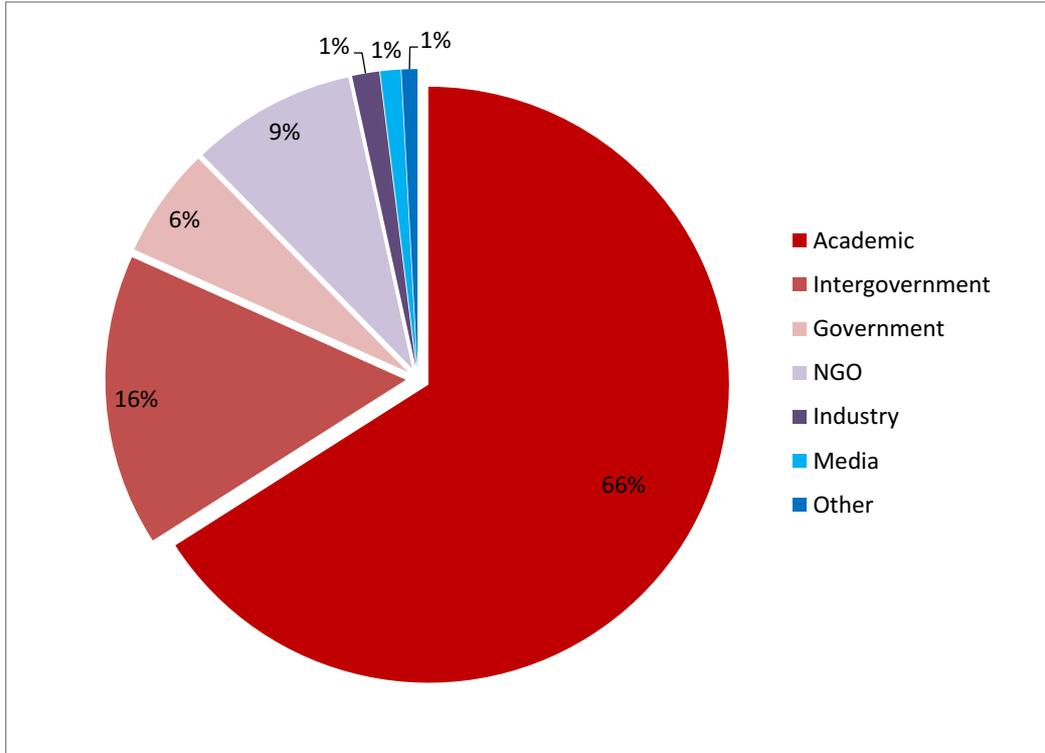
### Data gaps and capacity building

One outcome from the literature review was cataloging the datasets available for measuring climate co-benefit policy results. Of the 795 documents identified in the literature review, peer-reviewed academic papers made up 66%, followed by intergovernmental reports (16%), NGO reports (9%) and national government reports (6%) (Fig. 1.11). Furthermore, 24% of the literature contained exclusively primary data, with most of the literature based solely on secondary data (59%). In addition, 17% of articles used both primary and secondary data (Fig. 1.12).

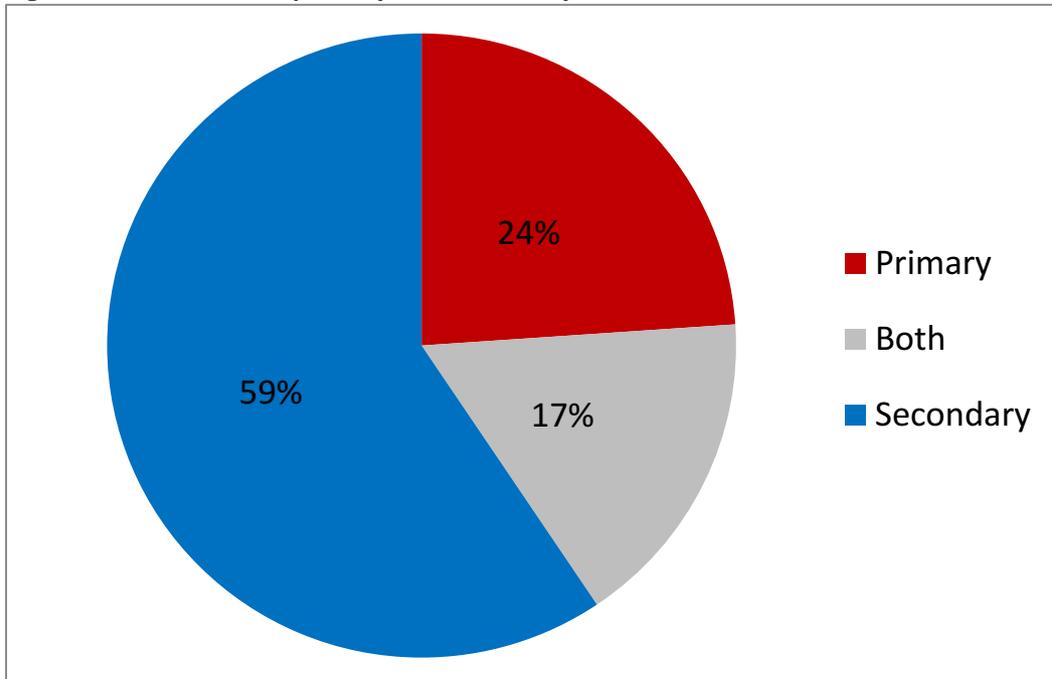
Based on the initial review of 795 documents, 75 data sources were identified relating to the co-benefits of urban climate action. Of these, 27 sources contained data or databases, 28 contained case studies, and 20 contained models, often with associated datasets. Furthermore, many of the 27 data sources relating to actual data and databases were found to contain data that was not relevant for individual governments to assess co-benefits in their own cities. In some cases, this was because the data were not at an appropriate scale. In other cases, the data were not sufficient for estimating a relevant indicator that could be used for policy monitoring. Furthermore, very few datasets provide data for a comprehensive range of cities, so that even if the *type* of data may be useful for a city, a municipal government would not be able to access data specific to its own city. This major gap in data indicates a huge barrier for cities to use co-benefits as part of their climate action.

Evidence suggests that richer data exists at the city level, but is currently inaccessible, unpublished, uncollated or unanalysed. This should be examined further. A discussion of the challenges facing cities in terms of collecting and analysing data is set out in Box 1.5.

**Fig. 1.11 Breakdown of co-benefits data sources identified in the literature search.**



**Fig. 1.12 Breakdown of primary and secondary co-benefits data identified in the literature search.**



**Box 1.5 LSE Cities analysis on the data challenge for cities and the need for accounting frameworks and metrics**

As part of the New Climate Economy research, LSE Cities set out some of the challenges that cities face in terms of data gaps, along with the need for a standardised integrated accounts model for the future. The following is an extract from the findings.

*“A key barrier preventing governments from assuming greater leadership to manage cities more effectively is the lack of capacity to measure and monitor the vast amounts of data that are central to planning and implementing city-based policies. For example, recent analysis by World Bank staff suggests that currently only around 20% of the world’s 150 largest cities have the basic analytics required for low-carbon planning (World Bank 2013a). Two areas of reform stand out: governance, policy and finance for municipal financial accounting and building a better understanding of carbon emissions.*

*A standard accounting framework, similar to those used by national governments, would provide municipal governments with a stronger basis for short-term and long-term decision making. It would also allow greater transparency, trust and accountability for local governments, giving civil society a clearer insight into government affairs and contributing to national efforts to track the flows of climate finance.*

*In moving to an ‘integrated accounts’ model, an important first step for cities would be to develop a framework similar to the Standard National Accounting system (UN Statistics Division 2009; Severinson 2010). This means a clear, reliable and integrated set of macroeconomic accounts based on common standards. As an example of greater consistency in city-based accounting, the US Governmental Accounting Standards Board has been working with state and local governments on common principles. In a 2008 survey, they found that 67–72% of state and local governmental authorities included in the study followed the ‘generally accepted accounting principles’ (GASB 2008). The development of common standard accounts should be complemented by municipal capacity building, particularly the introduction of accounting software that can provide adequate feedback to municipal administrations (Abraham 2013).*

*The development of an internationally recognised system of municipal accounts would form an important part of establishing a municipal credit rating system. Having a standard baseline against which to measure the financial management of municipalities enables potential investors to differentiate between more and less creditworthy local actors. It would also provide administrations with a tool to improve their credit rating, by understanding how their accounts affect their rating. Cities could then build on this by introducing into their accounting practices some of the core principles of the ‘integrated reporting model’, such as the recognition of environmental or social capital. Reform could take the shape of developing accounting methods that can adequately value the benefits of green infrastructure, on cost-benefit scales, compared to grey infrastructure (Pickle 2014).*

(Continued)

*Metrics for cities to measure and monitor carbon emissions are also inconsistent. This is a challenge for all cities – even higher income cities with relatively high levels of technical capacity. In a survey of over 100 cities worldwide for this paper, only 60 had published carbon emissions, and only 40 had published recent carbon emissions between 2010 and 2013. Of these, only 29 cities had a breakdown by scope and sectors for these emissions and most of these breakdowns were not comparable. For example, some cities include Scope 3 emissions from aviation, marine transport or shipping, while others do not report these emissions. A common challenge is emissions double counting, where several institutions are sometimes credited with overlapping emissions activities. The level of detail in reporting is also highly variable, providing further challenges to benchmarking and comparability. Overall, only 12 cities included a clear breakdown of carbon emissions from industry, transport, buildings and electricity consumption, four of the main sources of emissions from energy use in most cities.*

*The lack of a commonly agreed methodology on measuring emissions is one challenge, with differing perspectives on which sectors to include and whether methodologies should be focused on production or consumption (McCarney, Blanco et al. 2011). As a result, many cities are unable to set out evidence-based plans for mitigating carbon emissions or to collaborate regionally and globally with other municipalities on reduction efforts. Encouragingly, more sub-national governments are utilising platforms such as the Carbon Climate Registry and the Carbon Disclosure Project (CDP). The Global Protocol for Community Scale Emissions project currently being developed by ICLEI, IEAP, WRI and C40, and supported by the World Bank, UN-Habitat and UNEP, aims to produce a new comprehensive methodology for accounting for greenhouse gas emissions associated with city-based economic activity and consumption (Greenhouse Gas Protocol 2012). A complementary programme will be developed to help city officials and private sector actors build greenhouse gas emissions inventories using the new methodology.”*

Source: Floater et al. 2014. Steering urban growth: governance, policy and finance. New Climate Economy Paper 2.

Note: The Global Protocol for Community Scale action has now been developed by ICLEI, WRI and C40 to provide a new standard for GHG emissions accounting, see <http://www.c40.org/gpc>

## Part 3: Future research

The evidence suggests that citizens are more likely to take action on climate change, or more likely to support governments that take action on climate change, if the wider co-benefits of those actions are emphasised. At the same time, policies that are aimed at supporting innovation, delivering economic benefits and enhancing the quality of life of citizens can potentially lead to major climate co-benefits (e.g. reduced greenhouse gas emissions) which would be more challenging to achieve if climate action were the primary objective. At the city level, the potential of co-benefits is particularly great as citizens can often witness the results of policy actions more directly on their daily lives.

The term co-benefits has a wide range of definitions in the climate literature, with over 20 terms identified in the literature that are used synonymously or in a similar context. The term co-benefits varies in intentionality (e.g. is climate the primary or secondary objective, or simply an unintentional benefit), scope (e.g. does it include mitigation benefits, adaptation benefits or both), and scale (e.g. are the benefits short term and local, or long term and global). Co-benefits may be (1) secondary benefits from climate policy action, (2) secondary climate benefits from other policy actions, or the combination of climate and non-climate benefits both of which are targeted under an integrated policy programme. The wide range of established definitions of co-benefits used by authoritative organisations means that formulating a taxonomy of co-benefits with broad buy-in from policy makers is challenging.

Current co-benefits frameworks tend to be focused on three areas: (1) the green economy, (2) benefit-cost approaches, and (3) resilience frameworks. In many of these frameworks, the term co-benefits is not explicitly used. However, none of these frameworks are sufficient to capture the full landscape of co-benefits comprehensively. This report suggests a new potential framework for city co-benefits around five strategic sectors: Health, Mobility, Buildings, Resources, and Economy.

The five strategic sectors are central to the strategy of many cities, including those in developed, emerging and developing countries. The strategic sectors can be subdivided into city goals and associated policy actions. Alternative policy actions can be assessed based on their climate and non-climate impacts. Based on the findings of the literature review in this report, promising areas for future research where co-benefits are potentially high include: 1. Traffic pollution, 2. Healthy lifestyles, 3. Smart transport systems (including Bus Rapid Transit), 4. Flooding and building damage, 5. Valuing the size of the environmental goods market.

Cities also need robust data and standard indicators to measure and monitor the impact of policy actions on co-benefits. The review identified three types of data source with potential to quantify co-benefits: data, case studies and models. However, much of the data contained in these sources are of little value to individual cities.

The evidence suggests that currently few cities have benchmark indicators against which authorities can measure and monitor policy impacts on co-benefits. Where these do exist, they are not standardised across different cities. The evidence from the literature also suggests that many cities do not collect the primary data to estimate such indicators. Other cities may hold relevant data, but are currently not using it either due to lack of capacity or the lack of a co-benefits framework. Gaps in data and technical capacity for analysing data are major barriers to implementing policy actions that maximise co-benefits.

Given the gaps and inconsistencies in defining, framing, measurement, communication and policy action for delivering climate co-benefits, this review provides a set of recommendations for future research and city action.

## Recommendations

### Recommendation 1. Develop a co-benefits framework based on five strategic sectors: Health, Mobility, Resources, Buildings and Economy.

- Initiate a **global level collaboration** to develop a co-benefits framework.
- Build on and extend the **LSE/C40 co-benefits framework** (Annex 1 and 2) for the five strategic sectors, to provide a more comprehensive landscape of co-benefits, linking them to C40's Climate Action in Megacities.
- Develop a methodology for **measuring the green economy** and related co-benefits.
- Upgrade existing methods for measuring economic, social and environmental co-benefits and adjust to a **climate resilience framework**.
- **Using pilot studies, develop an integrated accounting framework** for municipal governments that includes climate, economic, social and environmental indicators and data.

### Recommendation 2. Improve the collection and analysis of climate co-benefits data.

- **Using pilot cities, build a detailed database of co-benefits data and indicators** beginning with the following areas: 1. Traffic pollution, 2. Healthy lifestyles, 3. Smart transport systems (including Bus Rapid Transit), 4. Flooding and building damage, 5. Valuing the size of the environmental goods market.
- Support a **data capacity building** programme for cities by sharing best practice on data and indicators.

### Recommendation 3. Implement a research programme on governance and finance required for delivering co-benefits.

- Develop best practice guidance for departmental and multi-level **governance** to deliver cross-departmental co-benefits through integrated policy.
- Develop action plans for allocating **public finance** more effectively and efficiently to deliver cross-departmental co-benefits and leverage private finance.
- Develop **planning frameworks** capable of integrating considerations across sectoral, spatial and temporal scales.
- Develop a **tool for prioritising policy programmes** that maximise climate impacts and co-benefits.

### Recommendation 4. Develop a communication strategy for taking action based on co-benefits.

Develop an evidence base for **best practice to communicate co-benefits to mayors, senior city officials, business, citizens and NGOs**.

## Annex 1: Framework of mitigation co-benefits

Mitigation								
Strategic Sectors	City Goals	Policy Actions	Co-Benefits			Climate Mitigation Benefits	Supporting Data (example)	Coordinated Governance
			Economic	Social	Environmental			
Resources	Improve energy security	Diversify/increase local renewable and low-carbon energy supply (solar, wind, CHP, geothermal, and waste-to-energy generation)	Local job creation Revenue from energy generation (e.g. landfill methane capture) Stable power supply for commercial operations Reduced price volatility for energy services	Reduced fuel poverty Improved health via reduction in outdoor air pollution Provision of health/social services to poor and vulnerable populations during grid outages	Improved air quality Reduced landfill waste	GHG emissions reductions from less reliance on fossil fuels, methane emission reductions	Energy production from renewable sources, MWh per annum	Energy, Waste, Health, Land Use, Buildings, Disaster & Emergency, Economy
	Improve energy security	Foster behaviour change (energy efficiency)	Energy security Cost savings to occupiers	Health impacts from improved air quality	Improved air quality	GHG emissions reductions	Per capita electricity consumption (kWh)	Energy, Education, Buildings, Economy, Health
	Create smarter utilities	Deliver decentralised energy networks and smart grids	Cost savings from energy and resource efficiency measures, demand management Cost savings to building owners and occupiers Local job creation (mainly short term) Technology innovation Increased productivity (commercial buildings)	Reduced fuel poverty Improved health via reduction in outdoor air pollution Provision of health/social services to poor and vulnerable populations during grid outages	Improved air quality (load shifting/demand management to reduce use of dirty/least efficient 'peaker' plants)	GHG emissions reductions	Number of utility customers with smart meters (2-way communication)	Energy, Buildings, Transport, Economy, Disaster & Emergency, Water, Digital, Health

			Improved service reliability and long-term cost structures					
Provide basic services (electricity, water, etc.)	Invest in compact urban growth and quality infrastructure	Increased economic efficiency	Quality of life	Reduced health impacts	GHG emissions reductions	Number of utility connections (percentage of households connected), electricity, water, and wastewater	Energy, Water, Waste, Buildings, Digital, Food Security, Health, Land Use, Transport, Disaster & Emergency, Economy	
Provide basic services (electricity, water, etc.)	Improve water efficiency	Cost savings for householders and industry	Increased water security for the vulnerable in cities impacted by drought	Reduced droughts and water shortages	GHG emissions reductions from reduced pumping, water heating	Per capita water consumption	Water, Buildings, Energy, Waste, Food, Economy	
Provide basic services (electricity, water, etc.)	Improve wastewater management practices	Cost savings with waste water treatment Revenue streams from by-product processing Less virgin resource extraction	Food Security from the recovery of organic material for fertilisers Health impacts from less contamination of water and fewer disease outbreaks	Reduced pollution	GHG emissions reductions	Bacteria concentrations in receiving waterways (average and peak); leakage rates	Waste, Water, Health, Land Use, Disaster & Emergency, Energy, Food Security	
Improve food security	Promote agricultural production	Possible reduction in food price volatility Revenue generation for urban low-income groups Increased economic efficiency	Food security Quality of life	Increased urban green space, biodiversity Improved air quality from reduction in transport Reduced health impacts	GHG emissions reductions from lower food miles	Volume of food produced within municipal boundary	Food Security, Waste, Water, Health, Land Use, Transport, Buildings, Energy, Education, Disaster & Emergency	
Improve food security	Facilitate urban composting	Potential revenues in agriculture		Organic fertilisers	Methane emission reductions and transportation carbon emission reductions	Volume of organic waste diverted from landfill; amount of biogas produced from Food Waste Cogeneration	Food security, Waste, Economy, Land Use, Education	

Health	Improve outdoor air quality	Reduce air pollution from power stations	Reduced costs (from poor health or damage from acid rain) Increased productivity of healthier workers	Improved health (e.g. reduced respiratory diseases, premature deaths from air pollution)	Improved air quality	GHG emissions reductions	Number and location of hospital admittances for asthma	Health, Air Quality, Energy, Buildings, Economy
	Improve outdoor air quality	Reduce conventional vehicle use (by congestion charging, low emission zones or parking management)	Reduced congestion Reduced health costs associated with poor air quality Municipal revenues (congestion charging, parking fees)	Improved access Reduced mortality and injuries from road-related accidents Reduced premature deaths and health impacts from air pollution	Improved air quality (reduced PMs, SO <sub>2</sub> , NO <sub>x</sub> , other pollutants) Reduced environmental noise	GHG emissions reductions	Vehicle kilometres travelled in urban core	Health, Transport, Land Use, Energy, Digital, Economy, Air Quality, Buildings, Tourism
	Improve outdoor air quality	Increase the proportion of low-carbon vehicles (electric, hydrogen, compressed natural gas, biofuels)	Energy security (reduced oil dependence and exposure to price volatility) Technological spillovers (e.g. battery technologies for consumer electronics)	Reduced health impacts from air pollution Improved access	Improved air quality (reduced PMs, SO <sub>2</sub> , NO <sub>x</sub> , other pollutants) Reduced environmental noise	GHG emissions reductions	Number of alternative fuel/powered vehicles	Health, Transport, Land Use, Digital, Economy, Energy, Education, Tourism, Air Quality
	Improve outdoor air quality	Reduce urban industrial pollution	Increased productivity of healthier workers Reduced health costs associated with air pollution	Reduced premature deaths and health impacts from air pollution	Improved air quality (reduced PMs, SO <sub>2</sub> , NO <sub>x</sub> , other pollutants)	Potential GHG emissions reductions	Number of enforcement actions against industrial companies	Health, Air Quality, Energy, Buildings, Economy, Land Use
	Improve indoor air quality	Improve building insulation and building standards	Increased productivity of healthier workers Reduced health costs associated with air pollution	Reduced premature deaths and health impacts from air pollution	Improved air quality	GHG emissions reductions	Average household and commercial energy consumption, electric and thermal (kWh per m <sup>2</sup> of floor area)	Health, Air Quality, Energy, Buildings, Economy

	Improve indoor air quality	Facilitate shift to low-carbon cooking methods (e.g. improved cookstoves)	Reduced health costs associated with air pollution	Reduced premature deaths and health impacts from air pollution	Reduced PMs, SO <sub>2</sub> , NO <sub>x</sub> , other pollutants	GHG emissions reductions Black carbon reductions	PM <sub>10</sub> and PM <sub>2.5</sub> measurements (average and peak)	Health, Buildings, Energy, Education, Air Quality
	Facilitate active lifestyles	Increase cycling and walking networks	Reduced congestion	Improved physical health, such as reduction of cardiovascular disease, some cancers, diabetes and obesity Reduced mortality and injuries from road-related accidents Improved access Quality of life	Improved air quality	GHG emissions reductions	Modal split (percentage of work trips by bicycle, walking)	Health, Transport, Land Use, Digital, Education, Tourism, Culture, Air Quality, Economy
	Improve waste management practices	Improve waste diversion and reduce landfill	Local job creation, especially in developing countries Revenue from diverted material and by-product streams	Improved public sanitation at/near landfill sites	Reduced extraction of primary resources Reduced land contamination	Methane emissions reductions	Volume of waste to landfill	Health, Waste, Land Use, Health, Energy, Food Security, Economy
	Improve health service delivery	Invest in smarter health systems	Reduced costs for service providers Decreased need for brick and mortar development	Strengthened diagnosis and health services delivery	Smarter health systems	GHG emissions reductions in hospitals, health service delivery	Yearly investment in digital technology for patient services	Health, Digital, Education, Disaster & Emergency
Mobility	Increase affordable transport	Increase mass infrastructure/routes	Increased productivity (reduced congestion)	Improved mobility Improved road safety Reduced health impacts from air pollution	Improved air quality Reduced environmental noise	GHG emissions reductions	Aggregate length of scheduled mass transit services; modal split (percentage of trips using public transport)	Transport, Land Use, Energy, Tourism, Air Quality, Disaster & Emergency, Economy

	Reduce congestion	Reduce private vehicle use	Increased productivity and economic efficiency	Improved quality of life Reduced health impacts from air pollution	Improved air quality Reduced environmental noise	GHG emissions reductions	Number of car registrations; motorisation rates (cars per 1000 inhabitants); modal split (percentage of trips using private vehicles)	Transport, Economy, Land Use, Digital, Energy, Education, Tourism, Air Quality
	Improve accessibility	Increase shared mobility services (car/bike sharing)	Reduced congestion Reduced consumer costs for vehicle maintenance, parking, taxes etc.	Reduced health impacts from air pollution Reduced need for car parking	Reduced need for parking space, with potential for more compact urban form and green space	GHG emissions reductions	Number of car registrations; modal split (percentage of trips using active transport vs private vehicles)	Transport, Land Use, Digital, Economy, Health, Buildings, Air Quality, Tourism
	Improve accessibility	Invest in smarter public transport networks	Reduced congestion Increased productivity and growth	Improved access and quality of life Reduced mortality and injuries from road-related accidents Reduced health impacts from air pollution	Improved air quality Reduced environmental noise	GHG emissions reductions from lower vehicle use	Percentage of transit trips/services within 5 minutes of scheduled time	Transport, Land Use, Digital, Economy, Health, Buildings, Air Quality, Energy, Tourism, Disaster & Emergency
Buildings	Reduce fuel poverty	Increase building energy efficiency (e.g. insulation)	Cost savings to building owners and occupiers Increase in property values through efficiency, 'green' branded buildings Local job creation (mainly short term) Increased productivity (commercial buildings)	Health improvements from improved air quality Increased thermal comfort	Improved air quality Ecosystem services (green roofs)	GHG emissions reductions	Elderly wintertime mortality; number of households in fuel poverty (after fuel costs they would be left with a residual income below the official poverty line)	Buildings, Energy, Health, Education

	Reduce operating costs	Develop low carbon hospitals, public buildings, schools and universities	Cost savings through energy efficiency	Improved student performance at comfort temperatures		GHG emissions reductions	Total energy consumption (electric and thermal), public buildings, kWh per m <sup>2</sup>	Buildings, Health, Energy, Digital, Economy, Education
	Reduce operating costs	Build and retrofit sports stadiums, museums and concert halls for low carbon	Local job creation (particularly short term) Lower energy demand in city			GHG emissions reductions	Value of investments made in energy efficiency retrofits (energy performance contracts, energy services agreements)	Buildings, Health, Energy, Digital, Tourism, Economy
Economy	Manage growth	Plan for compact urban growth	Increased productivity (reduced urban congestion and travel times) Reduced infrastructure expenditure from more efficient built form	Healthier lifestyles Reduced car dependency	Protect agriculture, forestry, ecosystem services Reduced energy consumption	GHG emissions reductions	Residential and worker density (average and peak)	Economy, Land Use, Transport, Buildings, Energy, Water, Waste, Air Quality, Tourism
	Stimulate economic growth	Undertake urban regeneration	Increase investment in buildings and infrastructure	Increased affordable housing	Reduced urban sprawl through use of brownfield sites	GHG emissions reductions	Acres of brownfield redevelopment	Economy, Land Use, Transport, Buildings, Energy, Water, Waste, Air Quality, Tourism
	Stimulate economic growth	Increase eco-friendly tourism	Economic benefits of eco/low-impact tourism sector		Increased resource and energy efficiency Reduction in urban waste Maintenance and increase in urban biodiversity Increased green space	GHG emissions reductions	Numbers of tourists internationally and in specific countries	Economy, Tourism, Energy, Water, Waste, Buildings

	Stimulate economic growth	Establish cleantech business clusters and incentives	Innovation Firm productivity SME growth in technology sector			GHG emissions reductions from energy and resource efficiency	New firm formation annually by sector	Economy, Education, Transport, Buildings, Digital, Water, Waste
	Improve resource efficiency / allocation	Increase water security	Reduced economic impacts of water variability	Security for the vulnerable in cities impacted by drought Resource equity	Aquifer protection - increase in natural buffers	GHG emissions reductions: reduction in vehicular transport of water; centralized systems have efficiencies of scale; resilience/protection of sources requires less processing of source water; reduction in transmission losses	Annual volume of greywater, stormwater recycling	Economy, Water, Waste, Land Use, Energy, Buildings, Education, Disaster & Emergency
	Improve resource efficiency / allocation	Promote climate education and awareness			Reduced environmental impacts through associated awareness	GHG emissions reductions through behaviour change for life		Economy, Education, Health, Disaster & Emergency, Energy

## Annex 2: Framework of adaptation co-benefits

Adaptation								
			Co-Benefits					
Strategic Sectors	City Goals	Policy Actions	Economic	Social	Environmental	Climate Mitigation Benefits	Strategic Sectors	City Goals
Resources	Improve energy security	Increase resilience of energy infrastructure	Cost savings from climate-related damages Reduced energy losses Stability of energy supply for production Short term job creation from upgrading infrastructure	Stable delivery of essential services	Improved air quality (from gas network losses) Reduced land contamination	Adaptation to extreme weather	Annual instances and total hours of electric and gas grid disruption	Energy, Buildings, Health, Air Quality, Disaster & Emergency, Economy, Digital
	Improve water security	Increase sources of water supply less subject to drought	Reduced economic impacts of water variability Security of water cooling for power stations	Security for the vulnerable in cities impacted by drought Improved access to clean water Improved sanitation	Reduced aquifer depletion	Reduced water shortages	Annual volume of greywater, stormwater recycling	Water, Energy, Land Use, Buildings, Economy, Health, Disaster & Emergency
	Provide basic services (electricity, water, etc.)	Invest in compact urban growth and quality infrastructure	Increased economic efficiency	Quality of life	Reduced health impacts	Uninterrupted or minimally disrupted utility supplies during extreme weather	Number of utility connections (percentage of households connected), electricity, water, and wastewater	Water, Energy, Waste, Land Use, Transport, Health, Buildings, Digital, Food Security, Air Quality, Disaster & Emergency, Economy
	Improve food security	Maintain and increase urban agriculture	Revenue generation potential and local job creation, particularly for low-	Increased food security	Maintained and increased biodiversity and green space	Increased food security Decreased urban flooding	Volume of food produced within municipal boundary	Food Security, Land Use, Transport, Buildings, Water, Waste

			income groups Possible reduction in food price volatility		Improved air quality from decreased food transport			
Health	Protect vulnerable populations	Improve health planning for heatwaves	Increased labour productivity and economic production through reduced heat stress Reduced direct health costs	Reduced mortality and health impacts from heat		Heat adaptation	Heat-related mortality and morbidity in elderly residents	Health, Energy, Buildings, Air Quality, Economy, Disaster & Emergency, Digital, Education
	Protect vulnerable populations	Reduce impacts of flooding on health	Reduced damage costs Reduced direct health costs Increased property values	Reduced mortality and health impacts from flooding directly, from water-borne diseases and from contamination of drinking water	Reduced contamination	Urban flooding adaptation	Incidences of disease outbreaks tied to flood conditions	Health, Water, Land Use, Buildings, Economy, Disaster & Emergency, Digital
	Improve public health services	Improve disease information and protection	Reduced direct health costs	Reduced mortality and health impacts from specific diseases		Reduced post-event disease	Incidences of heat-related vector-borne diseases	Health, Disaster & Emergency, Air Quality, Waste, Water, Education, Digital
	Improve public safety and security	Improve disaster planning and management	Reduced damage costs Reduced disruption of energy, transport, water and communications networks Increased economic resilience	Reduced mortality and health impacts from disasters		Reduced impacts from extreme weather events	Average response time, first responders	Health, Disaster & Emergency, Transport, Education, Digital, Buildings, Tourism

Improve public health	Increase urban green space	Increased labour productivity and economic production through reduced heat stress Increased property values from proximity to green spaces	Reduced health impacts from heat and flooding Increased physical and mental health Enhanced public amenity	Improved biodiversity and ecosystems Maintained and increased green space	Reduced urban heat island effect and reduced flooding	Percentage of urban land area dedicated to green/open space	Health, Land Use, Transport, Economy, Water, Buildings, Tourism
Improve public health and safety	Increase awareness of climate impacts and promote behaviour change	Reduced impacts on productivity	Reduced impacts on vulnerable groups	Reduced environmental impacts through associated awareness	Increased resilience	Evidence in education curricula, training programmes for civil servants	Health, Education, Digital, Tourism, Energy, Water, Transport, Disaster & Emergency, Economy
Facilitate active lifestyles	Protect and increase green space for sports and recreation, schools/universities, and tourism	Increased labour productivity, economic production and school performance through reduced heat stress Increased property values from proximity to green spaces Longer term productivity benefits from healthy, educated population	Reduced health impacts from heat and flooding Improved public amenity Improved health from physical activity Improved student performance Improved student mental performance	Increased biodiversity and ecosystem services Maintained and increased green space	Reduced urban heat island effect and reduced flooding	Number of adults undertaking regular physical activity	Health, Education, Tourism, Land Use, Water, Transport, Disaster & Emergency, Economy
Facilitate active lifestyles	Increase cycling and walking networks	Reduced congestion	Improved physical health, such as reduction of cardiovascular disease, some cancers, diabetes and obesity Reduced mortality and injuries from road-related	Improved air quality	Reduced urban heat island effect and reduced flooding	Modal split (percentage of trips walking or cycling)	Health, Transport, Land Use, Digital, Education, Tourism, Culture, Health, Economy

				accidents Improved access Quality of life				
Mobility	Maintain and improve service levels	Flood resistant transport infrastructure (e.g. overhead cabling, raised tracks)	Reduced damage costs Reduced travel disruptions leading to productivity gains	Reduce impact of future climate change events		Reduced flooding impacts	Percentage of transit trips/services within 5 minutes of scheduled time during extreme weather events (precipitation, wind, etc.); costs of restarting transit services following flooding	Transport, Land Use, Energy, Tourism, Health, Disaster & Emergency, Economy
	Maintain and improve service levels	Heat resistant rail infrastructure (e.g. high temperature construction materials)	Reduced damage costs Reduced travel disruptions leading to productivity gains	Reduce impact of future climate change events		Reduced impacts of rail buckling	Percentage of transit trips/services within 5 minutes of scheduled time during extreme heat events	Transport, Land Use, Tourism, Health, Disaster & Emergency, Economy
Buildings	Maintain and improve building stocks	Promote passive and active cooling strategies for new buildings, existing building retrofits (housing, commercial, public and institutional, sports/cultural/leisure)	Increased labour productivity and economic production through reduced heat stress Reduced direct health costs	Reduced mortality and health impacts from heat Improved student performance		Heat resilient buildings (in higher average temperatures, extreme heat events)	Heat-related morbidity and mortality	Buildings, Energy, Health, Education, Economy, Tourism, Digital, Disaster & Emergency
	Maintain and improve building stocks	Promote design strategies for new buildings, existing building retrofits to mitigate flood risks (housing, commercial, public and	Cost savings from reduced flooding damages Reduced direct health costs Increased labour productivity and	Reduced mortality and health impacts Improved student performance (minimise disruption)		Flood resilient buildings	Level of insured, non-insured losses from flood-related property damage	Buildings, Health, Water, Land Use, Economy, Education, Tourism, Disaster & Emergency

		institutional, sports/cultural/leisure)	economic production through reduced flood disruption Increased property values					
	Maintain and improve building stocks	Promote design strategies for new buildings, existing building retrofits to mitigate extreme storm risks, e.g. wind damage (housing, commercial, public and institutional, sports/cultural/leisure)	Reduced damage costs Reduced direct health costs	Reduced mortality and health impacts from storms		Resilience from storms and high winds	Level of insured, non-insured losses from storm-related property damage	Buildings, Health, Water, Land Use, Economy, Education, Tourism, Disaster & Emergency
	Reduce fuel poverty	Increase building energy efficiency (e.g. insulation)	Cost savings to building owners and occupiers Increase in property values through efficiency, 'green' branded buildings Local job creation (mainly short term) Increased productivity (commercial buildings)	Health improvements from improved air quality Increased thermal comfort	Improved air quality Ecosystem services (green roofs)	Cold resilient (extreme weather events) housing	Elderly wintertime mortality; number of households in fuel poverty (after fuel costs they would be left with a residual income below the official poverty line)	Buildings, Energy, Health, Education
Economy	Maintain and improve levels of economic growth	Improve resiliency of infrastructure	Reduced damage costs Reduced disruption to utilities and travel	Reduced mortality Reduced health impacts of flooding Reduced number of householders forced from homes	Reduced water pollution Effective/uninterrupted water collection and security	Reduced climate-related impacts on transport, energy, water, communications networks and buildings	Annual instances and total hours of mass transit service disruption	Economy, Land Use, Transport, Buildings, Energy, Water, Waste, Tourism, Digital, Education, Disaster & Emergency

Maintain and improve levels of critical infrastructure	Improve stormwater management	Reduced costs from flood-related damages	Reduced mortality Reduced health impacts of flooding Reduced number of householders, businesses forced from homes, places of work	Reduced water pollution Water collection and security	Reduced flooding	Average and peak receiving water quality measures (e.g., bacteria, suspended solids)	Economy, Water, Buildings, Economy, Land Use, Health, Tourism, Digital, Education, Digital, Disaster & Emergency
Maintain and improve levels of critical infrastructure	Improve flood defences	Reduced costs from flood-related damages	Reduced mortality Reduced health impacts of flooding Reduced number of householders, businesses forced from homes, places of work	Erosion control Enhanced biodiversity Enhanced greenspace	Reduced flooding	Level of investment in engineered flood defence	Economy, Water, Buildings, Land Use, Health, Tourism, Education, Digital, Disaster & Emergency
Maintain and improve levels of critical infrastructure	Improve liveability through 'green and blue' infrastructure	Higher property prices near to green space	Recreation	Enhanced biodiversity and greenspace	Reduced heat and flooding impacts	Percentage of urban land area dedicated to green and blue infrastructure	Economy, Water, Buildings, Land Use, Energy, Health, Tourism, Education, Digital, Disaster & Emergency
Bring forward new development areas for urban expansion	Improve land planning and development control	Reduced damage costs Higher property values	Social inclusion Protection of more vulnerable groups	Flood plain areas protected	Reduce development risks in flood plains/flood zones	Number of development approvals in flood-prone areas	Economy, Land Use, Transport, Buildings, Water, Tourism
Stimulate economic growth	Establish cleantech business clusters and incentives	Innovation Firm productivity SME growth in technology sector			Improved resilience through utilisation of adaptation-related goods and services	New firm formation annually by sector	Economy, Education, Transport, Buildings, Digital, Water, Waste

	Stimulate economic growth	Increase ICT in adaptation systems	Reduced damage costs Reduced disruption to transport, energy, water and communications networks Reduced health costs	Reduced mortality and health impacts		More effective pre-, during, and post-event communications and response	Annual instances and total hours of mobile telephony service disruption	Economy, Digital, Disaster & Emergency, Water, Energy, Transport, Buildings

## Annex 3: Co-benefits framework in action - five examples

In order to assist cities in developing strategies and tools for assessing the impact of alternative policy actions on climate and non-climate benefits, Annex 3 provides examples of the decision-making approach for each of the five strategic sectors of the co-benefits framework. Table 1.7 provides a summary of these five examples.

The process begins with five high-level strategic sectors in which local governments have strong institutional and governance settings; Health, Mobility, Buildings, Resources and Economy. All five strategic sectors include an element of improving quality of life, with perceived benefits for citizens that are both direct and tangible. The strategic sectors are not individual government departments per se, but rather represent core functional abilities of governments and expectations of urban citizens. In fact, the policy actions for effective outcomes in each of these areas require action by multiple departments and institutions (see Coordinated Governance in Table 1.5).

**Table 1.7. Examples of policy actions for co-benefits in five strategic sectors.**

Strategic sectors	City goals (examples)	Policy actions (examples)	Co-benefits	Climate mitigation benefits	Climate adaptation benefits	Time horizon	Public finance required	Coordinated governance
HEALTH	Improve outdoor air quality	Reduce conventional vehicle use	Reduced premature deaths and health problems	High	Low	Short term	Low	Health, Transport, Land Use, Energy, Digital, Economy, Air Quality, Buildings, Tourism
MOBILITY	Reduce congestion	Reduce vehicle use	Increased economic efficiency, quality of life, air quality	High	Low	Medium term	Medium	Transport, Economy, Land Use, Digital, Energy, Education, Tourism, Air Quality
RESOURCES	Improve food security	Promote agricultural production	Increased economic efficiency, quality of life, reduced health impacts	High	High	Long term	Low	Food Security, Waste, Water, Health, Land Use, Transport, Buildings, Energy, Education, Disaster & Emergency
BUILDINGS	Reduce fuel poverty	Increase building energy efficiency	Cost savings	Medium	Medium	Short term	Potential pay back	Buildings, Energy, Health, Education
ECONOMY	Support economic growth	Establish cleantech business clusters and incentives	Innovation, productivity, SME growth in technology sector	Medium	Medium	Short term	Low	Economy, Education, Transport, Buildings, Digital, Water, Waste

# 1. HEALTH

## Example: Improve outdoor air quality

Strategic sectors	City goals (example)	Policy actions (example)	Co-benefits	Climate mitigation benefits	Climate adaptation benefits	Time horizon	Public finance required	Coordinated governance
HEALTH	Improve outdoor air quality	Reduce conventional vehicle use	Reduced premature deaths and health problems	High	Low	Short term	Low	Health, Transport, Land Use, Energy, Digital, Economy, Air Quality, Buildings, Tourism

### The challenge of improving outdoor air quality

Air quality in most cities is deteriorating due to an increase in internal combustion engine (ICE) private motor vehicles, reliance on fossil fuels for stationary energy such as coal fired power plants, and air pollution from space heating and cooling in buildings, amongst other factors. The growth in vehicle-derived urban air pollution in some large emerging economy cities has been particularly rapid. The city of Bangalore, for example, experienced a 34% increase in air pollutants on average between 2002 and 2010 (Alpert, Shvainshtein and Kishcha 2012), of which 41% of particulate matter (PM<sub>10</sub>) and 67% of NO<sub>x</sub> emissions were emitted by road vehicles (CPCB 2010).

Air pollution is projected to become the top environmental cause of premature mortality by 2050 (OECD 2012). The World Bank has estimated total deaths attributable to transport-related air pollution at a minimum of 184,000 a year for 2010, with the number of deaths increasing by over 10% in the previous two decades (World Bank 2014). A similar study by the International Council for Clean Transportation estimates mortality attributable to ambient particulate matter PM<sub>2.5</sub> from motor vehicles at 230,000 deaths per year in 2005 (Bhalla et al. 2014).

Cities are particularly exposed to transport-related emissions because high numbers of vehicles emit at ground level in areas that are highly populated (World Bank 2002).

### Policy action example: reduce conventional vehicle use

Transport generates more than 80% of the air pollution in cities in developing countries (UNEP 2011). Reducing conventional vehicle use can reduce carbon emissions whilst also reducing outdoor air pollution. Reducing vehicle use can be influenced by a number of measures, including demand-side (e.g. congestion charges, low emission zones or parking management) and supply-side (e.g. mass transit service, cycle routes and cycle-share programme) actions. Cleaner fuel standards and switching to electric vehicles can deliver significant air-quality related health benefits while contributing modestly to carbon mitigation (i.e. black carbon<sup>7</sup> and non-absorbing aerosols reductions<sup>8</sup>).

<sup>7</sup> Black carbon is a short-lived pollutant that absorbs solar radiation and amplifies the greenhouse effect. On a 20 year scale, it causes around 3,200 times more radiative forcing than CO<sub>2</sub> on a per-unit basis.

<sup>8</sup> Non-absorbing aerosols increase the albedo of the atmosphere, decreasing the irradiance at the earth surface.

There are other policies that aim to reduce carbon emissions that have a negative impact on air quality (such as increasing the use of biomass). But reducing conventional vehicle use is one policy that can improve air quality as well as reduce carbon emissions.

#### ***Mitigation potential of reducing the use of conventional vehicles***

- Business as usual projections show that the global vehicle fleet is set to multiply three or fourfold in the next few decades, which is surpassing the pace of technology factors such as fuel efficiency or alternative power sources to keep carbon emissions from the sector in check (UNEP 2011). This highlights the importance of demand reduction.
- A scenario study for US metropolitan areas in cities such as Atlanta and Phoenix suggests a reduction of 7 to 10% in carbon emissions as a result of a 20 to 40% reduction in vehicle-miles-travelled due to compact urban development (Ewing et al. 2008).
- Controlling for other factors, the difference in transport intensity between high- and low-density areas can be more than 40% in vehicle-miles-travelled per capita (Ewing et al. 2008).
  - In Hong Kong, a city which is very dense and well-served by mass transit, annual carbon emissions from passenger transport are estimated at 378kg per person, compared with around 1,000kg in European cities and over 5,000kg in Houston, USA (Rode and Floater 2013).
  - Policies in Shanghai which have limited private (light-duty) vehicle use (e.g. an expensive license auction and investments in mass transit in lieu of road capacity) have created significant differences compared to Beijing which has similar levels of population and affluence but three times as many light-duty vehicles (Sims et al. 2014).
  - The forecasted range from several studies of US cities of a 5-12% vehicle kilometres travelled reduction was shown based on doubling residential densities, with a higher 25% forecast produced when combined with other strategies such as road pricing (NRC 2014).

#### ***Adaptation potential of reducing the use of conventional vehicles***

- This depends on the alternative transport used, if at all.
- Respiratory diseases will increase with climate change due to heat, particulates in wildfires and changes in allergens. A reduction in air pollution may offset the rise in respiratory problems to some degree.

#### ***Potential for improving outdoor air quality***

- Fewer cars on the road directly reduces GHG emissions as well as PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>x</sub> and other air pollutants.
- In a study of four Indian megacities, vehicle emissions already comprise 20 – 50% of fine particulate matter (PM<sub>2.5</sub>) emissions alone (Chowdhury et al. 2007).
- In Europe options for decarbonisation and energy efficiency (largely in transport) could reduce aggregate NO<sub>x</sub> emissions by a further 38% relative to a baseline scenario inclusive of current and planned air quality legislation by 2030 (Colette et al. 2012).

**Other co-benefits of reducing the use of conventional vehicles**

- Reduced premature deaths and health problems, such as respiratory diseases
- Increased productivity of healthier workers and reduced health costs associated with air pollution
- Improved air quality (reduced PM, SO<sub>2</sub>, NO<sub>x</sub> and other pollutants) and reduced environmental noise
- Reduced congestion and travel times, raising potential productivity
- Reduced injury and mortality from road accidents and reducing noise stress
- Improved access
- Municipal revenues (congestion charging, parking fees)

**Key urban data for measuring policy impact**

- Numbers of cars on the road and vehicle kilometres travelled
- Accessibility metrics (to jobs, shopping, etc.) by auto, transit, and non-motorised mobility
- Levels of GHG emissions from transport sector
- Levels of PM, SO<sub>2</sub>, NO<sub>x</sub> and other pollutants
- Levels and growth of respiratory diseases in urban population groups

**Time horizon**

This policy implies a short-term horizon for implementation because reducing car use has an almost immediate effect on air quality. Relative to CO<sub>2</sub> which has a longer atmospheric lifetime, pollutants from ICE vehicles (i.e. aerosols and ozone) are short-lived and reduction benefits realised quickly (UNEP 2011).

Reducing vehicle kilometres travelled (VKT) requires medium/long-term planning and implementation/measurement periods for infrastructure changes and for influencing travel behaviours, alongside integrated action related to land use and development form.

- Policy combinations (e.g. VKT charges, upgrading transit, and more compact development) from simulation studies in Helsinki, Dortmund, Edinburgh and Sacramento yielded estimates of 14.5% reductions in VKT within 10 years and 24% declines over 40 years (Rodier 2014).

**Coordination of governance and finance**

Outdoor air pollution has traditionally been regarded as an environmental policy matter primarily and a transport issue secondarily. A more strategic approach to reducing the use of conventional vehicles would involve other government departments:

- The way urban planners *use land*, specifically the investment in transport infrastructure, will lock in transport-related emission patterns for many years. A *digital* policy that reduces journeys (whether by supporting home working or electronic based public services) will also affect transport-related emissions.
- Air pollution is putting increasing pressure on urban *health services* as a result of the rising levels of respiratory diseases. This knock-on effect on worker productivity has an effect on the *economy*. Similarly, *tourism* policy can be affected by the quality of the air in the city.

- Reducing a city's reliance on petrol and diesel whilst promoting alternative energy use in urban transport options can increase *energy security* (reduced oil dependence and exposure to price volatility).
- Finally, *education* plays a significant role in promoting new behaviours that reduce conventional vehicle use.

In terms of public financing, the cost of reducing car use in many cities through investment in public transport, walking and cycling is lower on a capacity factor basis than investment needed in roads to serve lower density development patterns (Rode et al. 2014). Cities are increasingly funding mass transit investments through value capture mechanisms, which in turn are supported by the substantial evidence for increases in land values around new and existing transit stations (IPCC 2014).

These costs could also be offset to some degree in the longer term by reduced health service costs of air-pollution related illnesses and other health problems. Net economic costs and savings would also be affected through travel time savings, raised work productivity and reduced vehicle pollution.

The costs of inaction also need to be factored in: the OECD estimates that road transport accounted for approximately half of the total estimated annual cost of outdoor air pollution of US\$1.7 trillion in 2010, in addition to representing a substantial percentage of the economic cost in China and India (US\$1.4 trillion and US\$500 billion respectively) (OECD 2014). A recent estimate suggested that the heavy haze in China in January 2013 alone caused US\$3.7 billion in direct losses to society (Mu and Zhang 2013).

## 2. MOBILITY

### Example: Reduce congestion

Strategic sectors	City goals (example)	Policy actions (example)	Co-benefits	Climate mitigation benefits	Climate adaptation benefits	Time horizon	Public finance required	Coordinated governance
MOBILITY	Reduce congestion	Reduce vehicle use	Increased economic efficiency, quality of life, air quality	High	Low	Medium term	Medium	Transport, Economy, Land Use, Digital, Energy, Education, Tourism, Air Quality

### The challenge of congestion

Congestion arises when urban traffic volumes exceed the capacity of the local infrastructure. Peaks tend to be linked to commuters and overall trip demand driven by the rise in urban populations. High rates of urbanisation suggest a worsening of congestion; modelling under business as usual scenarios suggests that the global vehicle fleet is set to multiply three or fourfold in the next few decades, with most of this growth in developing countries (UNEP 2011). Transport congestion has negative economic and health effects, raises fuel consumption and increases air pollution.

The financial and welfare costs of congestion to cities and citizens can be substantial. For example, the New York City metropolitan region alone is estimated to lose US\$13 billion annually as a direct result of traffic congestion, resulting in a notional loss of about 52,000 jobs annually (PFNYC 2013). The costs of congestion are frequently even higher in relative terms for developing and middle income countries, with estimates of up to 2.6% of GDP in Mexico City and 3.4% of GDP in Buenos Aires and Dakar (World Bank 2002).

### Policy action example: reduce vehicle use

Reducing vehicle use can reduce carbon emissions whilst also easing congestion. Congestion charges, such as those in Stockholm and London, and new mass transit BRT systems, such as in Bogotá, Lagos, Ahmadabad, Guangzhou, and Johannesburg, have demonstrated the potential for reducing congestion costs borne by city residents (UNEP 2011).

#### **Mitigation potential of reducing vehicle use**

- Transport is the second highest source of global energy-related CO<sub>2</sub> emissions, and the fastest-growing sector. Reducing vehicle use and congestion cuts GHG emissions from cars as well as PMs, SO<sub>2</sub>, NO<sub>x</sub> and other air pollutants.
- For example, in Curitiba, which has the highest rate of mass transit use in Brazil, the reduction in congestion means much less fuel is wasted in traffic jams; only US\$930,000, compared with an estimated US\$13.4 million in Rio de Janeiro (Suzuki et al. 2010).

#### **Adaptation potential of reducing vehicle use**

- This depends on the alternative transport used, if at all.
- Respiratory diseases will increase with climate change due to heat, particulates in wildfires and changes in allergens. A reduction in air pollution may offset this to some degree.

**Potential for reducing congestion**

- Fewer cars on the road directly reduces GHG emissions as well as PMs, SO<sub>2</sub>, NO<sub>x</sub> and other air pollutants. Fewer cars means less congestion, which reduces fuel consumption.
- Reducing vehicle demand through planning for dense, mixed-use environments creates shorter trip distances and improved travel options. These types of urban environments tend to have lower per capita congestion delays than more sprawling, single-use, auto-dependent urban environments (Litman 2015).

**Other co-benefits of reducing use of vehicles**

- Increased economic efficiency – less time spent in traffic jams and less public and private expenditure for automobiles and associated infrastructure
- Improved air quality and reduced environmental noise
- Reduced premature deaths and health problems, such as respiratory diseases
- Reduced injury and mortality from road accidents

**Key urban data for measuring policy impact**

- Numbers of cars on the road
- Vehicle kilometres travelled
- Average travel times
- Accessibility metrics (to jobs, shopping, etc.) by auto, transit, and non-motorised mobility
- Levels of GHG emissions
- Levels of PMs, SO<sub>2</sub>, NO<sub>x</sub> and other pollutants
- Levels and growth of respiratory diseases in urban population groups

**Time horizon**

This policy implies a medium-term horizon for implementation because alternative forms of transport need to be put in place as well as the infrastructure to reduce vehicle use (e.g. demand management or congestion charging).

**Coordination of governance and finance**

Congestion has traditionally been regarded as a transport issue and yet, a more strategic approach to reducing vehicle use would involve other government departments:

- Congestion has a direct impact on the urban *economy*: travel times increase and productivity decreases. Longer journeys are factored into travelling times.
- The way urban planners *use land*, specifically the investment in transport infrastructure, will lock in transport-related emission patterns for many years. A *digital* policy that reduces journeys (such as by supporting home working or electronic based public services) will also affect transport-related emissions.
- Reducing a city's reliance on petrol and diesel whilst promoting alternative energy use in urban transport options, can increase *energy* security (reduced oil dependence and exposure to price volatility).
- *Education* plays a significant role in promoting new behaviours that reduce conventional vehicle use.
- A heavily congested city reduces its *tourist* appeal.

In terms of public financing, the cost of reducing car use in many cities is related to planning policies and investments for more compact, transit-oriented growth. Modelling shows that a reallocation of 0.34% of global GDP in support of public transport infrastructure and efficiency improvements to road vehicles would reduce the expected increase in travel volume of road vehicles by around one-third by 2050 (UNEP 2011). These investments would address the economic inefficiencies (e.g. travel time savings and raised work productivity) that result from congestion. For example, congestion costs in 439 urban areas of the United States exceeded US\$100 billion in 2009, while congestion in Toronto cost the city more than US\$3.3 billion in productivity (1.2% of Toronto's GDP)<sup>9</sup> (UNEP 2011).

Costs for reducing congestions would be further offset to some degree in the longer term by reduced costs to the health service of air-pollution related illnesses and other health problems. In addition, municipal revenues can be raised from congestion charging or parking fees.

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<sup>9</sup> Economic losses in developing countries are difficult to quantify due to lack of traffic data, though it is estimated that losses are generally of a higher order of magnitude.

### 3. RESOURCES

#### Example: Improve food security

Strategic sectors	City goals (example)	Policy actions (example)	Co-benefits	Climate mitigation benefits	Climate adaptation benefits	Time horizon	Public finance required	Coordinated governance
RESOURCES	Improve food security	Promote agricultural production	Increased economic efficiency, quality of life, reduced health impacts	High	High	Long term	Low	Food Security, Waste, Water, Health, Land Use, Transport, Buildings, Energy, Education, Disaster & Emergency

#### The challenge of food insecurity

According to the FAO about 793 million people globally were undernourished in 2015 (FAO, IFAD & WFP 2015). A rise in urban food insecurity is seen where growing populations increase the demand for food as well as, in some cases, displace agricultural production. The pressure on the food supply, compounded by price instability and climate variability, can leave the urban poor unable to feed themselves adequately. Negative climate change impacts on agricultural production are expected to be felt most in developing countries which at present face the most acute risks from decreased crop yields and malnutrition (Rosenzweig and Parry 1994).

#### Policy action example: promote agricultural production

Urban agriculture can enhance food security for the urban poor (de Zeeuw 2011), while at the same time reducing carbon emissions due to the reduction of mechanised agriculture and need for transport (i.e. ‘food miles’) (RUAF 2014a). Urban agriculture also acts as a carbon sink and benefits from the fact that plants’ captive capacity is at its highest in the growth phase of vegetation. The use of urban agriculture keeps these city ecosystems more continuously in a production phase (highest carbon absorption capacity), resulting in more CO<sub>2</sub> per surface area captured than in natural systems like tropical forests (Deelstra and Girardet 2000).

#### **Mitigation potential of maintaining and increasing urban agriculture**

- Globally, Agriculture, Forestry, and Other Land Use is responsible for roughly 25% of anthropogenic GHG emissions mainly from deforestation and agricultural emissions from livestock, soil and nutrient management (Smith et al. 2014).
- Localised food production offers an opportunity to reduce the carbon intensity of the food system of individual cities. For example, an urban food systems scenario study undertaken by an NGO<sup>10</sup> in 2014 found that in Rosario, Brazil, 95% of the city’s CO<sub>2</sub> emissions related to food transports and cooling could be reduced by producing the six main vegetables consumed by the population in the urban and peri-urban area. The total production area needed for this was 6,150 hectares and could be accommodated through area land use plans.
- Increased green areas in and around cities can dampen the urban heat island effect, thereby reducing cooling energy required for city inhabitants.

<sup>10</sup> the International network of Resource Centres on Urban Agriculture and Food security

- Urban agricultural production can create closed-loop nutrient recycling opportunities, reducing GHG emissions from municipal solid waste and sewage streams.

#### ***Adaptation potential of maintaining and increasing urban agriculture***

- Green space from the use of urban agriculture can improve urban micro-climates by: alleviating the urban heat island effect; by contributing to storm water management and flood control during times of increased rainfall; and by reducing wind erosion of soils.
- To the extent that climate change brings further uncertainty to crop yields, prices, delivery reliability, food quality and food safety, maintaining some local food production can help urban populations reduce those risks. A better fed population is also more resilient to climate change.

#### ***Potential for reducing food insecurity***

- Urban agriculture currently accounts for 5-15% of total agricultural production in most developing countries (Fritsche et al. 2015) and thus presents a potentially scalable model. World-leading examples show the potential for individual cities in both developing and developed contexts: Singapore is fully self-reliant in meat and produces 25% of its vegetable needs; and Bamako, Mali, is self-sufficient in vegetables and produces half or more of the chickens it consumes (Deelstra and Girardet 2000).

#### ***Other co-benefits of maintaining and increasing urban agriculture***

- Revenue generation potential and local job creation, particularly for low-income groups
- Possible reduction in food price volatility
- Increased urban green space, biodiversity and quality of life
- Improved health impacts from increased availability of fruits and vegetables
- Improved air quality from reduction in transport and increased urban green space
- Increased job opportunities in low-income/informal communities

#### **Key urban data for measuring policy impact**

- Acreage of land devoted to urban agricultural production
- Area available/in-use for rooftop agricultural production
- Volume/percentage of food produced and consumed within local area (e.g. 20 or 50 km radius)
- The prevalence of malnutrition and malnourishment in specific urban populations, such as the proportion of underweight children under 5
- Levels and growth of diseases linked to malnutrition
- Levels of GHG emissions
- Levels of PMs, SO<sub>2</sub>, NO<sub>x</sub> and other pollutants

#### **Time horizon**

Implementation of this policy would probably require a long-term horizon because of the ongoing need to maintain productive land.

## Coordination of governance and finance

The reducing of food insecurity is a cross-cutting policy challenge, involving many government sectors beyond the *health* departments:

- Ensuring the continued availability of agricultural land depends on *effective planning rules* about land use as well as building policies.
- *Transport* infrastructure is needed for effective distribution.
- *Solid waste, wastewater, and potable water infrastructure* can all contribute to fertiliser and irrigation inputs needed for production and can be part of an integrated waste and water management scheme.
- Increased understanding about good nutrition and preparation methods lies with *health* departments and can be part of *education* policy.

The cost of reducing food insecurity in many cities will depend on land availability and land/property markets. Undertaking planning and policy development, rather than direct expenditure on land or infrastructure, is likely to be the primary role for local governments. The value-added from local agricultural production to the local economy may be significant. The 1980 US census found that urban metropolitan areas produced 30% of the dollar value of US agricultural production. By 1990, this figure had increased to 40% (Deelstra and Girardet 2000). In many cases, low-value or derelict land that otherwise would be a liability or have little other use can be relied upon for local production. There are numerous examples of where derelict (post-industrial) land has been put to productive agricultural uses in the United States, Britain, and Germany (e.g. Detroit, New York City, Essen) (Deelstra and Girardet 2000).

## 4. BUILDINGS

### Example: Reduce fuel poverty

Strategic sectors	City goals (example)	Policy actions (example)	Co-benefits	Climate mitigation benefits	Climate adaptation benefits	Time horizon	Public finance required	Coordinated governance
BUILDINGS	Reduce fuel poverty	Increase building energy efficiency	Cost savings	Medium	Medium	Short term	Potential pay back	Buildings, Energy, Health, Education

### The challenge of fuel poverty

Fuel poverty, when inhabitants cannot afford to keep their home heated to a reasonable level, is a growing problem in many cities. It is dependent on income, the price of energy and the energy efficiency of the home. Fuel poverty applies principally to heating requirements but is meaningful for cooling considerations as well, given anticipated increases in average and extreme heat conditions. The social costs on households' health and wellbeing are significant; under- or over-heated homes lead to excess winter and summer mortality, estimated at between 10 and 40% for winter deaths (Lucon et al. 2014). According to The Institute of Health Equity, a British NGO, living in cold homes doubles the likelihood of a respiratory illness such as asthma in children and quadruples the risk of mental health problems for teenagers (Marmot Review Team 2011).

### Policy action example: increase building energy efficiency

Increasing the energy efficiency of domestic buildings can reduce climate change emissions but also contribute to tackling fuel poverty.

#### ***Mitigation potential of increased building energy efficiency***

- Energy demand from the buildings sector globally accounts for approximately 30% of energy related GHG emissions globally (UNEP 2014). The IPCC Fourth Assessment report showed the buildings sector as having the largest potential for low-cost CO<sub>2</sub> mitigation in the short to medium term.

#### ***Adaptation potential of increased building energy efficiency***

- Thermally efficient buildings are better suited to maintaining occupancy comfort and reducing energy demand during weather extremes. This includes passive design for cooling households where mechanical air cooling is unaffordable, given that several hundred million urban dwellers in low- and middle-income nations lack mechanical cooling (IPCC 2014a).
- Improved building energy/thermal performance allows comfortable conditions to be maintained during short-periods of centralised energy outages. It also increases the viability of microgeneration to maintain baseload heating, cooling and power at individual buildings at times when centralised energy networks are unavailable.

***Potential for addressing fuel poverty***

- Of the monetised benefits of energy efficiency investments, evidence suggests that approximately one-third of the total are based on the value accrued from alleviating fuel poverty (IPCC 2014b).
- Community housing trials conducted to measure the benefits of installing insulation and effective heating on households' health and wellbeing and found improved well-being, and reduced hospitalisations and excess winter mortality (Howden-Chapman et al. 2015).
- Addressing fuel poverty and delivering the resulting health impacts are of greater significance in developing nations as a greater share of the population is affected (WHO 2011).

***Other co-benefits of increased building energy efficiency***

- Cost savings to building owners and occupiers from lower energy bills
- Reduced negative public health impacts from improved air quality and increased thermal comfort
- Improved air quality and ecosystems (green roofs)
- Increased property value
- Increased local job opportunities in housing renovation/retrofit industries

**Key urban data for measuring policy impact**

- Numbers of new builds meeting energy efficiency standards
- Peak cooling and heating demands
- Numbers of households retrofitting for thermal efficiency, microgeneration and/or taking up public incentive schemes
- Levels of GHG emissions from housing
- Levels of PMs, SO<sub>2</sub>, NO<sub>x</sub> and other pollutants
- Hospital admittances from extreme heat or cold events
- Levels of winter and summer mortality and resulting from persistent or extreme cold and extreme heat events

**Time horizon**

The implementation of this policy would likely require a short-term horizon because the skills and materials needed are generally available. The uptake of this policy depends on the availability and extent of public and market information and incentive schemes, and any supply or service bottlenecks in delivering the service.

## Coordination of governance and finance

Increased energy efficiency in buildings has traditionally been seen as an issue for either the energy or buildings (planning and permitting) department, but it involves many other policy areas:

- Ensuring energy efficiency is integrated into the design of new buildings can only be achieved with the active planning of municipal authorities in *land use and development* policy.
- Improving energy efficiency in homes can have positive impacts on *Health and hospitalisations*. *Health delivery/health and social care services* have a role to play in identifying people at risk from cold homes at times of routine/non-emergency visits and at point of discharge.
- *Education policy* has a role to play in informing urban populations about the benefits of improving insulation or heating efficiency, as well as about any financing available.

For financing, there is a broad portfolio of effective policy instruments available that show reductions of emissions at low and negative costs (IPCC 2014b). Numerous barriers and market failures are preventing these investments ranging from: high upfront costs; information asymmetry; principal/agent motivations; and access to financing. Policy measures are available that can spread the cost of increasing energy efficiency between individual households, energy suppliers and public authorities. In many cases, these costs are paid back in the form of lower energy bills and increased property valuation.

Even without the carbon mitigation gains, the immediate health co-benefits of thermal envelope improvements are likely to more than justify new investments in terms of the costs of avoided sick days, doctor visits and hospitalisation (WHO 2011).

## 5. ECONOMY

### Example: Support economic growth

Strategic sectors	City goals (example)	Policy actions (example)	Co-benefits	Climate mitigation benefits	Climate adaptation benefits	Time horizon	Public finance required	Coordinated governance
ECONOMY	Support economic growth	Establish cleantech business clusters and incentives	Innovation, productivity, SME growth in technology sector	Medium	Medium	Short term	Low	Economy, Education, Transport, Buildings, Digital, Water, Waste

### The challenge of stimulating economic growth

A prolonged period of slow economic growth, stagnation or recession has a deleterious impact on urban populations through prices, wages and public spending. In cities where the population is shrinking, economic stagnation can be particularly acute. In contexts of slow or no growth, urban poverty tends to stagnate or rise and unemployment can become a particular challenge.

### Policy action example: establish cleantech business clusters and incentives

Through the agglomeration effect, cities are uniquely placed to drive innovation and cleantech growth. Compared to lower-density, sprawling settlements, agglomeration offers inherent advantages for both developed and developing countries<sup>11</sup> in terms of reduced infrastructure costs and knowledge spill-overs. As a means of bringing together businesses which are developing clean technologies and innovations, cleantech clusters can have a positive impact on economic growth as well as on developing and applying products and services for emission reductions and climate resilience.

#### *Mitigation potential of establishing cleantech business clusters and incentives*

- According to the IPCC, urban areas are associated with around 70% of global energy consumption and over 70% of energy-related carbon emissions, and are expected to rise on a business as usual trajectory up to 2050.
- Emerging economy cities are expected to be the largest contributors to GHG growth through 2050. In these cities, a majority of the infrastructure to be in place by this date has yet to be built (Floater et al. 2014). Investment flows to green urban infrastructure can avoid the lock-in effect from high-carbon/high-polluting activities and create job opportunities in support of this required investment.
- Successful cleantech businesses targeting the market for urban carbon emissions can provide products or services that directly or indirectly reduce GHG levels. The global market for such product and services is estimated at more than US\$0.5 trillion per annum (Rode and Floater 2013).

<sup>11</sup> Empirical studies in developed countries find that doubling the employment density of an urban area typically raises its labour productivity by around 6%. In developing economies, similar processes boost productive efficiency by lowering transport costs and widening trade networks (UNEP 2011).

***Adaptation potential of establishing cleantech business clusters and incentives***

- Some cleantech businesses may provide products or services that reduce vulnerability to the effects of climate change.

***Potential for addressing economic stagnation***

- Boosting jobs in new industries and attracting inward investment for environmentally friendly technologies and services (e.g. in transport, energy services, waste management, resource-efficient product design and materials) are viewed by many cities as key motivations for pursuing green growth.
  - In a survey and study of 90 cities worldwide on how cities are transitioning to urban green economies, 65% of respondents described economic growth as a primary goal of their green policies (Rode and Floater 2013).
- Denmark and Copenhagen have both created explicit policies to link green growth to economic development. Turnover in the Danish cleantech sector created more than 10% of Danish export earnings in 2010, with green exports from the Copenhagen capital region increasing 77% between 2004 and 2009 (Floater, Rode and Zenghelis 2014)
- Green building technologies and retrofits offer strong local economic benefits to cities that pursue low-carbon building strategies.
  - For building-efficiency retrofits, it is generally accepted that every US\$1 million invested creates 10-14 direct jobs and 3-4 indirect jobs (UNEP 2011).
  - Estimates by the US Department Energy show that by adopting standards for washing machines, water heaters, and fluorescent lamps, 120,000 US jobs could be created by 2020 (Bain et al. 2015).

***Other co-benefits of establishing cleantech business clusters and incentives***

- Increase innovation and firm productivity
- High rates of worker productivity and value added in goods and services
- Increased inward investment
- SME growth in technology sector

**Key urban data for measuring policy impact**

- Numbers of cleantech businesses, number of clusters
- Economic growth in cleantech businesses
- Levels of new firm formation and patents
- Indicators of inward investment
- Number of high-speed internet connections
- Levels of GHG emissions
- Levels of PMs, SO<sub>2</sub>, NO<sub>x</sub> and other pollutants

**Time horizon**

Implementation of this policy would probably require a medium- to long-term horizon due to the time needed to generate a critical mass of business/industries that are contributing pieces to a

larger green economy, and the pace of infrastructure investment through which government can facilitate demand for green goods and services.

### Coordination of governance and finance

Addressing economic stagnation is a cross-cutting policy challenge, involving many government sectors outside the economic department:

- *An education policy* that delivers the right skills for the innovation and high-technology sectors is a prerequisite to the success of cleantech clusters.
- *Infrastructure planning and management* will contribute to standards, specifications and procurement of new infrastructure investments in water, wastewater and solid waste, energy supply, buildings, and energy.
- *Economic development and skills policy* will be needed to set long-term objectives for green business creation and attraction, and supporting incentives and infrastructure (R&D facilities, technology and manufacturing corridors, tax or fiscal incentives).
- *Digital policy* that creates alignment between ‘smart city’ and ‘green city’ development can help harness IT investments for resource and carbon efficiency and that extend employment opportunities to small business or workers excluded from the mainstream economy through investments in high-speed broadband.
- *Transport, Buildings, Digital, Water, Waste policies* that create markets for new low carbon and climate resilient technologies and solutions.

The cost of creating cleantech business clusters and incentives will vary, but in many cities can be seen as a shift of emphasis rather than increase in expenditure where economic development and infrastructure spending already planned can incorporate goals for resource efficiency and carbon emissions reductions.

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