Europe's urban air quality — re-assessing implementation challenges in cities

ISSN 1977-8449

European Environment Agency

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Luxembourg: Publications Office of the European Union, 2019

ISBN 978-92-9480-059-6
ISSN 1977-8449
doi:10.2800/214599

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Acknowledgements

This report was prepared by the European Environment Agency (EEA) and its European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM). The EEA project manager was Evrim Doğan Öztürk and the ETC/ACM manager was Mar Viana.

The authors of the report were Evrim Doğan Öztürk, Anke Lükewille and Alberto González Ortiz (EEA) and, from the ETC/ACM, Mar Viana (Spanish Council for Scientific Research — CSIC), Alena Bartonova and Cristina Guerreiro (Norwegian Institute for Air Research — NILU) and Frank de Leeuw (Netherlands National Institute for Public Health and the Environment — RIVM).

The EEA reviewers were Martin Adams, Catherine Ganzleben, Anke Lükewille and Alberto González Ortiz.

The EEA is grateful for the cooperation of the city representatives who provided valuable input and feedback: Els Van Duyse (Municipality of Antwerp); Martin Lutz (Berlin Senate); Martin Fitzpatrick (Dublin City Council); Ángeles Cristóbal and María Encarnación de Vega (Municipality of Madrid); Mårten Spanne (Municipality of Malmö); Guido Lanzani (ARPA Lombardia, Milan); Olivier Chrétien (Municipality of Paris), Karine Léger and Sophie Moukhtar (Airparif, Paris); Elena Naydenova (Municipality of Plovdiv); Mária Kazmuková (Municipality of Prague); and Heinz Tizek (Municipality of Vienna). The EEA acknowledges comments received on the draft report from the participating city representatives. These comments have been included in the final version of the report as far as possible. The viewpoints expressed by city representatives as documented in this report do not necessarily reflect official positions of the participating municipalities.

The EEA acknowledges comments received on the draft report from the European Commission's Directorate-General for Environment (DG ENV) and the pilot cities participating in this initiative. These comments have been included in the final version of the report as far as possible.

Executive summary

Air pollution is one of the most important environmental problems affecting people's health, particularly in urban areas of Europe. Over the past decade, air quality has slowly improved in many of Europe's cities, as a direct result of more robust air quality policies across various governance levels, the introduction of targeted measures and actions, and technological improvements that have reduced emissions from various sources. Nevertheless, many cities and regions still experience exceedances of the regulated limits for air pollutants.

During 2012 and 2013, a selection of 12 cities from across Europe, supported by the EEA and the European Commission's Directorate-General for Environment, participated in the Air Implementation Pilot project (EEA, 2013a). Implementation of EU air quality policy is often addressed in terms of compliance: ensuring that countries attain the limit values and pursuing legal infringements if they exceed the limit values. While compliance is of course essential, both pilot projects also focused on another important aspect: the collaborative work needed to build capacity and knowledge in order to deliver policy more effectively in the long term. This initiative therefore documented the lessons learnt from the implementation of EU air quality legislation at the urban level, helping identify and address some of the key reasons for the implementation 'gap' between the many initiatives being taken to improve air quality and the resulting high concentrations of air pollutants in many of Europe's cities.

This report, prepared in cooperation with 10 of the 12 original cities — Antwerp (Belgium), Berlin (Germany), Dublin (Ireland), Madrid (Spain), Malmö (Sweden), Milan (Italy), Paris (France), Plovdiv (Bulgaria), Prague (Czechia) and Vienna (Austria) — describes the state of play 5 years after the pilot project was concluded. Its objectives are to evaluate progress since then, to continue to support the exchange of good practice information and to identify new challenges with respect to the implementation of air quality legislation at the urban scale.

Scope of the 2018 assessment

The 2018 follow-up assessment focused on assessing progress over the past 5 years across the same five air quality-related work streams that were addressed in the 2013 Air Implementation Pilot project, i.e.:

1. local emission inventories;

2. modelling activities;

3. monitoring networks;

4. management practices; and

5. giving information to the public.

To evaluate progress across the five dimensions over the past five years and to review current management practices and the implementation of local air quality policies in cities, representatives from each of the 10 participating cities provided input to the updated study.

Five years after the Air Implementation Pilot: challenges

In general, the 10 participating cities have all improved their practices on air quality management over the past 5 years, particularly in their use of assessment tools and methods to quantify the effects of measures. They have demonstrated an increased understanding of the sources of local air pollution and the transport of air pollutants.

This improved understanding is a pre-requisite to developing effective mitigation policies, protecting human and environmental health, and identifying co- and dis-benefits of action (e.g. across air quality and climate mitigation actions). Nevertheless, cities still face many challenges. The main challenges found by the cities in recent years during their implementation of air quality improvement measures include how to effectively communicate air quality issues to the public, and how to achieve coherent governance across various administrative levels, in particular in terms of analysing the co-benefits of measures in implemented in the areas of climate change, noise, urban planning, and air quality.

There are several platforms designed to support EU cities in increasing their knowledge of air quality issues, such as the EU Urban Agenda, the Covenant of Mayors for Climate and Energy, Local Governments for Sustainability (ICLEI) and Eurocities, as well as EU funding opportunities for research, including the LIFE Programme, Horizon 2020 and Urbact. While such initiatives have often led to a number of sources of information and guidance being available to support local air quality implementation, often local air quality practitioners are not aware of their existence. This suggests a need for a more coherent approach across Europe to allow an improved and more regular exchange of knowledge and experience concerning, for example, good practice, capacity building and possibly establishing a single authoritative information platform at EU level, summarising effective management approaches and supporting the sharing of experience and best practice.

Further steps

As many European cities are growing rapidly in size and population, and more people are potentially exposed to air pollution, it becomes increasingly necessary for local authorities to follow coordinated and integrated policy strategies to achieve better air quality in cities.

Actions undertaken at the city scale have considerable potential to address local sources of air pollution and encourage behavioural change to help improve air quality, but they must be supported through cooperation and coherent action across various governance levels, e.g. regional, national and EU levels. The degree of complexity in implementing EU and national regulations in the urban context was highlighted as a limitation in certain cases (e.g. for off-road machinery).

Involving local administrations and policymakers at an early stage of national air quality planning processes has proved to be highly successful, as it helps the implementation of mitigation measures. Economic incentives, as well as environmental benefits, have also been seen to be powerful drivers of change.

Further to this, channels that allow regular exchange of information, needs and challenges between city peers are considered very beneficial. The exchange of specific, experience-based results from successful (and unsuccessful) air quality improvement strategies was put forward by the cities as an example, encouraging future collaboration between cities in areas of emerging interest such as the pollution sources inland shipping, wood burning or construction/demolition.

Finally, adopting a multi-disciplinary and more integrated approach to the future of air quality management at all levels of government was proposed by participating cities, whether aiming for behavioural change regarding urban mobility, assessing the future of low-emission zones in view of decreasing on-road emissions from new vehicles, or discussing the most important air pollutants to be monitored to establish links with health. In particular, the importance of highlighting the co-benefits of air quality measures in relation to other policy areas, such as health, noise and climate change, and targeting specific pollutant sources was identified.

Other key needs to help establish a future roadmap for improved air quality in European cities were considered to be improved local communication and outreach strategies, both to increase public awareness and engagement and, in some instances, to ensure better communication to help bring about public acceptance of measures introduced to address poor air quality. Consistency of political decision-making over time and strong political support at the local level were also identified as important factors contributing to the successful implementation of local air quality measures.

1 Introduction

Air pollution, particularly in urban areas, is a public health concern, as clean air is vital for the quality of life and well-being of the public in Europe. Managing air quality is a common challenge for many of Europe's cities, where the population's exposure to high levels of air pollution can be considerable because of a mixture of urban activities, proximity to road traffic emissions and the difficulty of dispersing air pollutants away from highly urbanised areas. Cities can also be affected by poor air quality because of background concentrations caused by transboundary emissions from industrial and agricultural activities, as well as city-specific emissions from the transport and energy sectors.

The contributions from the various emission source sectors to ambient air concentrations and air pollution impacts depend not only on the amount of pollutant emitted but also on the proximity to the source, the emission conditions (e.g. height and temperature) and other factors such as dispersion conditions and topography. Emission sectors with low emission heights, such as traffic and household emissions, generally make larger contributions to surface concentrations and health impacts in urban areas than emissions from, e.g. high industrial stacks (EEA, 2018a).

Moreover, cities themselves may not only be air pollution hot spots, where high exposure to air pollution occurs, but are also sources that contribute to background air pollution levels elsewhere in Europe. Therefore, all levels of authorities play a key role in managing local, national and regional sources of air pollution to achieve clean air in cities. Achieving significant reductions in exposure to urban air pollution, especially in terms of particulate matter (PM), therefore, requires coordinated actions from local, national and international authorities.

1.1 Managing air quality in the European Union

The overall air policy strategy of the EU is directed towards meeting the air quality guideline values of the World Health Organization (WHO) in the coming decades, as stated in the Seventh Environment Action Programme (7th EAP) of 2013. The 7th EAP captures the EU's 2050 vision of 'living well within the limits of the planet', recognising the EU's long-term goal of achieving levels of air quality that do not give rise to significant negative impacts on, and risks to, human health and the environment. It aims to significantly improve outdoor air quality and move closer to the values set in the WHO guidelines (WHO, 2006) by 2020.

EU air pollution policy follows a twin-track approach: by setting legal limits for concentrations of air pollutants and by establishing agreements and standards to reduce emissions at source, i.e. national emission reduction commitments (total emissions) and sector-specific sources.

Several policy packages have been released by the European Commission in recent years with the objective of ensuring full compliance with existing air quality standards across the EU as soon as possible. The 2013 Clean Air Programme for Europe (EC, 2013) included two legislative measures to help cut air pollution (a revised National Emission Ceilings Directive, containing emission reduction commitments for 2020 and 2030, and a directive to reduce pollution from medium-sized combustion installations), as well as focusing on improving air quality in cities, supporting research and innovation, and promoting international cooperation.

Subsequently, the European Commission has published its 2018 communication 'A Europe that protects: Clean air for all', describing the current context of air quality management in the EU, namely the 'policy efforts of the EU to support and facilitate the necessary measures of the Member States to meet their targets, and the enforcement action being taken to help ensure that the common objective of clean air for all Europeans is achieved and maintained across the EU' (EC, 2018).

There are three main approaches adopted within the EU to reduce air emissions at source and to define minimum standards of air quality:

1. definition of ambient air quality standards;
2. setting of national emission reduction targets and
3. setting of emission and product standards for key specific sources of air pollution.

1.1.1 Air quality standards

The Ambient Air Quality Directives (AAQDs; EU, 2004, 2008), are the backbone of air quality policy in Europe. Air quality standards for 12 key air pollutants to be attained and maintained across the EU are set in the AAQDs, requiring the Member States to develop and introduce air quality plans for zones and agglomerations within which pollution levels exceed these standards and to maintain the air quality in all other areas to protect human health and the environment.

1.1.2 National targets for reducing emissions

In addition to the legislative framework on air quality standards, the National Emission Ceilings (NEC) Directive (EU, 2016a) sets 2020 and 2030 emission reduction commitments for five main air pollutants — sulphur oxides (SO_x), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), ammonia (NH_3) and primary fine particulate matter of 2.5 microns or less in diameter ($PM_{2.5}$). It also ensures that the emission ceilings for 2010 set in the previous (2001) NEC Directive remain applicable for Member States until the end of 2019. Furthermore, the 2016 NEC Directive requires that Member States draw up national air pollution control Programmes by 2019 that should contribute to the successful implementation of air quality plans established under the AAQDs to comply with their emission reduction commitments.

1.1.3 Emission standards for key sources of air pollution

Sector-specific legislation is used in the EU for establishing standards, such as emission limit values or quality standards, for important sources. The areas addressed include:

- industrial emissions (e.g. through EU, 2010; EC, 2001; EU, 2015);
- road and non-road vehicles (e.g. through EC, 2008; EC, 2009; EC, 2012; EC, 2016c; EU, 2017);
- fuels (EU, 2016d; EU, 2003), as well as handling and storage of fuel (EC, 1994; EU, 2009; EC, 1999);
- product design standards for certain equipment such as domestic stoves, implemented through, for example, the Eco-design Directive, 2009/125/EC (EU, 2009b).

1.2 The role of cities in managing air quality

The EU AAQDs require Member States to take appropriate measures to ensure compliance with the limit and target values within a specified deadline and/or to maintain compliance once the limit and target values have been met. Therefore, air quality plans are required in polluted zones and agglomerations where air quality standards are exceeded and/or in zones and agglomerations where there is a risk of exceedances. These plans aim to reduce concentrations of air pollutants to below the legislative limit and target values specified in the Directives in the shortest possible time, and details of the plans must be reported by Member States to the European Commission via the European Environment Agency (EEA).

The AAQDs leave the choice of means of achieving the air quality objectives to the Member States, but they do explicitly require Member States to prepare and adopt air quality plans detailing appropriate measures to achieve related limit values or target values when any limit value or target value, plus any relevant margin of tolerance, is exceeded and to keep the exceedance period as short as possible when the limit values are exceeded for which the attainment deadlines have already expired.

In many Member States, responsibility for developing and implementing the air quality plans has been devolved by national authorities to local governments.

City air quality plans typically include a series of measures based on an assessment of air quality and trend forecasts for the future and detailed analysis of the high level of concentrations, including the sources responsible. Understanding the reasons for high levels of air pollution in cities is crucial for decision-making on urban air quality management. In spite of initiatives such as the Forum for Air Quality Modelling in Europe (Fairmode), at the regional and/or city scale, local air quality experts do, however, often lack access to and/or expertise in using modelling tools to assess the impact of various strategy options on air quality.

1.3 Urban air quality in Europe — current status

Air pollution continues to have significant impacts on the health of the European population, particularly in urban areas where millions of EU citizens are still being exposed to air pollutants that are above the EU's air quality standards and the more stringent WHO air quality guidelines (EEA, 2018a).

According to the EEA's estimations of exposure of the urban population to air pollution in the period 2014-2016 (EEA, 2018b), a significant proportion of the urban population in the EU-28 was exposed to concentrations of certain air pollutants above EU limit or target values, despite past reductions in emissions that have taken place in countries. The number of people exposed was even higher when the more stringent WHO air quality guideline values were applied. In terms of exposure to:

- Fine particulate matter ($PM_{2.5}$): 6-8 % of the EU-28 urban population was exposed to concentrations in excess of the EU limit value, while 74-85 % was exposed to concentrations above the WHO guideline value.

- Particulate matter 10 microns or less in diameter (PM_{10}): the respective exposure estimates were 13-19 % above the EU limit value and 42-52 % above the WHO guideline value.

- Ozone (O_3): estimates were 7-30 % above the EU target value and 95-98 % above the WHO guideline value.

- Nitrogen dioxide (NO_2): estimates were 7-8 % above for both the EU limit and the WHO guideline values.

It is unlikely that the air quality standards for NO_2, PM and ground-level O_3 will be met in all Member States by 2020 because of continuing widespread exceedances in many urban areas. Achieving air quality standards in line with the more stringent WHO guidelines is much further away for most air pollutants. The percentage of the population exposed to higher $PM_{2.5}$ and NO_2 concentrations is generally higher for the urban population than for the total population, because of the higher concentrations found in urban environments (EEA, 2018a). Exceedances of air quality standards for these pollutants can be mainly attributed to the high level of emissions from road traffic and residential combustion in urban areas, often coupled with unfavourable conditions for the dispersion of emissions due to topography and meteorological conditions.

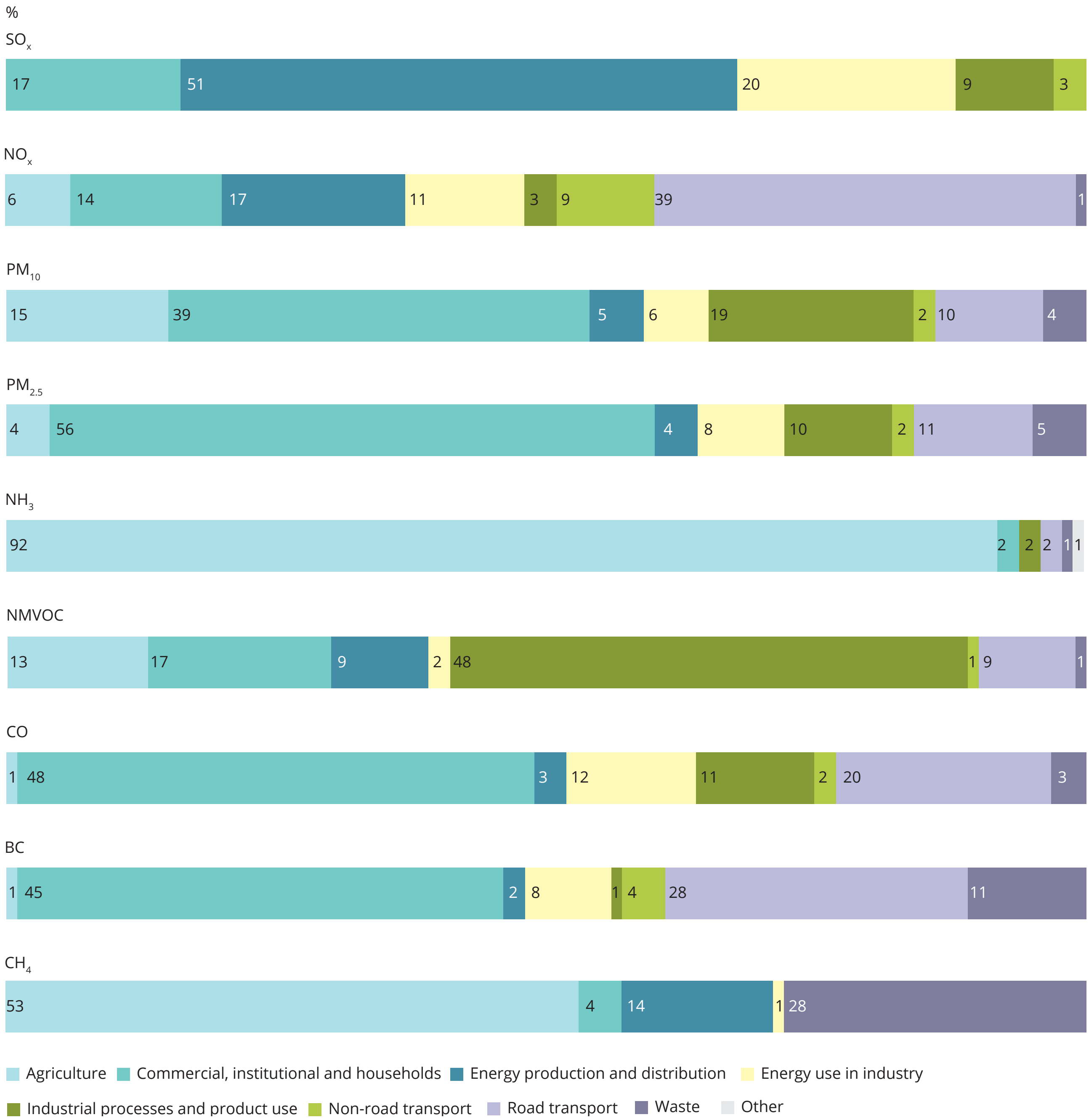
In terms of health impacts, exposure to air pollution leads to cardiovascular and respiratory diseases, major healthcare costs and lost working days, and it is the most significant environmental cause of premature death in the EU. The most recent data indicate that exposure to $PM2_{.5}$ is responsible for almost 400 000 premature deaths per year in the EU with some 76 000 directly linked to NO_2 (EEA, 2018a).

As shown in Figure 1.1, the road transport sector contributed to EU-28 emissions (urban and non-urban emissions) and had the highest share of NO_x emissions (39 %), followed by the energy production and distribution sector (17 %), and the commercial, institutional and households sector (14 %). The road transport sector is also a source of PM_{10} and $PM_{2.5}$ emissions, contributing 10-11 % to each in 2016. However, its contribution to ambient NO_2 and PM concentrations, especially in urban areas, is considerably higher, because its emissions are close to the ground and are distributed over densely populated areas (EEA, 2018a).

Emissions in cities can contribute significantly to national and EU overall PM background concentrations, reinforcing their important role in reducing air pollution on a national scale. For instance, the relative contribution of all emission sectors to the $PM_{2.5}$ urban background concentration levels in a country, calculated using the European Commission Joint Research Centre's Sherpa tool, is over 50 % in greater cities Madrid, Milan and Paris, over 45 % in Dublin, over 30 % in greater cities Antwerp, Berlin and Vienna and over 20 % in Prague, but less than 20 % in Plovdiv and less than 15 % in Malmö (Thunis et al., 2017).

Most of the measures in air quality plans reported by Member States over the last 3 years are aimed at reducing concentrations and the number of exceedances of the limit values of PM and NO_2. In general, the road transport sector is the largest contributor to total NO_2 emissions in the EU, while fuel combustion in the commercial, institutional and

Figure 1.1 Contribution to EU-28 emissions of NO_x, PM_{10} and $PM_{2.5}$ from main source sectors in 2016



Source: EEA, 2018a.

households sector is the largest contributor to PM emissions.

According to the measures reported by countries, and consistent with the main sources of pollution identified, more than 50 % of the measures implemented were traffic related and addressing emissions from road traffic (e.g. strategies such as lower speed limits or congestion charges, public procurement of clean(er) vehicles) and actions designed to improve urban mobility (e.g. promoting public transport, promoting active transport modes). The second and third most frequent measures reported concern commercial and residential combustion, and the industry sectors for PM_{10}; and the industry, and commercial and residential combustion sectors for NO_2 (EEA, 2018c). Measures targeting the industry, and commercial and residential combustion sectors mainly target a shift towards low-emission fuels, emission control equipment and retrofitting. Certain cities have also planned measures on emerging sources of pollution (e.g. at construction sites, ports) in recent years. Finally, measures focusing on public information are also important in all cases. They typically aim to give the public targeted information about individual actions that they can take to reduce air pollution. The local administrative level is responsible for the majority of the plans and for implementing many measures (EEA, 2018c).

1.4 Re-visiting the key findings of the 2013 Air Implementation Pilot on management of air quality

During 2012 and 2013, a selection of 12 cities from across Europe, supported by the EEA and the European Commission's Directorate-General for Environment, participated in the Air Implementation Pilot project (EEA, 2013a).

This project was designed to obtain an understanding of what cities need to improve their implementation of EU air quality legislation and of the challenges in implementing air quality policy at local level. The participating cities were Antwerp (Belgium), Berlin (Germany), Dublin (Ireland), Madrid (Spain), Malmö (Sweden), Milan (Italy), Paris (France), Ploiești (Romania), Plovdiv (Bulgaria), Prague (Czechia), Vienna (Austria) and Vilnius (Lithuania). These cities were selected to ensure that cities from different parts of Europe, of different population sizes, with different administrative traditions, and with a variety of sources of pollutants were included in the project.

Implementing EU air quality policy is often addressed in terms of compliance: ensuring that countries attain the limit values and pursuing legal infringements if they exceed the limit values. While compliance is of course essential, the pilot project focused on another important aspect: the collaborative work needed to build capacity and knowledge in order to deliver policy more effectively in the long term.

The outcomes of the 2013 Air Implementation Pilot on management of air quality are summarised and presented below. Full results of the 2013 pilot project are published in an EEA report (EEA, 2013a).

1.4.1 Measures to reduce air pollution in cities

The number and characteristics of the measures implemented varied from city to city; however, in most of the cities more than 50 % of the measures were related to traffic and urban mobility. The most common traffic measures implemented by the cities targeted reducing traffic volumes and a modal shift to cleaner modes of transport (e.g. improving public transport, adopting low-emission zones, promoting cycling). The other measures aim to reduce traffic emissions due to driving style by managing traffic flow and limiting speed.

The three most important measures discussed during the workshop, held as part of the 2013 Air Implementation Pilot, targeted road traffic, and only a few measures focused on industry and on fuels (e.g. biomass/bituminous fuel burning) used for residential heating. It was noted that measures such as restricting vehicle access in certain areas may have effects beyond improved air quality in the restricted area, such as accelerating fleet renewal or modal shift and also shifting the weight of traffic to other areas (e.g. ring roads), in particular for transit traffic.

Common industrial measures focused on technological improvements (e.g. enhanced abatement technology), changes in fuels (e.g. ensuring compliance with new low-sulphur standards for shipping fuels in port areas and measures to reduce diffusive dust emissions in ports) and relocating factories and industrial sites out of the urban area. Measures in the commercial and residential sectors targeted efficient use of energy (insulating buildings and creating district heating) and the use of environmentally friendly fuels for heating (e.g. banning the use of bituminous coal).

The agriculture sector was not mentioned by the cities, except for Milan in 2013, as being an important contributor to air pollution in terms of PM_{10}.

All cities implemented or planned to implement communication campaigns and awareness-raising strategies. They also identified economic and administrative (competences) challenges during the implementation of measures, as well as public/political opposition (EEA, 2013a).

1.4.2 Criteria for the selection of air quality measures and associated challenges

The criteria used by the participating cities in 2013 to help determine the selection of measures were the impact of reducing emissions, legal feasibility/competences, identified co-benefits (e.g. climate change mitigation, noise reduction, improved traffic safety), economic and social proportionality and technical feasibility. The importance of cost as a major criterion was highlighted during discussions with city representatives.

The main challenges identified during the implementation of measures were opposition (public, political, commercial), technological, cultural and economic challenges, competences/administrative challenges, lack of funds and lack of technology. Other challenges were illegal trading of banned fuels, legal loopholes, the conditions for EU grants, side effects (increase in congestion), and technical and administrative risks. Public opposition was considered by many of the participating cities to be a significant challenge, referring to the difficulty linked to modifying the public's perception of a given environmental problem (e.g. climate change versus air quality) or solution (e.g. biomass burning to reduce CO_2, emissions).

Legal aspects such as competences, which may be split between different levels (state/region/municipality), or legal issues regarding privacy, and the way that public opinion determines the action taken by policymakers, also posed limitations when implementing air quality measures.

Finally, 'politics' was also perceived as a challenge given that air quality in 2013 may not have ranked very highly on political agendas. The general challenges discussed were lack of human resources and funding in the context of the economic situation in 2013 and trying to change that situation to convert air quality improvement into an opportunity for economic growth (EEA, 2013a).

1.4.3 Estimating the effectiveness and costs of air quality measures

The Air Implementation Pilot project demonstrated the difficulty of standardising air quality monitoring and pollutant emission inventories to allow for meaningful comparisons between cities; such inventories are important tools for estimating the effects of measures. An even greater challenge is generating data to effectively quantify the impacts and monetised costs of air pollution to human health when considered in relation to proposed measures (EEA, 2013b).

The cities used different strategies to estimate the effectiveness of measures. Before identifying and implementing measures, estimates of emissions, air quality modelling and air quality impact studies were used by the cities. After implementation, the effect of the measures was generally assessed using monitoring networks, changes in emissions, evaluation of specific indicators defined by the cities for the specific measure and changes in fleet composition.

Estimating costs and effects of technological measures seemed to be slightly more feasible than it was for certain other types of measure (e.g. structural changes, such as low-emission zones). Overall, it was concluded that quantifying the costs and benefits (effectiveness) of measures is highly complex and that no standardised or comparable protocol is available to carry out this kind of assessment. Quantifying costs/benefits was especially challenging for structural measures.

The Air Implementation Pilot project highlighted the importance of considering the population actually affected by a reduction in emissions rather than just focusing on a reduction in air pollutant concentrations. Concerning improvements in air quality, the effect of reducing the traffic volume in certain streets can be considerable, positively affecting many citizens and raising opportunities for positive communication and raising public (and political) awareness.

Cost-benefit estimation was clearly the most complex issue, according to the cities. In general, specific data are available when it comes to technological measures addressing traffic (e.g. cost of a new or retrofitted bus), but this is not always the case when the measures are structural.

Concerning cities' experiences with public acceptance of measures, this was found to range from indifference (e.g. technological measures in public transport) to acceptance (e.g. bike-sharing programmes) and opposition (e.g. low-emission zones, circulation/access restrictions). Experience showed that acceptance was higher when public perception and knowledge were high, when the city provided alternatives and when there were economic incentives. Cases of failed measures were highlighted (e.g. the recent economic downturn resulted in a number of major strategic transport projects being postponed in Dublin). It was also pointed out that some of the measures implemented did not always target air pollution control as their primary aim but rather reducing greenhouse gas emissions, reducing noise or re-designing of the city centre. However, they also led to benefits in terms of improved air quality (EEA, 2013a).

Finally, certain existing frameworks such as Fairmode (2018a) were highlighted in the 2013 Air Implementation Pilot project as key mechanisms to support the cities in applying models for regulatory purposes, for instance assessing emission control scenarios for long-term planning and local measures to improve air quality and health.

1.5 Scope and report outline

This present report, prepared in cooperation with 10 of the 12 original cities (Antwerp (Belgium), Berlin (Germany), Dublin (Ireland), Madrid (Spain), Malmö (Sweden), Milan (Italy), Paris (France), Plovdiv (Bulgaria), Prague (Czechia) and Vienna (Austria)) describes the state of play 5 years after the 2013 Air Implementation Pilot project was concluded. Its objective is to evaluate progress since then, to continue to support the exchange of good practice information and to identify new challenges with respect to implementing air quality legislation at the urban scale.

The report addresses the same five air quality-related work streams that were addressed in the 2013 Air Implementation Pilot project, i.e.:

1. local emission inventories;
2. modelling activities;
3. monitoring networks;
4. management practices; and
5. giving information to the public.

Chapter 2 of this report describes the cities' progress and experiences over the past 5 years in relation to the work streams listed above. The following chapter (Chapter 3) provides an assessment of the challenges and difficulties the cities continue to face in implementing air quality legislation, based upon feedback obtained from city representatives. Finally, Chapter 4 provides a summary of the main findings.

There are some initiatives to support local governments in improving air quality at both EU and global levels, which are summarised in Boxes 1.1 to 1.3.

Box 1.1 Urban Agenda for the EU Partnership for Air Quality

The Urban Agenda (Urban Agenda for the EU, 2017) aims to promote cooperation between Member States, cities, the European Commission and other stakeholders to stimulate growth, liveability and innovation in the cities of Europe. With respect to air pollution, the main goal of the partnership is to improve air quality in cities and put a 'healthy city' higher up the agenda at local, national and EU levels.

The partnership has identified four main challenges and actions to address them (for details, see Annex 1, Table A.1):

1. better regulation and implementation (filling gaps in regulations on sources of air pollutant emissions; better air quality planning and governance);

2. better funding mechanisms (targeted funding to improve air quality);

3. better knowledge at all levels and coordination (focusing on protecting and improving people's health, awareness raising, knowledge sharing and outreach);

4. links with other commitments (cross-cutting issues, New Urban Agenda and Sustainable Development Goals)

Table A.1 in Annex 1 provides a summary of specific actions to improve the existing regulation and implementation of measures to improve urban air quality. With a focus on better implementation and regulation, the project identified the following needs:

- Encourage local administrations to adopt a continuous improvement approach to reducing emissions of the main pollutants, particularly PM and NO_x, as many cities struggle to comply with the limit values set in the Ambient Air Quality Directive.

- Focus on measures to accelerate the switch to low- and zero-emission vehicles (e.g. electric buses and cars) and zero-emission modes of transport (e.g. cycling) and to deploy intelligent transport system (ITS) solutions that help transition.

- Improve the coherence of cities in their approaches to implementing low-emission zones (LEZs), e.g. via road pricing, speed limits or reducing on-road parking facilities.

- Promote additional actions for local governments to improve the transport infrastructure, as well as initiatives on car sharing and negative fiscal incentives for cars.

- Set up a multilevel governance working group to provide input to the European Commission and/or established policy processes addressing relevant policy and regulatory developments, e.g. during the fitness check of the EU AAQDs.

- Consider collaboration on issues such as urban mobility, climate and energy topics.

The partnership's findings highlighted that EU and national regulatory instruments and/or the way they are implemented might not always ensure adequate and timely reductions in air pollutant emissions and an improvement in air quality. Two major requirements for better air quality planning (governance) are:

- to improve the coordination between different levels of governance (national, regional, local);

- to improve the coordination within cities between air, health, energy, transport and urban planning authorities, taking into account contributions that could come from citizens' involvement in urban policy development.

The partnership has further identified four concrete topics relevant for urban air quality:

1. modelling of city-specific situations;

2. mapping of existing regulations and funding;

3. assessing good practice in air quality management and identifying barriers;

4. developing guidelines for compiling air quality action plans in cities.

Box 1.2. Covenant of Mayors for Climate & Energy

This European Commission initiative helps European cities to mitigate climate change by implementing intelligent local sustainable energy policies that aim to increase citizens' quality of life and to address crucial social and environmental issues. Through reducing greenhouse gas (GHG) emissions and promoting the transition to a low-carbon economy at urban level, urban air quality can also improve.

The Covenant of Mayors has collected best practice examples and case studies covering many mitigation and adaptation measures for climate change, including efforts to save energy and use more renewable energy sources (http://www.covenantofmayors.eu/en). Energy and climate measures that, for example, promote sustainable mobility, improve the energy performance and resilience of buildings, develop the green/blue infrastructure and re-naturalise urban spaces can also help to improve air quality in cities.

Box 1.3. International Council for Local Environmental Initiatives (ICLEI)

ICLEI is a global network of over 1 500 cities, towns and regions, which is committed to building a sustainable future. Local and regional governments across the ICLEI network work alongside a team of global experts in 22 offices active across 124 countries. The ICLEI network addresses the local impacts of global change, from climate change to urbanisation, aiming for urban development to have the least possible impact on global systems and to build communities that are people centred and equitable.

In relation to air pollution, the mayors of 22 cities adopted the Tokyo Declaration on Realization of Clean Cities and Clear Skies (ICLEI, 2018).

ICLEI supports cities in the EcoMobility Alliance and engages them in a variety of programmes and tools as part of the low-carbon city agenda and the healthy, happy and inclusive communities agenda. It is also a partner in the Climate and Clean Air Coalition (ICLEI, 2018), which is the only global effort that unites governments, civil society and the private sector and is committed to improving air quality and protecting the climate.

2 Evaluating recent progress of the Air Implementation Pilot cities

This chapter summarises the progress of the cities originally involved in the Air Implementation Pilot project of 2013, focusing not only on their improvements and successes but also on the continuing gaps in the implementation of legislation when comparing the current situation with that of 5 years ago. A summary of the recent air quality trends in each of the participating cities is also provided.

2.1 Approach to evaluating progress over the past 5 years

This 2018 follow-up focused on evaluating progress of the participating cities across the same five work streams as in the 2013 Air Implementation Pilot project, i.e. local emission inventories, modelling activities, monitoring networks, management practices and giving information to the public. Of the 12 original cities that participated in the pilot project, 10 also participated in this update, namely Antwerp (Belgium), Berlin (Germany), Dublin (Ireland), Madrid (Spain), Malmö (Sweden), Milan (Italy), Paris (France), Plovdiv (Bulgaria), Prague (Czech Republic) and Vienna (Austria). In the updated assessment, the EEA was supported by its European Topic Centre on Air Pollution and Climate Change Mitigation (ETC/ACM).

The views of city representatives on management practices and local air quality policy implementation in cities were obtained throughout the course of the project via a questionnaire and through webinars and a dedicated workshop.

A compilation of the replies and conclusions based upon the project's outcomes is provided in the following sections.

2.2 Recent air quality trends in the participating cities

The following figures illustrate the recent evolution of the concentration of two main air pollutants, PM_{10} (Figure 2.1) and NO_2 (Figure 2.2), for the participating cities for the most recent 5 years for which data are available, i.e. 2012-2016. Data are provided for various air quality monitoring station types, i.e. PM_{10} 90.41 percentile concentration values at traffic and background urban/suburban stations, as well as the combined average, shown in relation to the respective EU standard, EU daily limit value (50 µg/m^3) in Figure 2.1. NO_2 annual mean concentration values at traffic and background urban/suburban stations, as well as the combined average, shown in relation to the respective EU standard, EU annual limit value (40 µg/m^3) are shown in Figure 2.2. This information is based on the official data e-reported by Member States to the European Commission and the EEA under the requirements of the EU AAQDs.

As seen in Figure 2.1, 6 of the 10 participating cities have experienced 90.41 percentile concentrations of PM_{10} in traffic and/or background urban/suburban stations above the EU daily limit value of PM_{10} (50 µg/m^3) for at least one of the years 2012-2016. Only in Dublin, Madrid, Malmö and Vienna were PM_{10} 90.41 percentile concentrations below the daily limit value over the entire period. The 90.41 percentile concentrations of PM_{10} in Milan and Plovdiv were still above the EU threshold in 2016.

As seen in Figure 2.2, most cities have reported exceedances of the EU annual limit value of NO_2 (40 µg/m^3) at traffic and background urban/suburban stations or have the highest concentrations close to the limit (as in the case of Prague) for the years between 2012 and 2016. Only Dublin, Malmö and Prague have reported concentrations consistently below the NO_2 annual limit value in all stations. As for NO_2, it should, however, be noted that there are still exceedances of the hourly limit value of NO_2 (200 µg/m^3) in all cities (except Malmö) according to the data reported.

In accordance with the requirements of the EU AAQDs, all cities except Dublin have previously prepared air quality plans including measures that are designed to ensure compliance with the limit values.

In terms of the general perception of the importance of air pollution, feedback from city representatives

Figure 2.1 **Evolution over time of PM_{10} 90.41 percentile concentrations (in µg/m³) in pilot cities**

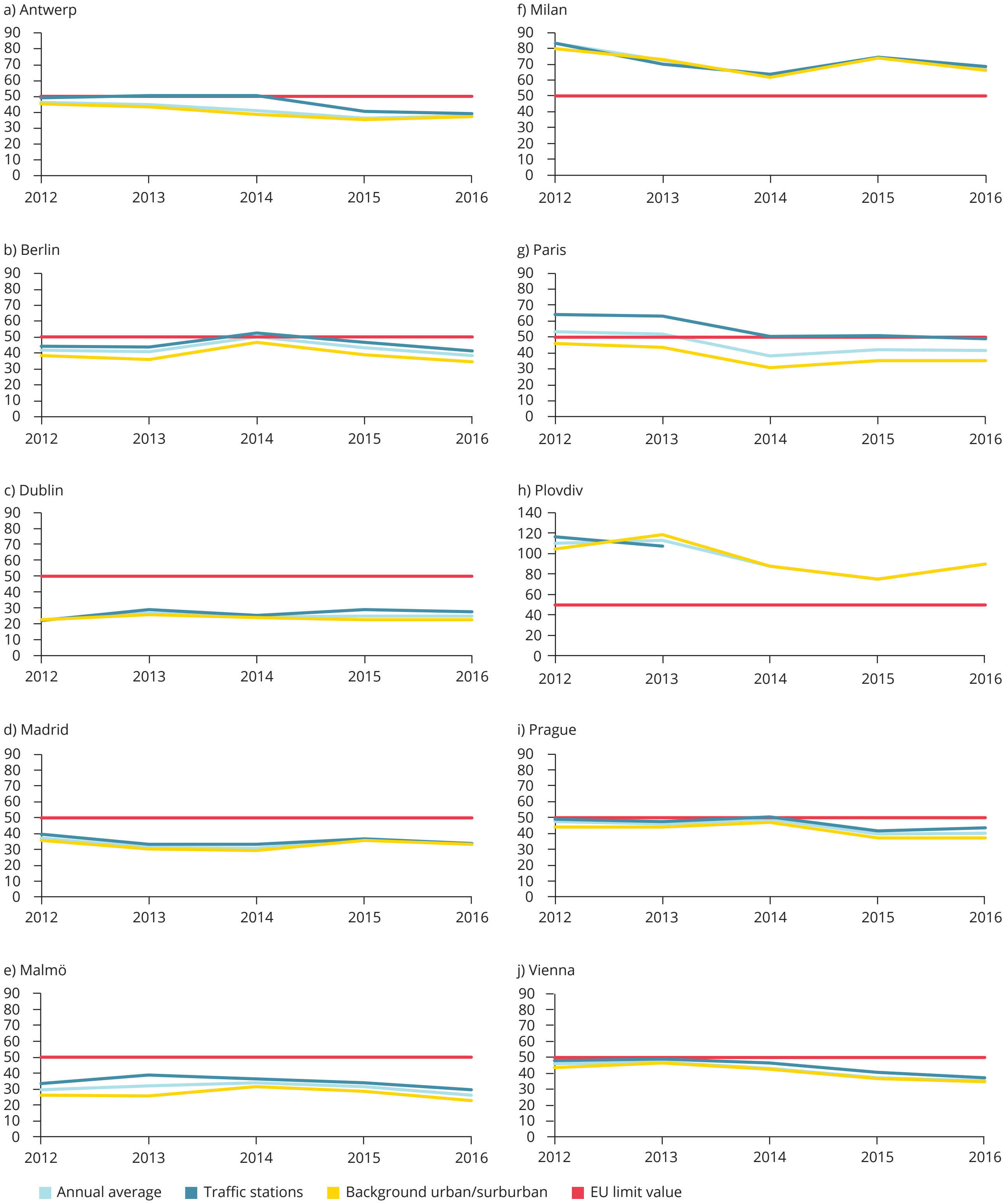
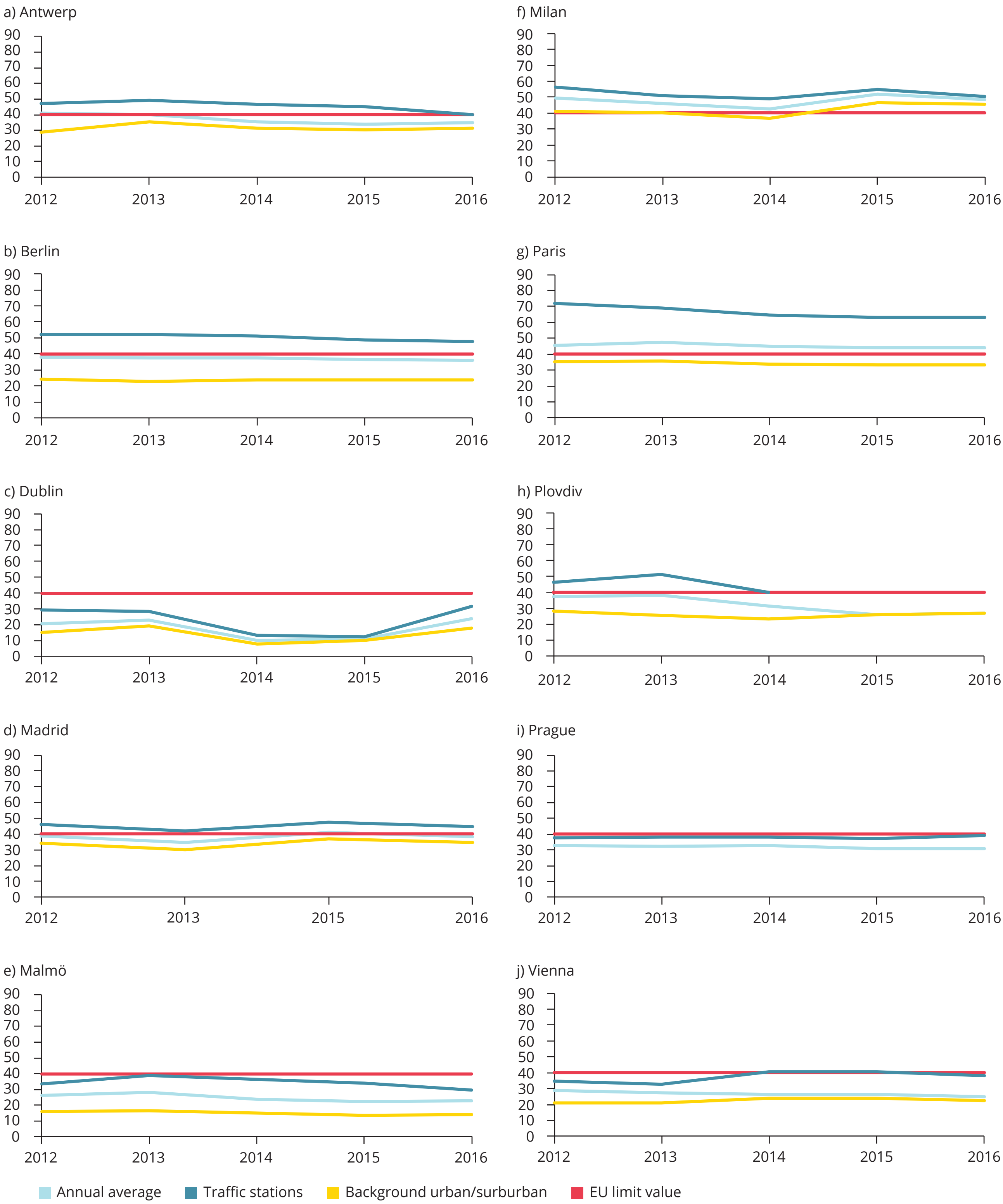


Figure 2.2 **Evolution over time in NO_2 annual mean concentrations (in μg/m³) of pilot cities**



indicates that the priority rating of air quality compared with those of other environmental issues has increased in two thirds of the cities (Figure 2.3).

Representatives from all the participating cities consider that there have been positive developments in terms of the management of air quality issues in their cities over the past 5 years (2013-2017). In 9 out of 10 cities, the representatives considered that these positive developments were because of changes in national and local regulations and air quality policies, i.e. mainly due to political pressure to properly implement the EU directives and regulations (Figure 2.4). However, around half of the participating cities are finding that, once EU limit values are met, there is relatively little political will to improve air quality further. More specifically, regional and national authorities are reluctant to support local authorities in implementing additional measures, since there is no legal pressure to put in place additional measures when cities are already complying with EU air quality standards. For this reason, the cities currently in compliance (or close to compliance) with EU limit values signalled the value of additional, more stringent, EU limit values, e.g. following the World Health Organization (WHO) guidelines, in order to drive further improvements in air quality for the health of their citizens.

Figure 2.3 Priority rating of air quality compared with other environmental issues over the past 5 years

Aside from EU regulations, positive impacts on the local management of air quality in the cities over the past 5 years are thought to be due to the successful implementation of abatement measures (in 8 out of 10 cities) and support from (local) decision-makers (in 7 out of 10 cities) (Figure 2.4). This is an improvement compared with the results of the 2013 Air Implementation Pilot project, when obtaining support from policymakers was regarded as only an objective. Increased collaboration between local, regional and national administrations and public support/engagement are also considered to have had a positive influence on air quality management (Figure 2.4) in most of the pilot cities.

2.3 Local emission inventories

Assessing the possible changes in concentrations due to the planned measures is a crucial element of air quality management. This typically requires the

Figure 2.4 Reasons for the observed positive developments in air quality over the past 5 years based on feedback from participating cities

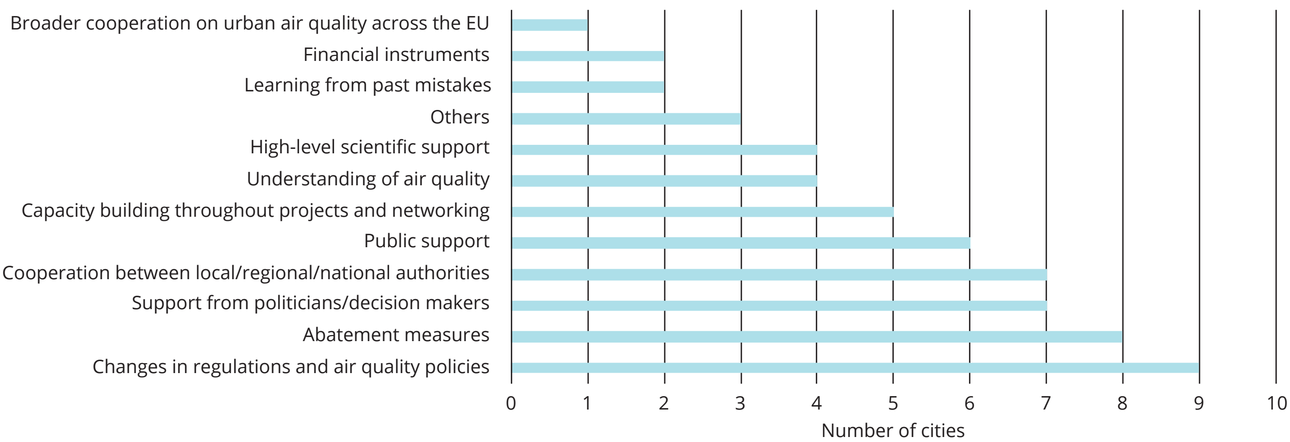


Figure 2.5 Remaining challenges for compiling emission inventories

use of suitable local air quality models and sufficient input information, especially covering the sources and magnitude of air pollutant emission sources, i.e. spatially resolved emission inventories, coupled with information on meteorological parameters.

2.3.1 Past situation

The 2013 Air Implementation Pilot assessment concluded that, of the 12 cities investigated then, 11 had emission inventories, but these were compiled using a variety of different methodologies, which did not usually allow them to be compared across cities or with national or regional emission inventories. Finding available data for relevant sources was identified as a difficulty. For example, the emission inventory methodologies in relation to the models the cities are using have subsequently been described, and it has been pointed out that there is a large variety of approaches and modelling tools used (ETC/ACM, 2013).

The cities faced problems in taking into account all sources of pollution because of the difficulty of finding available data or of appropriately quantifying different sources. The pilot project concluded that better input data and more guidance on inventory methodology were needed.

2.3.2 Current situation

Among the 10 participating cities, Dublin still does not have a local emission inventory. However, the Air Implementation Pilot project in 2013 helped Dublin to follow a national strategy/approach on compiling inventories and to build capacity on inventories in a short period.

The 2018 updated assessment showed that all 10 cities have made improvements in emission inventories in the intervening years. Seven cities reported improving at least one of the following: methodologies and emission factors, inclusion of more pollutants (e.g. benzo(a)pyrene (BaP), elemental and organic carbon, soot or black carbon, $PM_{2.5}$, or particulate matter 2.5 microns or less in diameter) and/or additional sources (e.g. inland shipping, local data on residential heating and traffic), improved source quantification and the spatial resolution of the inventory, or they have made other improvements to input data. Furthermore, efforts are being made to continuously improve the emission inventories.

Despite these improvements, a number of remaining challenges were identified by the city representatives (Figure 2.5), mainly related to input data, lack of technical capacity to perform the necessary improvement work for emission inventories and lack of human resources.

The main common challenge identified by the cities regarding local emission inventories is the lack of traffic intensity data with sufficiently high spatial resolution that is needed to inform local air quality models. Traffic data at street level are usually not available in cities, and it is often also too expensive for cities to compile it.

It was noted that road vehicle emission inventory models provide adequate approximations of real-world vehicle emissions by Euro emission class, pollutant and driving situation to support, for example, the development of national, regional or local emission inventories, but they may not provide sufficient detail (at the vehicle model level) to design access restriction schemes or other targeted air quality measures. High-resolution traffic data and modelling capacities may therefore be needed, for example, to estimate the concentration levels of pollutants at street level.

Some cities, such as Antwerp, Malmö, Paris, Vienna and Berlin would like to consider air quality issues in urban spatial planning schemes concerning, for example, schools and when assessing certain projects. In Antwerp and Malmö, the location of new schools and day-care centres is decided according to the ambient air quality concentrations to reduce the children's exposure to air pollution and to promote the construction of new day-care centres (for 1- to 6-year-old children) only in cleaner areas of the city and not close to major roads (following environmental assessment procedures).

Taking into account emerging sources of pollution, cities often also still face problems in finding data related to these new sources. For example, Antwerp has challenges in quantifying the effects of cruise ships emissions in its low-emission zone and Prague also has challenges in estimating the effect of inland ships' emissions on urban air quality.

Nevertheless, over the past 5 years, most of the cities have already improved their capacities in compiling emission inventories in terms of pollutants/sources covered by the inventory and of the methodological approach and emission factors used.

2.4 Modelling activities

As noted above, the use of air quality models to assess the potential changes in urban air quality concentrations is a fundamental element of air quality management.

2.4.1 Past situation

In 2012, cities reported using a wide variety of air quality models (ETC/ACM, 2013). Because air quality models make use of emission inventories, the uncertainties associated with these inventories were often carried over to the modelling activities. Additional issues encountered by the cities 5 years ago concerning the robust application of models included the use of other input data used in the models, such as meteorological information, to address air pollution coming from the regional background with a regional model. Another difficulty when applying models at urban level was how to accurately reflect the specificities of urban topography, such as pollution hot spots on kerbsides. Finally, many city representatives said that the results of their models were often highly complex, and therefore difficult to interpret, consuming a lot of resources and computational time. This complexity also made the subsequent validation of the results more difficult. From the results of the 2013 pilot project, it was concluded that greater training in modelling was needed, along with improved input data, and it recommended that the cities participate in the activities of Fairmode.

2.4.2 Current situation

In the 2018 updated assessment, only the city of Dublin reported that it is not using any models for air quality management. In most cases, cities apply models to assess the resulting air quality from both reference and emission abatement scenarios. However, cities report that their future intention is to increasingly use models to a greater extent to forecast emissions in order to take the necessary short-term measures. The impacts of changing air quality on the average exposure of the population and on health are also increasingly starting to be quantified.

All the other cities have made certain changes to their modelling capacities since 2012, ranging from contracting out modelling to external experts (one city) through to putting in place a number of in-house improvements, including more training and collaboration with external experts, leading to better understanding of the modelling tools and input data, better background information and more understanding of the various modelling tools and their specific uses. However, as can be seen from Figure 2.6, a number of difficulties remain, related to the elements necessary for the successful application of models. These include aspects such as the lack, or low quality, of input data on emissions (see also section 2.3), technical difficulties in running the models (model specifications and long computational times) and issues encountered while interpreting the results. Some cities are currently using simple models that do not include atmospheric chemistry, e.g. Malmö; however, they are aiming to use chemical models to estimate the concentrations with less uncertainty. Cities further need to determine the contribution of long-range transport of air pollution and add it to the model as background concentration, and they typically need support to do this from national air quality modelling teams.

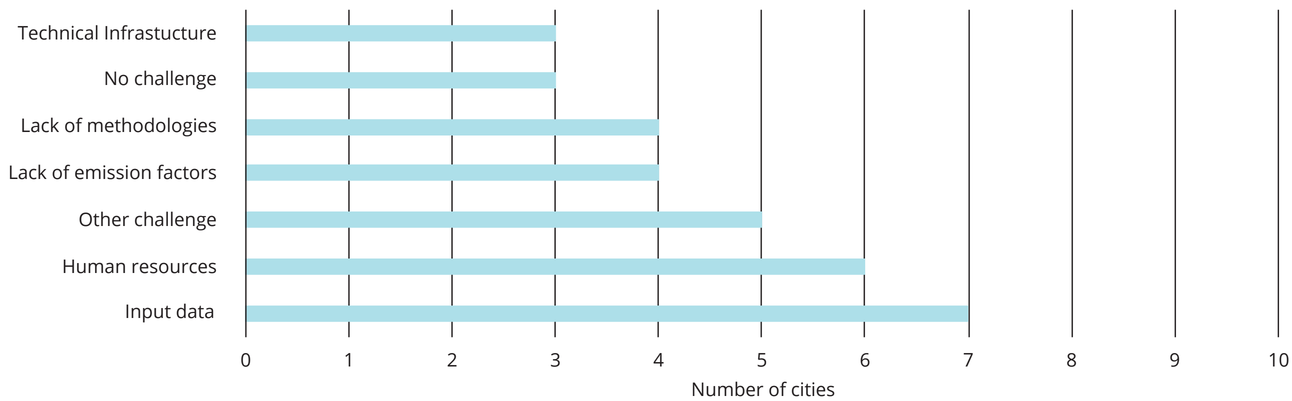
In the last 5 years, all cities using modelling reported increasing capacity-building activities on modelling through training courses and guidance in projects or by bringing in support from external experts. However, they still face technical difficulties in terms of establishing high-quality input data, and high levels of uncertainty. Most cities consider that, given the general importance of road transport emissions sources in their areas, they would benefit from using more advanced local traffic models to support better interpretation of potential traffic-related measures. Accompanying this is the need for improved guidance on the use of (traffic) models.

The main challenge for cities with the use of models is that they do not reflect the real air quality situation because of their intrinsic uncertainties. This can make relying upon their results difficult when it comes to establishing cost-effective mitigation measures. The models tend to be mainly used for scenario analysis to envisage the effect of measures before they are implemented, e.g. Malmö runs a model scenario banning road traffic, which includes population data to show the linkage between air quality and health (Malmqvist et al., 2018). In fact, cities agree that, although models do not simulate the real world, they are good tools to predict relative changes and trends in concentrations.

The cities are also increasingly aware of the potential for low-cost 'citizen science' sensors (Box 2.1) to help support the results of the air quality modelling. Nevertheless, city authorities do have reservations around the use of citizen science and citizen participation, whereby the use of sensors with low accuracy may impact negatively on the robustness of air quality information.

Other challenges with air quality models, in addition to high-quality road transport-related data, include obtaining information on other local and non-local sources that can contribute to poor air quality in cities, such as shipping traffic in some cities (whereby shipping routes vary), agriculture, and small-scale (domestic) heating, especially wood-burning appliances. Concerning the latter, the cities noted that it can be very difficult to quantify wood burning in domestic emission inventories, since most of it (approximately 90 %) uses non-regulated stoves, it is strongly dependent on the type of wood used and the combustion can take place under less than optimal conditions (e.g. poor burning/loading practices).

Figure 2.6 The main technical difficulties related to the use of air quality models identified by participating city representatives



Box 2.1 Citizen science approaches — the *Curieuze Neuzen* Flanders project

Citizen science approaches to air quality aim to engage the public with air quality monitoring to complement official monitoring data with additional measurements of local air quality. These approaches are also used as a tool for awareness raising in the policymaking community as well as among the general public.

The *Curieuze Neuzen* (Curious Noses) Flanders project is an example of a well-designed citizen science project in which citizens measure air quality using NO_2 passive sampling tubes in Flanders/Belgium. The data collected are used to test the state-of-the-art Atmosys computer model (developed by VITO for the Flemish Environment Agency) that is currently used to assess air quality in Flanders. By improving the predictive capabilities of this model, a better estimation of the population's exposure to NO_2 and its effects on public health is anticipated, providing better information and recommendations to policymakers.

Box 2.2 Air quality models

Different types of air quality model are increasingly used in Europe for estimating air quality or forecasting air pollution levels. The Ambient Air Quality Directive (EU, 2008) encourages modelling as one of the means of performing air quality management tasks such as air quality assessment, forecasting and planning.

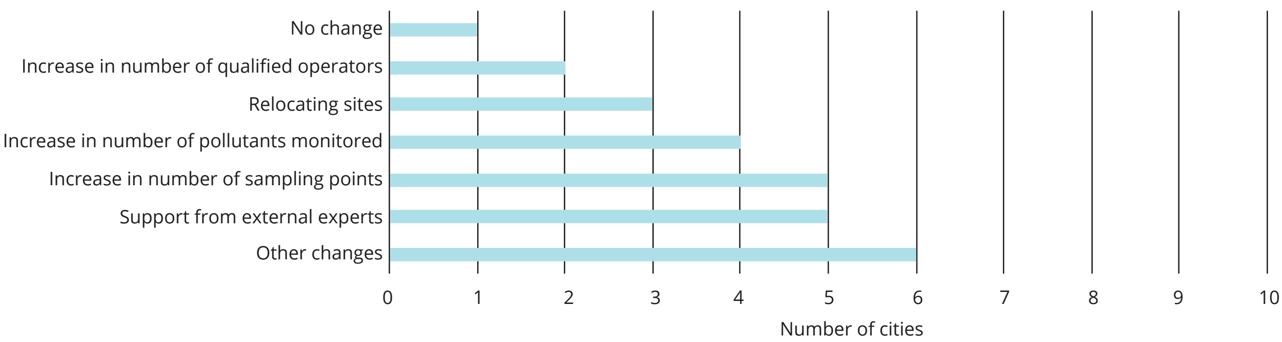
Models are essential tools for developing atmospheric emission abatement measures and air quality plans. Frequently, these plans are related to urban environments where the emission sources and the exposed population are concentrated.

Due to their ability to assess the efficiency of various emission reduction measures, numerical air quality models are useful tools for air quality management. They estimate pollutant concentrations in areas that are not covered by air quality monitoring stations and quantify the impact of projected emission scenarios on air quality.

Air quality models can be used at different scales: local, national, regional and European. The purpose of such models is to assess whether local/urban air quality limit values are exceeded, as laid down in the EU Ambient Air Quality Directive and whether critical loads for acidification and eutrophication and air quality limits for ozone in rural areas are exceeded (as agreed under the Long-Range Transboundary Air Pollution Convention). Key input data for the models typically include estimates of emissions from different source categories, such as energy industries, transport, manufacturing industry and the residential sector, and meteorological data.

Guidance documents on modelling quality objectives and benchmarking, whereby recommendations and guidance for evaluating model performance, are provided as part of the European Fairmode network (Fairmode, 2018b).

Figure 2.7 Changes implemented in the local air quality networks in the participating cities in the past 5 years and number of cities implementing each of them



2.5 Monitoring networks

2.5.1 Past situation

For monitoring urban air quality, the original Air Implementation Pilot project found that most of the cities had the necessary number of monitoring stations required by the relevant Ambient Air Quality Directive. However, the criterion for the macro-scale siting of ozone stations (their distribution between urban and suburban locations) was not always met in the participating cities.

The cities' experts recommended at the time that there was a need to better address the issue of the location of monitoring stations. Some experts also pointed out that the guidance available under the AAQDs could provide more detailed requirements for the measuring stations. These requirements would stipulate the macro-siting (where the stations are located with respect to major pollution sources) and micro-siting (where the stations are sited with respect to their immediate surroundings, such as their height and proximity to the kerb), as well as the representativeness of the stations (the spatial area over which the value measured at the station can be accepted as meaningful).

2.5.2 Current situation

During the last 5 years, air quality monitoring strategies have evolved in most of the cities in terms of the increasing number of sampling locations and input from external experts (Figure 2.7). In a small number of cities (Antwerp, Madrid, Malmö and Milan) there was an increase in the number of parameters monitored (e.g. to include non-regulated measurements of pollutants such as particle number concentration or real-time chemical composition of particulate matter). For some cities, it is still a challenge to ensure the necessary representativeness of the stations, especially for ozone, e.g. Madrid.

In addition to fixed measurements of air quality, some cities, e.g. Berlin, are using NO_2 passive sampling as indicative measurements to demonstrate the effect of measures (e.g. speed limits and traffic bans) and have contributed to multi-country studies on the sources of particulate matter (PM) for extra speciation analysis (e.g. black carbon emissions due to wood burning).

Interest in monitoring emerging and non-regulated parameters (particle number, black carbon, ozone precursors — which are not regulated in Annex X of Air Quality Directive 2008/50/EC — ammonia, visibility, pesticides, ultrafine particles, nitrogen and metals — which are not regulated in Air Quality Directive 2004/107/EC — emissions and those from different sources e.g. road dust) is expressed by a number of participating cities, including Antwerp, Berlin, Malmö, Milan, Paris and Vienna. However, they request clear guidance on a common method for measuring these pollutants. For instance, the results of chemical speciation of PM_{10} in some cities show that local measures may not always be effective, especially for long-range transported pollutants such as PM due to the contribution to local concentrations made by agricultural activities that occur outside city boundaries.

In urban areas, city participants recognise that increasing the number of sampling points for both NO_2 and PM can be beneficial for municipalities planning to draw up measures aiming to cut local air pollution, such as low-emission zones. Some cities (e.g. Antwerp, Dublin, Madrid and Prague) have increased the number of sampling points over the past 5 years to provide estimates that better represent the urban population's exposure to pollutants. However, some cities have also had challenges in ensuring the long-term siting of monitoring sites, since they are frequently located on land belonging to private companies and can therefore be subject to requests to relocate the stations.

Over the past 5 years, some cities have contracted external experts to assist with the running of their city air quality monitoring networks, e.g. Antwerp, Berlin, Dublin, Madrid and Prague. Furthermore, some cities have improved the quality assurance/quality control of monitoring data, e.g. Malmö, whereas some others have developed supersites to better represent exposure in relation to changes in air pollutant emissions (by developing low-emission zones and changing traffic patterns), e.g. Milan.

As noted in section 2.4, another emerging area on the measurement of air quality is the promotion of (citizen science) sensors. Some cities (e.g. Antwerp, Madrid and Paris) have already explored the use of low-cost sensors. Micro-sensors and/or mini-stations (sensor nodes) are used during fieldwork campaigns in these cities, but there are technical problems relating to power source, data transmission, data storage, and data handling and assessment.

2.6 Management practices

Various measures have been taken by the participating cities to reduce emissions of air pollutants. The plans and programmes adopted have included actions such as reducing emissions from large combustion plants, industrial facilities and road transport in line with EU requirements. However, despite implementing measures in many cities to mitigate air pollutant emissions, as described earlier the regulatory standards for certain pollutants, particularly for PM and NO_2, continue to be exceeded, the latter particularly along the main roads in many city centres.

2.6.1 Key pollutants addressed in the air quality plans

The two main pollutants targeted by the cities participating in the Air Implementation Pilot project are NO_2 and PM. Some cities also have local problems with other pollutants (e.g. lead in Antwerp and BaP in Milan), for which they have already taken the necessary measures through action plans already in place.
No specific measures have been defined to reduce emissions of volatile organic compounds as ozone precursors, although cities in southern Europe had exceedances of ozone target values.

2.6.2 Emission sources

All cities participating in the updated project have revised and/or planned to update local air quality plans in the last 5 years, including where necessary measures to ensure that air quality standards are met. These plans include actions to reduce emissions from specific sources.

Box 2.3 National ban on smoky coal in Ireland

In the 1980s, Dublin was frequently subjected to episodes of smog, largely attributed to incomplete burning of fossil fuels (mainly bituminous coal) in domestic fireplaces. One major contributory factor was government policy in response to the fuel crises of the 1970s, which in the 1980s required new houses to be fitted with open fires and provided incentives to existing householders to convert from oil-fired heating to systems burning solid fuels. This led to an increase in the quantity of solid fuel (mainly bituminous coal) used for domestic heating, which in turn gave rise to repeated incidences of extremely high concentrations of black smoke during the winter months. On one day in early 1982, the daily concentrations of black smoke exceeded 1 700 $\mu g/m^3$.

When the Air Pollution (Marketing, Sale and Distribution of Fuel) Regulations were enacted in 1990, this effectively banned the sale of bituminous fuels in the Greater Dublin area. This led to an immediate, dramatic and sustained reduction in smoke levels.

Research indicates that the ban in Dublin has resulted in 350 fewer annual deaths. An estimate of these benefits in financial terms put the value at over EUR 20 million. Additional benefits of the regulations include many householders switching from solid fuels, which generally are less efficient and more polluting, to more efficient and less polluting gas or oil. The associated reduced fuel costs to consumers are estimated at EUR 184 million per year.

This ban now applies in 26 cities and towns. Air quality monitoring by the Environmental Protection Agency has shown lower levels of particulate matter (PM_{10}) in these areas than in towns where the ban does not apply.

A ban on the burning of smoky coal and other prohibited fuels now applies in all smoky coal ban low-smoke zones to complement the ban on the marketing, sale and distribution. The Irish Minister for Environment announced on 6 December 2017 the intention to introduce a nationwide low-smoke zone. The ban on the sale of smoky coal in the existing zones, which has been in place in larger towns for some time, was extended countrywide from autumn of 2018, with a 12-month period given to coal distributors to sell off existing stocks before a total ban comes into effect in 2019.

For householders who continue to rely on solid fuel, there is now a range of innovative low-smoke solid fuel products, including low-smoke coal products, available on the market. Low-smoke solid fuel is cleaner as well as more carbon and heat efficient. It can help to deliver climate benefits as well as improved air quality and human health benefits. Under the Regulations all low-smoke solid fuel products must be clearly labelled in accordance with the Regulations. This allows householders to make an informed choice about the products they purchase.

The original ban in Dublin is now cited widely as a successful policy intervention within the international clean air community.

Source: Representatives of the city of Dublin.

To address one of the main sources of high PM emissions in urban areas — domestic combustion — in some cities the use of solid fuel for residential heating purposes has already been banned (e.g. Dublin, see Box 2.3, and Vienna in new installations that come into operation) or is planned to be banned in some cities (e.g. Malmö and Milan), particularly to reduce the high levels of air pollution in winter episodes. Such measures are considered highly effective in reducing PM emissions. For instance, reflecting that the share of solid fuel was only 5 % of total fuel burned but the source of 50 % of PM emissions in Dublin, national legislation was drafted to ban bituminous coal for residential heating, which is a good example of the importance of enabling effective national legislation to enable certain measures to be implemented at local level. In contrast, wood burning in other cities is still a problematic local issue (e.g. Antwerp, Berlin and Milan), as it contributes considerably to PM emissions.

Road transport is still the most important local source of pollution in cities, particularly with regard to NO_2 but it also contributes to PM_{10} pollution. Additional short- and long-term measures described by the cities aim mostly to reduce road transport emissions, including not only exhaust emissions from vehicles but also road dust and dust due to tyre and brake wear. Planned measures also include more ambitious low-emission zones, such as Madrid's 'central priority area', hardware and software retrofitting and banning of some or all diesel vehicles.

Many of the city representatives pointed out that the fact that the real-world emissions are higher than those in the type-approval test cycles has contributed to NO_2 concentrations in most of the cities not decreasing as much as should have been expected. This has also reduced the effectiveness of certain introduced abatement measures on motor technology and traffic volumes (e.g. in Berlin and Paris). Vehicle technological developments and emission control technologies driven by the introduction of increasingly stringent carbon dioxide (CO_2) and Euro standards have significantly reduced CO_2 and PM emissions but not nitrogen oxides (NO_x) emissions from vehicles, especially those fuelled by diesel.

Emission sectors that require ongoing action (e.g. road traffic, residential combustion) are addressed by ongoing measures in all of the participating cities, although domestic wood burning fires and stoves for recreational purposes were specifically identified as an emerging source in the city in Paris. Regional-scale transport of pollutants is also identified as a source of urban $PM_{2.5}$ in Milan (from agriculture) and Vienna (from wood burning in neighbouring countries). Agriculture is a relevant source of secondary PM in other cities too (e.g. Paris, Antwerp), although it is not targeted by dedicated mitigation strategies at the urban scale.

It is noteworthy that a number of the cities are also increasingly introducing measures to address emissions from certain sectors, such as construction and inland shipping, that previously may have been overlooked or not prioritised compared with those traditionally responsible for a large share of emissions, e.g. road transport, residential combustion. In particular, representatives from several cities (Antwerp, Berlin, Prague, Vienna) express significant concerns in terms of air quality impacts from growing inland shipping activities (mainly due to tourism), the lack of strict emission standards for these significant emitters and the fact that ships are at times allowed into areas of the cities that are sensitive to negative impacts on air quality, sometimes including even inside designated low-emission zones for road transport. Construction/demolition works are also highlighted as increasing emission sources, particularly in growing cities such as Berlin and Vienna.

2.6.3 Implementation status of measures

Previously implemented measures

An analysis of the implementation status of the measures specified by cities 5 years ago in the Air Implementation Pilot project show that most of these measures are still being implemented (Figure 2.8), and a number of additional measures are planned for future implementation across the participating cities.

To reduce transport emissions, many cities are promoting cycling and establishing a bike-friendly infrastructure, i.e. increased public space for bicycles and public transport (bike lanes and bike lane networks). Some cities have introduced public (electric) bike rental and bike-sharing systems (e.g. Milan). Vienna, for instance, has introduced economic initiatives for public transport, and in general there is increased investment in the greenest modes of public transport across the participating cities.

One of the most widely implemented measures on road transport is low-emission zones, and they are considered to have reduced transport emissions in cities so far, especially for traffic-related soot particles and PM_{10} concentrations (e.g. in Milan and Berlin) (although, as noted above, the effectiveness of low-emission zones in reducing NO_2 emissions has at least been partly offset by the (much) higher than expected levels emitted by diesel vehicles under real-world driving conditions). The majority of the cities have currently implemented or plan to introduce low-emission zones in their most densely populated urban areas.

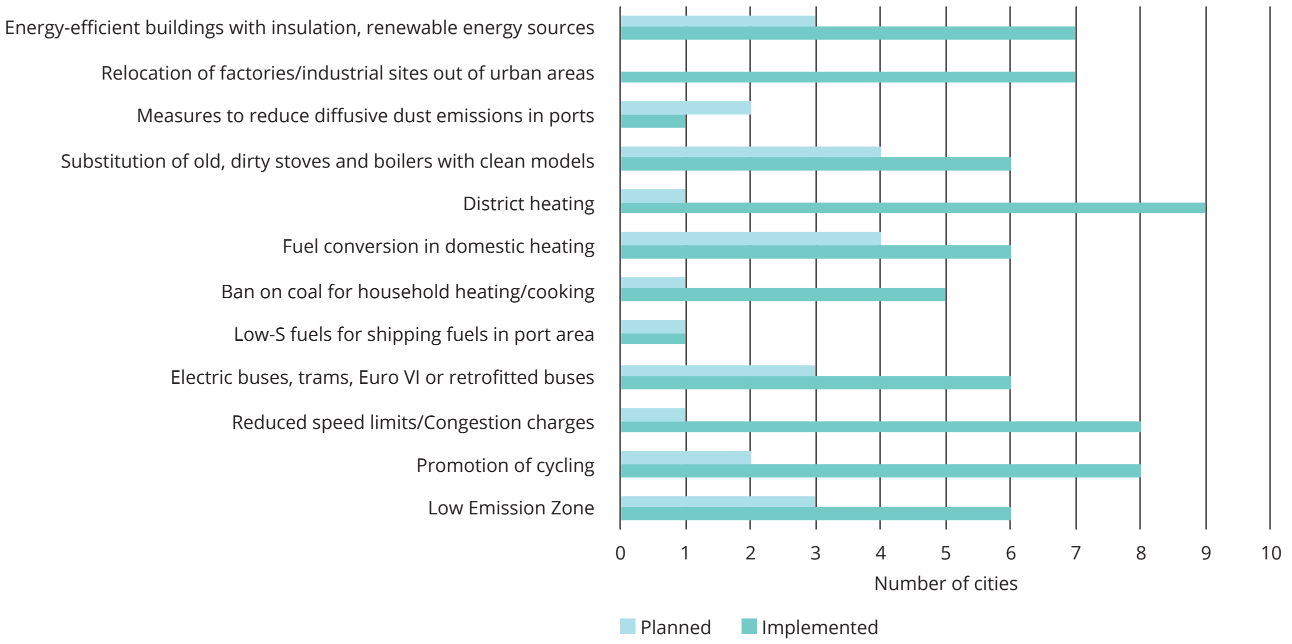
Several cities have introduced technological improvements such as retrofitting and promoting e-mobility. Examples are retrofitting programmes for municipal heavy-duty vehicles, especially for Euro V refuse trucks (Berlin), and introducing electric buses and e-bikes (Berlin, Paris and Vienna).

The main emission sources targeted in the past and at present also include industrial emissions (measures applied by all cities, e.g. relocating industrial facilities), as well as residential heating (nine cities, e.g. district heating infrastructures) and road traffic (nine cities, e.g. via strategies such as introducing lower speed limits or congestion charges). The overall number of measures reported by cities was largest for those addressing road traffic and urban mobility.

Recently implemented and future measures

Figure 2.8 shows a number of additional measures being planned for future implementation across the participating cities. When looking to the future, planned measures still largely address urban mobility with, for example, low-emission zones, promoting traffic restrictions and electric mobility (in buses, trams) and retrofitting of existing vehicles. Residential heating remains a concern for the cities, with measures mainly targeting polluting stoves and boilers (through stricter emission standards) and their substitution by clean alternatives (more natural gas and district heating). Table 2.1 provides an overview of short- and long-term implemented and planned measures in each city.

Figure 2.8 Examples of the main air quality measures in place and planned



Transport and mobility

Cities are complementing the above-mentioned measures that address road traffic and mobility with sustainable transport policies based on urban development plans. These aim to, for example, support environmentally friendly transport modes and optimise traffic management to integrate the mobility requirements of growing cities in a healthy and sustainable manner. All cities are investing more in public transport and bike lanes.

Construction and inland shipping

Berlin has introduced emission criteria to its public procurement of construction machinery by requiring machinery to comply with the latest EU particle emission standard and by retrofitting older non-road machinery with diesel particle filters to reduce their contribution to local PM levels in the city centre.

Concerning air pollutant emissions from shipping, Berlin has also set emission criteria for cruise ships and required retrofitting of inland cruise ships with diesel particle filters.

Exposure of vulnerable population groups

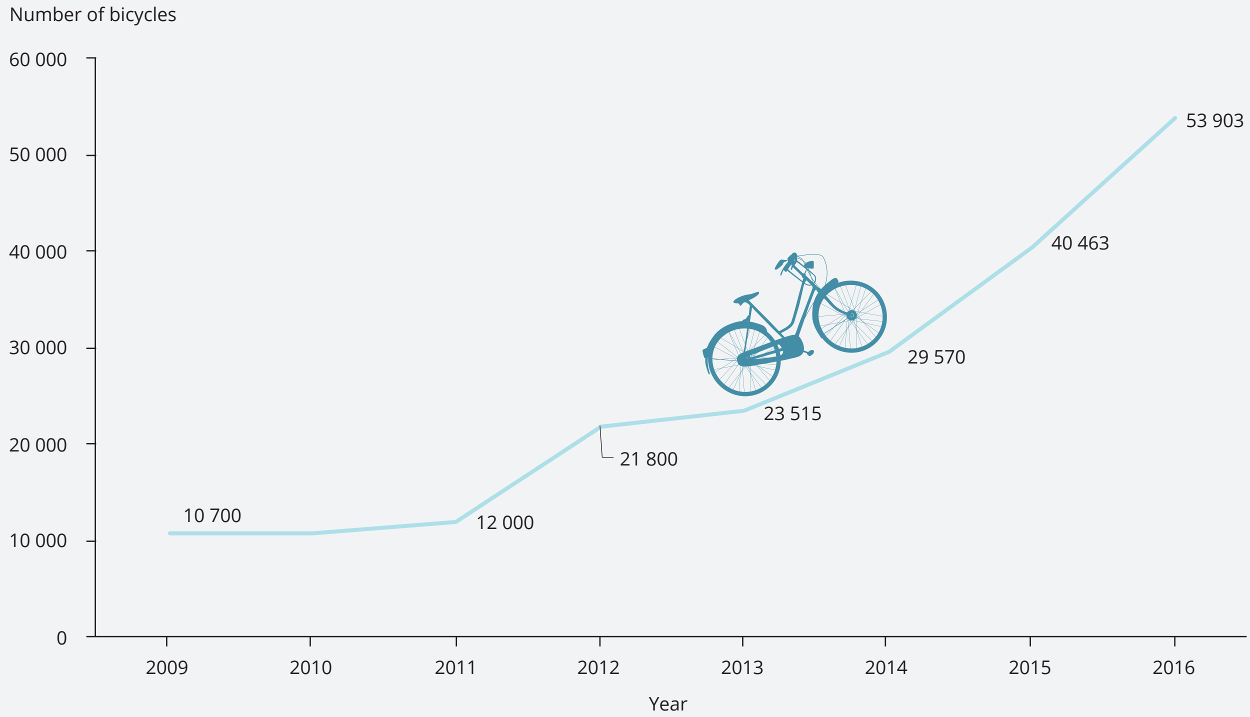
Although an adaptation measure rather than mitigation measure, specific cities are acting to protect the public, especially vulnerable groups, against air pollution. Some cities (e.g. Antwerp and Malmö) have non-regulatory measures (considering air quality issues in decisions about the location of schools), targeting not the emission source but the exposure of the public, to reduce the exposure of sensitive groups (particularly children) to air pollution. Antwerp, Malmö and Paris (only for indoor air quality) implement specific plans to reduce exposure to poor air quality. In Berlin and Vienna, environmental assessment studies are required before new schools can be built.

Furthermore, cities such as Paris and Vienna have put effort into reducing the general public's exposure to air pollution through urban space management and forward-looking urban planning, including the public transport infrastructure, at the earliest stages of urban development (constructing roads for cyclists and pedestrians or putting restrictions on the constructing flats in the lower floors of apartment buildings or having the main windows of flats oriented away from the main roads in Vienna). Additional urban planning strategies are implemented in Paris.

Box 2.4 Side effects of congestion charging in Milan — increased bike sharing

In central Milan, a EUR 5 Area C congestion charge must be paid to enter the city centre in a car. Pre-Euro 4 diesel cars are not permitted in any case. One, perhaps unintended, side effect of introducing the congestion charging scheme is linked to the decrease in traffic in the city centre (down 30 %, as estimated by Milan municipality). The reduction in traffic volumes is being linked to a significant increase in the use of bicycles in the city, as demonstrated by the increase in subscribers to the public bike-sharing service in Milan (available to users at a cost of EUR 36 per year). BikeMe subscribers increased from 10 700 in 2009 to around 54 000 active users in 2016, with around 20 000 rentals every day. The bike-sharing service has been further developed by the recent introduction of two private companies, which offer bicycles not at fixed points, as for BikeMe, but with the potential to pick up and leave them everywhere (using an app). Other initiatives being taken to promote cycling and the use of alternative mobility modes include an increase in bike routes (from 28 km to 167 km, with further increases planned) and private car-sharing schemes, which at the end of 2016 included 334 903 subscribers. The car sharing has benefited from incentives including free admission to Area C and allowing free parking of cars in public car parks in which there is normally a charge.

Figure 2.9 Bike-sharing in Milan



Source: Representatives of the city of Milan.

Table 2.1 Review of participating cities' implemented and planned measures

City	Emission source addressed	Measure
Antwerp	Road emissions	• Low-emission zone • Bike and car sharing • Speed limited to 30 km/h • City bike projects, with a higher number of rides per day than the number of inhabitants • Installing electric charging stations for electric vehicles
	Non-source targeted measures (urban planning)	• Use of a planning tool for vulnerable groups to decide on location of schools as a function of NO_2 concentration levels • Greening the city
	Shipping emissions	• Onshore power supply in the port area
Berlin	Domestic heating	• Stricter local emission standards for small solid fuel combustion appliances • Enforcement and wide application of the existing legislation on the restriction on new small solid fuel heating systems in the city centre • Extending the use of natural gas/district heating
	Road emissions	• Retrofitting programme for municipal heavy-duty vehicles, especially for Euro V garbage trucks and Euro 4/5 diesel buses • Shift to clean transport modes (e-bikes and electric buses) • Ban on heavily NO_2 polluting diesel cars • Low-emission zones with stricter strategies that meet certain emission standards
	Off-road emissions	• Setting emission criteria in public procurement of construction machinery by requiring machinery to comply with the latest EU particle emission standard or by retrofitting with diesel particle filters
	Shipping emissions	• Setting emission criteria for cruise ships or retrofitting of inland cruise ships with diesel particle filters
Dublin	Road emissions	• Promoting the use of public transport via two new light rail lines
Madrid	Road emissions	• Restricting the traffic on alternate days according to odd-even licence plates for smog episodes (short-term measure) • Central priority area integrating climate and mobility measures (park and ride, speed limits, dedicated platform for buses, plan to limit access to all diesel cars by 2025)
Malmö	Road emissions	• Introducing hybrid buses (short-term action plan for NO_2)
	Non-source targeted measures (urban planning)	• New day-care centres (for 1- to 6-year-old children) are not allowed to be built in areas that do not comply with national goals for 2020
Milan	Domestic heating	• Promoting energy-efficient stoves • Classification system for stoves • Ban on non-ecodesign stoves
	Road emissions	• Access restrictions for Euro 4 and Euro 5 vehicles in all urban areas with greater than 30 000 inhabitants and a plan to restrict access for Euro 4 vehicles in all conurbations by 2020 • Decrease in highway speed limits • Improved public transport • Congestion charge • Low-emission zone • Bike and car sharing

Table 2.1 Review of participating cities' implemented and planned measures (cont.)

City	Emission source addressed	Measure
Paris	Domestic heating	• Fossil fuel free city by 2030
	Road emissions	• Ambitious cycling plan • Low-emission zone (currently access restrictions for Euro 1 and Euro 2 vehicles, plan to limit access of all diesel cars by 2024) also included in the climate plan • Potential to enlarge the low-emission zone to other regions • Car-free days (on Sundays) • Vehicle access restrictions in city centre • Economic initiatives for use of electric cars, giving up old diesel cars, collective bike park
	Non-source targeted measures (urban planning, innovation, financial)	• Rebalancing public space • Creating places for air quality innovations to be public (AirLab) with Airparif
Plovdiv	Domestic heating	• Ban on marketing, sale and distribution of bituminous coal for household heating/cooking • Fuel conversion in domestic heating • Promoting substitution of old, dirty stoves and boilers with clean models • Energy-efficient buildings with insulation • Use of renewable energy sources
	Road emissions	• Low-emission zone • Promoting cycling • Managing traffic flow by reduced speed limits and congestion charges
Prague	Domestic heating	• Local and national subsidies for the exchange of old boilers • Only renewable sources allowed in new buildings
	Road emissions	• Low-emission zone planned • Promoting public transport by incentives, priority lanes (bus, taxi, bike) and traffic lights for trams • Integrating regional and city public transport • New park-and-ride schemes • Parking zones • Speed limited to 30 km/h • Support for electric cars (favourable parking prices in the centre) • Support for cycling and pedestrians (new bike lanes and pedestrian zones) • Car sharing (only electric cars) and bike-sharing schemes
Vienna	Road emissions	• Low-emission zone for heavy-duty vehicles • Promoting public transport (low prices and well linked with railways) • Cycling infrastructure and pedestrian zones • Speed limits reduced from 50 to 30 km/h • Parking space management • Salting roads instead of using sand in winter (also decreasing the amount of salt from 130 000 tonnes in 1996 to 100 tonnes in 2017) • Economic initiatives for using public transport
	Non-source targeted measures (urban planning)	• Integrating Sustainable Development Goals into a smart city approach considering quality of life, resources and innovation

Public awareness raising

All cities undertake communication and public awareness-raising activities, often with measures specifically designed to increase public awareness and engagement with citizens. Further examples of such measures are provided in Section 2.7.

2.6.4 Quantifying the costs and effects of measures

Some of the deficiencies identified in previous work streams have implications for air quality that carry over: improving inventories and modelling tools, for instance, would better enable cities to assess which of their measures are most effective in improving air quality.

Criteria commonly used to judge the effectiveness of a measure (*ex ante* or *ex post*) include:

- the estimated effectiveness of the measure to reduce emissions and improve air quality, particularly where the public is exposed to high levels of pollutants;
- the ease of implementation, which affects the timescale and cost for the delivery of the measure; and
- resource requirements that impact on the cost of the measure.

The characteristics of ease of implementation are applicability (contributing to the strategic objective of improving air quality), appropriateness (providing overall benefit in both environmental and economic terms), attractiveness (acceptability to the public), affordability (appropriate budgets need to be available for the measures to be implemented) and achievability (enforcement powers and other practical considerations are understood and in place).

Past situation

A common theme that emerged from all cities during the Air Implementation Pilot project in 2013 concerned how best to define and assess the effects of abatement measures, including how to manage uncertainty regarding the costs and benefits of measures. It was noted that public and political awareness are strongly dependent on the communication of air quality messages, which are more effective when they are supported by quantitative estimates of the costs and benefits of the measures.

Current situation

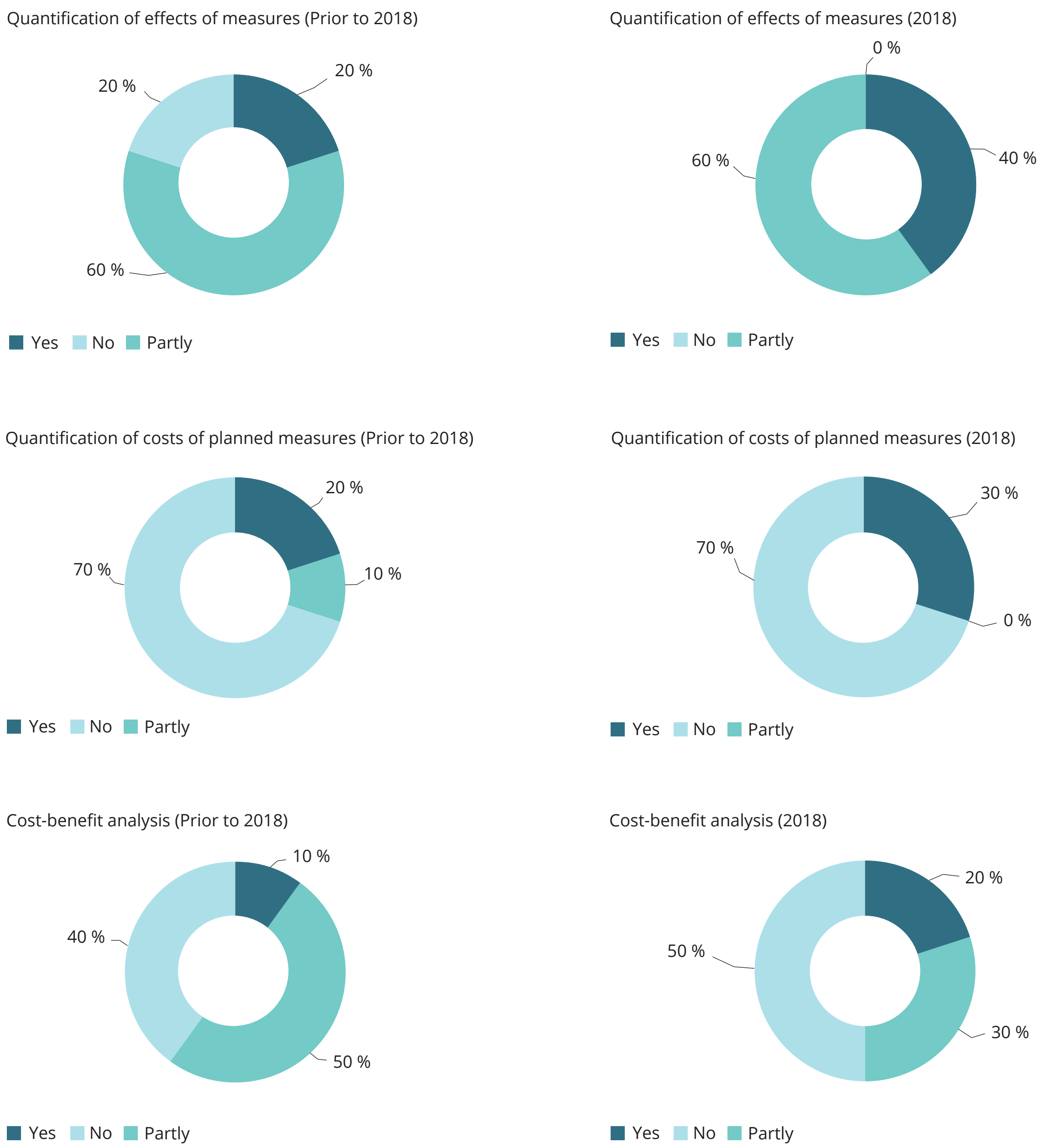
Participating city representatives still consider that public and political awareness of air quality management issues are more effective when they are supported by quantified information on the costs and benefits of measures. However, this kind of quantification is at present not fully carried out by all the cities consulted (Figure 2.12). The need for cost-benefit analyses is considered different in each city: whereas in certain regions the general public is happy to comply with air quality measures and regulations, and does not need additional justification, in others it is necessary to highlight the benefits, and more specifically the economic benefits, to engage the public in air quality improvement activities. When addressing the policymaking community, on the other hand, cost-benefit analyses are always considered an asset. Understanding and communicating co-benefits is also considered a key tool to engage both the public and policymakers, for example the air quality, noise, climate and health co-benefits of cleaner urban mobility solutions (in the case of Madrid).

When assessing the causes of the current absence of quantitative cost-benefit analyses in the cities, the main reasons found are the cities' limited experience with this kind of assessment and the lack of simple, comparable and easy-to-use methodologies/tools. Quantifying the effects of (proposed) air quality measures can be complex because of uncertainties in modelling input data and results, confounding factors such as meteorology, urban topography, costs, etc. However, within the participating cities, successful examples may already be found for specific measures in cities such as Berlin (e.g. quantifying the air quality improvement due to the low-emission zone and to reduced speed limits in Berlin's Clean Air Plan 2011-2017; see Box 2.5).

The uncertainties related to using models make them mainly suited to assessing relative trends, not absolute changes in air pollutant concentrations. Estimating health benefits (e.g. premature mortality or disability-adjusted life-years avoided) is useful for the cities to estimate the effectiveness of measures in terms of their relative benefits. The cities would really value expertise and tools to provide scenario analyses describing air quality improvements resulting from specific air quality measures and the consequent health benefits (e.g. Malmqvist et al., 2018 in Box 2.6).

In most cases, the impact of the measures on air quality is assessed using mesoscale Eulerian air quality models.

Figure 2.10 The share of participating cities assessing quantitatively the effects of measures (top), the costs of these measures (centre) and overall cost-benefit analyses (bottom) prior to 2018 (left) and in 2018 (right).



Box 2.5 Quantifying the impacts of various potential traffic measures to reduce NO_2 in Berlin

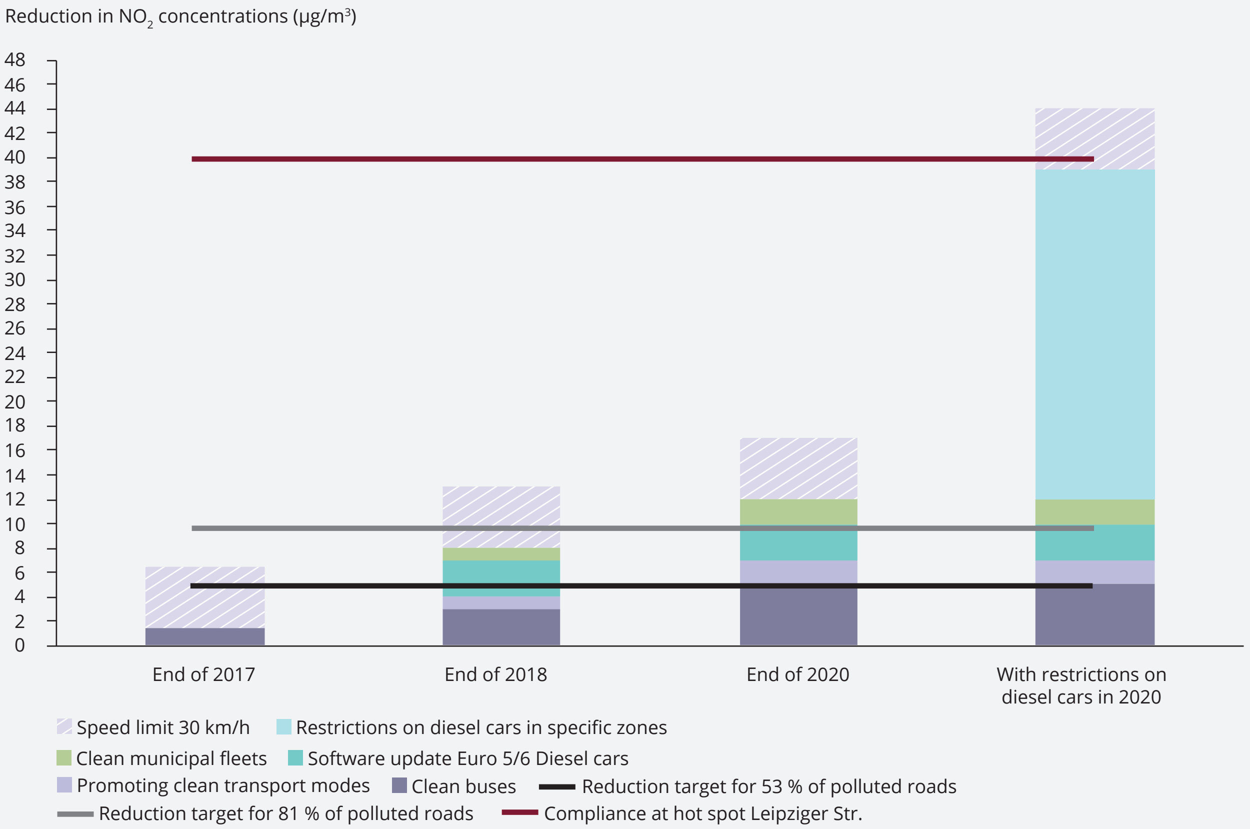
Over recent years, the effects of various implemented and potential traffic measures in Berlin have been explored using monitoring data (both continuous and indicative measurements), emission analysis, urban indicators (e.g. vehicle fleet composition) and modelling tools.

In 2015, the share of diesel cars in Berlin's total fleet composition was 37 %. NO_2 concentrations in Berlin had already been reduced by around 6-8 µg/m³ with the current measures (i.e. use of clean buses and introducing a speed limit of 30 km/h on certain streets — a measure brought in to also reduce night-time noise).

According to the scenario analysis of the effect of various possible measures on transport, further reductions in NO_2 concentrations can be achieved in Berlin. Short-term measures, such as a maximum speed of 30 km/h, developing and promoting bike routes, retrofitted buses and parking management, are considered helpful within the short timeframe until 2020, based on the experiences of other German cities, notably Stuttgart and Hamburg.

It is estimated that hardware retrofitting in relevant vehicles can bring an approximately 10-20 % reduction in NO_x emissions from road traffic. Euro 6a-c passenger vehicles have the necessary hardware to ensure lower real-world driving emissions but may require an update to their operating software. Heavy-duty vehicles with Euro 6 technology are already considered to have low real-world driving emissions, whereas Euro 4 and Euro 5 heavy-duty vehicles need a hardware retrofit to reduce NO_2 emissions. Light-duty vehicles and cars, which have high real-world driving emissions, can achieve a 70-90 % reduction in NO_2 emissions, and the cost of the retrofitting is EUR 1 500-3 000 per vehicle, which may be considered cost-effective for newer vehicles, e.g. Euro 5 cars. Overall, hardware retrofitting is estimated to contribute to delivering potential reductions of up to 26 µg/m³ by the end of 2020. A hypothetical restriction on diesel cars in specific zones by 2020 in the city would contribute to a total estimated reduction of up to 44 µg/m³ in NO_2 concentrations.

Figure 2.11 Modelled reduction in NO_2 concentration measures in Berlin



Note: Heavy-duty vehicles (HDVs) comprise trucks, buses and coaches. HDVs are defined as freight vehicles of more than 3.5 tonnes (trucks) or passenger transport vehicles of more than eight seats (buses and coaches). The HDV fleet is very heterogeneous, with vehicles that have different uses and drive cycles. Light-duty vehicles comprise cars and vans.

Source: Representatives of the city of Berlin.

Box 2.6 Scenario analysis of exhaust-free transport linked to health benefits in Malmö

The study aimed to estimate the health impacts attributable to a hypothetical decrease in air pollution concentrations in the city of Malmö in southern Sweden, corresponding to a policy that would ensure road transport without the exhaust emissions in the city centre. Air pollution data were modelled and used to calculate NO_x and $PM_{2.5}$ concentrations in Malmö. The modelling results indicate that fewer people would die prematurely (2-4 % of all premature deaths), there would be fewer asthma incidents (6 %) in children and fewer children would suffer from bronchitis (10 %) each year (Malmqvist et al., 2018).

Source: Representatives of the city of Malmö.

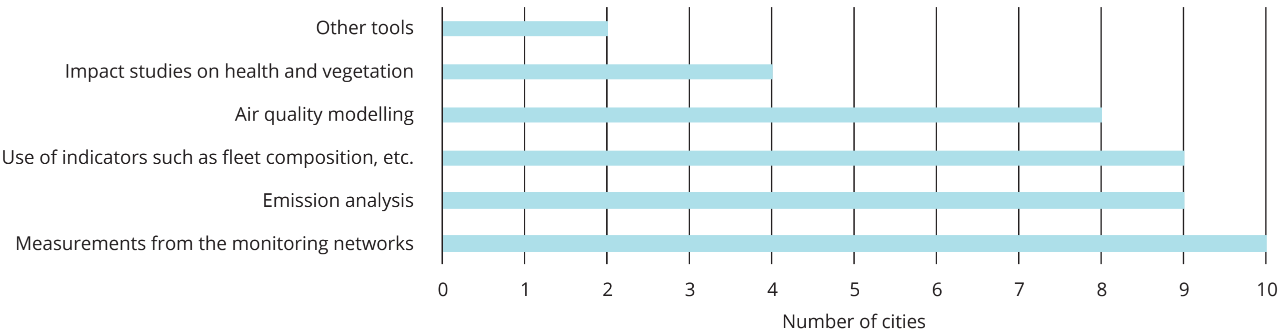
Despite the satisfactory performance of these models, the cities identified weaknesses at the urban scale. For example, strong concentration gradients of NO_2, usually associated with high road traffic flows, cannot be reproduced by these models, since there are typically large concentration variations within a single grid cell. To determine street-level concentration gradients, local-scale tools are needed, either high-resolution flow models that consider the buildings or street canyon models that are able to capture this local variability.

The results in Figure 2.10 show that, although the majority of the cities consulted do not yet carry out cost-benefit analyses (quantification of costs, quantification of benefits and cost-benefit analysis), the number of cities implementing these analyses is higher in 2018 than it was in 2013. In relative terms, the increase is greater for the number of cities quantifying the effects of measures than for those quantifying the cost of measures or carrying out cost-benefit analysis. The tools most frequently used to quantify the effects of measures are shown in Figure 2.12.

2.7 Giving information to the public

The EU AAQDs (Article 26 in Directive 2008/50/EC (EU, 2008) and Article 7 in Directive 2004/107/EC (EU, 2004)) require that Member States must ensure that a variety of information on air quality is made available to the public. This includes information on ambient levels of air quality, air quality plans and details of competent authorities. In addition, Directive 2008/50/EC requires Member States to provide information to the public regarding exceedances of alert thresholds, the content and implementation of short-term plans and exceedances of thresholds in relation to transboundary air pollution (Articles 19, 24.3 and 25, respectively). For most participating cities, these obligations fall on the local administrations, but in some they are the responsibility of regional authorities or of organisations mandated with this obligation.

Figure 2.12 Tools used by the cities to estimate the effects of measures, and the number of cities applying each of them



2.7.1 Past situation

With regard to providing information to the public, the Air Implementation Pilot project of 2013 showed that, by and large, the air quality information that is required by legislation to be made public was being promptly provided by the cities to the public, mostly through dedicated air quality internet sites. In general, the cities did not then use public media, social media websites or new technologies such as smartphone applications, or apps, efficiently. Most of the participating cities lacked feedback on their citizens' interest in air quality issues. In 2013, the most common way of providing information was through the internet, on dedicated web pages, often using annual reports but also daily or monthly reports or bulletins. Traditional mass media were less often used, and mainly to issue alerts of high pollutant levels. Two cities were using SMS warning systems.

There was thus potential for the cities to raise the profile of air quality issues in the media and for them to further develop their smartphone use and social media presences. In this context, one potential need flagged up during the 2013 pilot project was for the adoption of a common Europe-wide index for air quality, using the same colour codes to aid comprehension, which would also help make air quality information comparable across Europe ([1]).

2.7.2 Current situation

In a recent public opinion survey on the attitudes of the public towards the environment carried out in the 28 EU Member States, air pollution (46 %) was cited as the issue of most concern for the public after climate change (51 %), and a relative majority (47 %) of Europeans thought that air quality has deteriorated in the previous 10 years. They have legitimate expectations that effective action will be taken at all levels to reduce air pollution and protect them from its harmful effects. In short, public awareness about air pollution has increased in cities across Europe because the air quality issue is currently one of citizens' highest priorities (EC, 2017).

In 2018, 5 of the 10 participating cities had not changed their information strategy in the last 5 years. All cities continue to use either their own websites or those of the monitoring network (seven use both) to publicly communicate information on air quality. However, all cities use at least two different communication channels, and one (Vienna) uses five different channels (website on monitoring network and institutions, smartphone apps and social media, bulletins and billboards, telephone service, open governance data and teletext). One new challenge has emerged, identified by three cities: how best to get feedback on the different information and communication channels being provided, e.g. by using low-cost sensors.

The same main communication challenges identified in 2013 remain in 2018. These are related to how to best present air quality issues in the general media (six cities), using smartphone apps and social media (four cities) and adopting a common system of indicators. The perceived difficulty of providing information to the public in an understandable way remains. Several cities commented on the need to increase public awareness of air quality and knowledge of the common sources of air pollutants, such as

([1]) A European Air Quality Index has since been implemented by EEA: http://airindex.eea.europa.eu domestic heating or transport, and of behavioural change, such as the correct use of stoves, the importance of open fires as a source of air pollution and correct driving habits. However, as public awareness has increased, citizens have started to expect authorities to act to improve urban air quality.

There remain important challenges for city administrations on how to best communicate the introduction of certain measures in cities that may not always find favour with the public, such as introducing or maintaining traffic restrictions in polluted cities through congestion charges, low-emission zones and access restrictions. The participating cities considered in such instances that there is a strong need to raise awareness of the negative health effects of pollutants and the measures taken to reduce them. Highlighting the positive effects on health associated with introducing a measure offers clear opportunities to achieve greater public acceptance.

In contrast, some measures promoted to the public to reduce their exposure to air pollution depend on common knowledge, such as not jogging along a busy road and not opening the windows during rush hour if living near a busy road.

Giving more information to the public on the health and environmental consequences of air pollution raises awareness of the positive effects of transport modes other than cars on air quality and health. Events such as the European Mobility Week campaign, often culminating in a car-free day in some of the participating cities, have proved to be a useful tool to raise awareness of the benefits of clean air on health by promoting walking, cycling and using public transport.

The cities are nevertheless trying to find new ways to improve air quality and bring in new ideas, skills and resources to achieve better solutions. To take one example, initiated by Airparif (Paris) and partners, AirLab is building a user community to improve air quality by bringing companies, research institutes, public bodies and individuals together. Some cities, such as Paris and Antwerp, have also, for example, created space for citizens to test new technologies (such as sensors) and coordinate air quality innovations through public initiatives, such as AirLab in Paris and StadsLab2050 in Antwerp, which have set up air laboratories to facilitate and coordinate innovation, working together with researchers, urban planners and sociologists. This allows teams to take a multidisciplinary approach to testing mitigation strategies, helping to bring air quality issues closer to society and to foster the implementation of creative solutions.

The increasing availability and popularity of low-cost air quality sensors that can be used in citizen science monitoring campaigns bring a number of communication challenges for city air quality practitioners. Low-cost sensors offer air pollution monitoring at a lower cost than conventional methods and make air quality monitoring for air quality assessment purposes possible in many more locations, including estimates from traffic, personal exposure and health assessment, and in networks contributing to citizen science initiatives. Overall, increasing public engagement on air quality issues through citizen science projects, e.g. in Antwerp and Madrid, is considered to be good practice in terms of communication and increasing public awareness. Such initiatives can clearly be very successful tools for raising public awareness and, hence, that of policymaking communities. However, measurements from low-cost sensors are often of questionable quality compared with the results from traditional (static) monitoring stations used by local authorities. The difficulties, in terms of the time and staff resources required, of reconciling and communicating the reasons for differences between official monitoring results and those obtained by low-cost sensors used by the public are expected to be an increasing challenge in the future.

Regarding communication strategies, air quality information is still being provided by all the cities to the public, mostly through dedicated air quality internet sites. All cities still have challenges in terms of presenting air quality information to the public in the media and/or on using smartphone apps and social media. Professional communications support to develop a targeted media communication strategy is planned in some of the participating pilot cities e.g. in Berlin. All cities are continuing to make efforts to increase public awareness of air pollution issues, to avoid misinformation and to improve the information systems alerting the public to pollution episodes in real time. Some cities, such as Madrid, Milan, Paris and Vienna, use social media and/or smartphone apps to communicate air quality issues. Currently, public awareness of air quality is considered much higher than it was in 2013, and air quality issues have begun to find more room in local and national media than they did 5 years ago.

3 Summary: ongoing challenges for air quality management

The first part of this chapter describes the main ongoing challenges during the implementation of urban-scale air quality measures that were identified by the participating city representatives during the course of this update to the 2013 Air Implementation Pilot project. The second section of the chapter presents corresponding selected actions and identified needs for guidance.

3.1 Challenges

Figure 3.1 shows that the main challenges identified by city representatives during the implementation of air quality measures were legal or financial aspects or those arising from public opposition.

3.1.1 Administrative competences

These refer mainly to issues of administrative competences across different governance levels and therefore to collaboration between local, regional and national authorities. Some city representatives highlighted the challenges associated with taking proactive measures to improve air quality in situations where political support and/or resources from national governments may not be as ambitious. It was pointed out that the lack of coordination between national and local action planning can undermine local efforts to achieve air quality standards.

In addition to an occasional lack of coordination between local, regional and national authorities, the perceived failure of certain EU and Member State policies to reduce emissions was given as an important reason for continuing nitrogen dioxide (NO_2) limit value exceedances, as implementing such policies is not within the mandate of city authorities. One example concerns the EU light-duty vehicle type approval tests and Euro standards to reduce real-world emissions of nitrogen oxides (NO_x). The city representatives consider that the perceived failure of these policies to deliver real-world reductions in NO_2 emissions effectively undermines many of their actions to improve local air quality, resulting in delays in achieving the standards and inefficient use of resources at local and national levels.

Linked to administrative competences, and specifically for implementing legislation, effective collaboration between administrations is still seen as a key issue (Figure 3.2). This can be due to issues of competence in applying regulations and other legal instruments, for example in the case of the contribution of long-range transported pollution to urban air quality in which mitigation strategies must be implemented at international, national or regional scale to address emission sources such as agriculture and pollutants subject to long-range transport such as ozone and secondary inorganic aerosols. Another challenge linked to cooperation is that of ensuring coherent public information and the need for short-term measures during smog episodes, which may, for example, affect a city but not a whole region.

3.1.2 Financial mechanisms

Access to financial and fiscal measures to support citizen incentives or subsidies is also considered key to ensuring the uptake of new cleaner technologies at the local scale, e.g. for important emissions sources such as cleaner vehicles and domestic wood-burning appliances.

3.1.3 Public acceptance

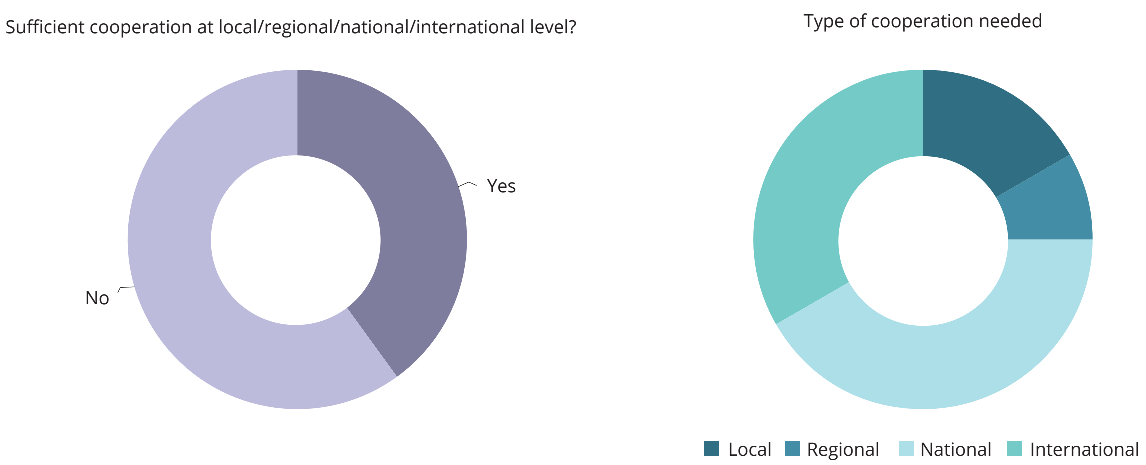
This refers to challenges in awareness raising and in overcoming opposition to specific mitigation measures either proposed for implementation or already in place.

3.1.4 Technological challenges

For example, several cities (Berlin, Madrid, Milan) highlighted the need for better modelling tools for forecasting periodic NO_2 peaks, given that the emissions that give rise to NO_2 peak concentrations (in the evening) are generated throughout the day, and for dealing with the small-scale spatial variations in NO_2 levels near emission sources (Vienna), as concentrations vary greatly within metres of the kerbside. Another challenge is the maintenance, and responsibility for enforcement, of low-emission

Figure 3.1 Relevance of challenges encountered by the cities during the implementation of air quality measures

Figure 3.2 Cooperation between the various administrative levels



vehicles (e.g. buses), as fraudulent practices have been detected that compromise their low-emission efficiency (e.g. tampering with exhaust filters).

3.1.5 Political stability/political support

Changes in governments often lead to the withdrawal or delay of mitigation strategies approved by previous policymakers. This is true in the case of a proposed ring road around Prague, which was approved but subsequently placed on hold. In contrast, strong political support for measures has had a positive influence on awareness raising among the public and subsequent acceptance.

3.1.6 Other challenges

Challenges such as a lack of human resources or technology and cultural aspects were seen by most city representatives as being rather less relevant.

In addition to the main challenges listed above, other specific challenges highlighted during discussions with the city representatives included aspects of managing real-world emissions from the road transport sector (see above), residential emissions and enforcing policy.

3.1.7 Residential emissions

Certain cities (e.g. Madrid, Milan and Prague) requested further guidance regarding the types of domestic stoves and boilers to be used or supported by incentives based on real-world emissions. They also highlighted that addressing social inequalities remains a challenge, given that cleaner but more expensive stoves may still be inaccessible for a large part of the population, even when subsidised. Furthermore, in certain cities (e.g. Milan), there are subsidies to substitute oil stoves (with relatively low air pollutant emissions) with wood eco-stoves (which aim to reduce their impact on climate change by using a renewable fuel source but which also result in higher air pollutant emissions). An integrated approach encompassing air quality and climate change concerns should be promoted to prevent this type of policy incoherence between climate- and air quality-oriented policies.

3.1.8 Policy enforcement

Legally enforcing certain introduced measures was highlighted by some participating city representatives as a specific implementation challenge. City representatives from Paris, for example, reported various challenges in enforcing low-emission zones

Box 3.1 Actions to decrease the impact of wood burning on air quality in the Lombardy region, Italy

Due to the adverse effects of topography and meteorological conditions on dispersion, high air pollution is frequently observed in the Lombardy region of Italy. It is estimated that wood burning is responsible for 47 % of the total PM_{10} emissions in Lombardy, and 23 % in Milan. Wood combustion for domestic heating is also the main source of benzo(a)pyrene (BaP) emissions.

Previous measures implemented include, since 2007, a ban on wood burning in stoves and fireplaces with a combustion efficiency less than 63 % or carbon monoxide (CO) emissions greater than 0.5 % (ref. 13 % oxygen) in all of the Po valley and in all metropolitan areas of the region. This ban has had only limited success.

Effective mitigation of this requires technological improvement of stoves and fireplaces. Consequently, a system of classification has been introduced based on emission standards of PM_{10}, nitrogen oxides (NO_x), CO and organic carbon. Better stoves in terms of lower emissions have more stars, and more polluting stoves have correspondingly fewer stars. Simultaneously, progressive limitations on installation have been introduced to guarantee that only high-performance stoves are installed.

During episodes of high levels of pollution, limitations were put on not only the installation of new stoves but also the use of older wood stoves. Additional rules have also been introduced to guarantee proper installation and maintenance of the stoves and the quality of pellets. It was important to have the collaboration of producers, who worked alongside the administration to provide information about certification and various limitations. A substantial communications programme is planned to inform the public about the importance of the correct use of wood-burning appliances (e.g. starting the fire from the top) and, in particular, about the importance of not burning the wrong sort of material (e.g. waste or burned wood) (ARPA Lombardia, 2018).

linked to recording licence plates to control access, while Milan reported challenges with enforcing underground injection of ammonia to reduce emissions due to agriculture in areas outside the city.

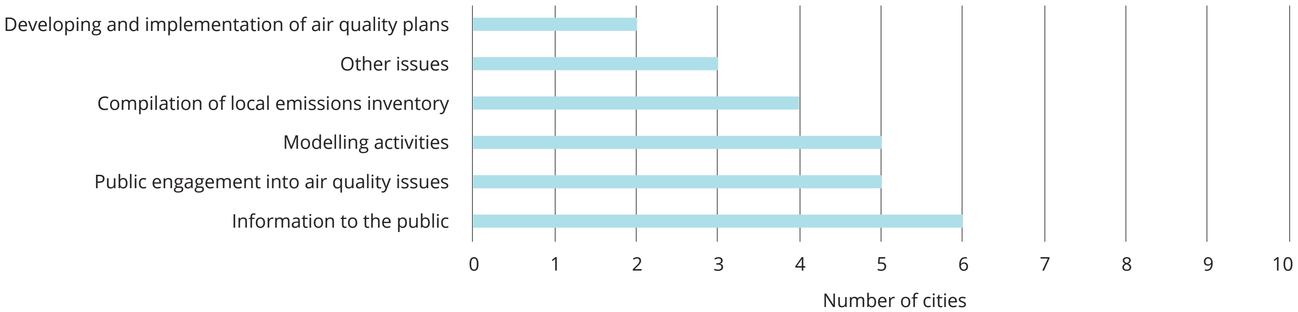
3.2 Further actions and guidance needs

In the light of the challenges described in the previous section, and drawing upon recent implementation experience over the previous 5 years, as noted in Chapter 2, city participants highlighted the need for a series of further measures and for more guidance. The main areas for which a need for continuing and/or further guidance was identified are shown in Figure 3.3.

3.2.1 Information to the public and public engagement on air quality

The main request for guidance in these areas refers to how best to communicate information on air quality to the public and ensure active engagement and interest from citizens. City air quality experts generally consider that they themselves lack the necessary expertise in communication and public engagement, and often their counterparts in municipal communication offices may also not have suitable expertise in communicating what is often very technically complex information. Air quality messages, which play a key role in ensuring citizens' engagement with and uptake of policies, therefore strongly benefit from input from specialists

Figure 3.3 The main areas identified by participating city representatives for which improved guidance is considered necessary



Box 3.2 Speed limitation to 30 km/h on main roads of cities

Reducing vehicle speeds/speed limits is a traffic management measure that can help in reducing both emissions of carbon dioxide (CO_2) and other air pollutants, as well as also potentially leading to significant co-benefits in urban areas in terms of reduced noise and potentially reduced severity of impacts arising from vehicle accidents. Particularly on motorways and highways, emissions of air pollutants such as NO_x and particulate matter can be reduced by reducing the applicable speed limits. In city streets, however, where traffic typically already moves at lower speeds, such measures may not be as effective, and in such instances it can be more useful to implement other measures to reduce the volume of traffic/congestion in order to reduce emissions.

As an example of speed-limiting measures, Berlin has implemented a speed limit of 30 km/h on several major roads by synchronising traffic lights. After introducing speed limits, traffic-related additional PM_{10} pollution decreased locally by up to 30 %, NO_x decreased by 18 % and NO_2 by 15 % (Senate Department for Urban Development and Environment, 2014).

Although reducing speed limits in city centres does not always have a significant impact on emissions, it can have an indirect effect on behavioural changes, as people prefer not to drive at low speed and they adopt other modes of transport such as cycling and walking (e.g. in Vienna) or they prefer to use faster public transport modes (e.g. in Paris). The other indirect impact is potentially ensuring smoother traffic flow with less stop/start traffic movements, which itself helps to reduce fuel consumption and also certain emissions.

experienced in working with air quality information. Opportunities to access external specialist expert support, as well as initiatives to share best practices and success stories of good communication campaigns that might subsequently be adapted for use in other cities, were therefore all considered important.

3.2.2 Modelling activities and local emission inventory developments

A second group of topics for which city representatives identified a need for further coordinated guidance concerned air quality modelling and compiling local emission inventories. In particular, all of the cities highlighted the need for guidance on how best to find information on and include real-world vehicle emissions in modelling. Examples of issues discussed included the real-world emissions of Euro 6d vehicles, difficulties in finding updated real-world emission factors for off-road vehicles (e.g. construction machinery), emissions of volatile organic compounds from petrol vehicles under real-world driving conditions, and detailed information on the reliability of current modelling tools (e.g. GAINS (**G**reenhouse Gas-**A**ir Pollution **In**teractions and **S**ynergies) and Copert (**Co**mputer **P**rogramme to calculate the **E**missions from **R**oad **T**ransport) models). These issues are considered important given the need for robust information to properly design and estimate the future impacts of possible measures addressing the transport sector in cities, e.g. access limitations for older generation vehicles and retrofitting existing vehicles.

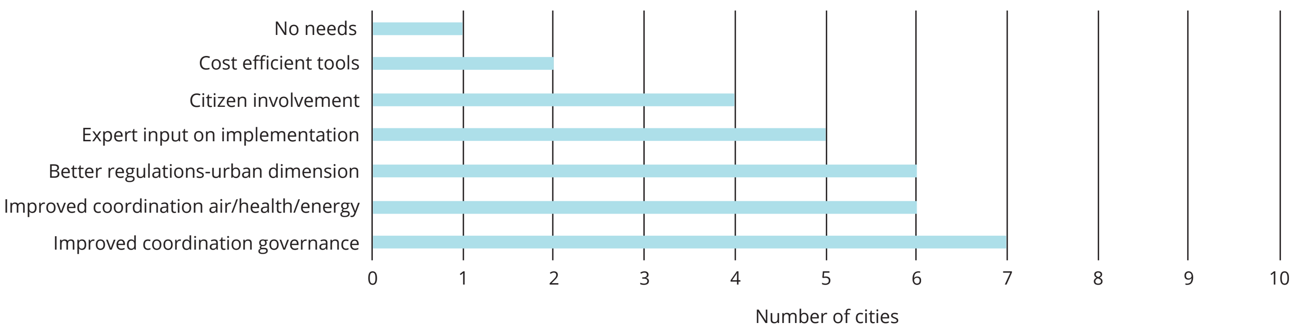
3.2.3 Other issues and topics

Finally, Figure 3.4 shows a variety of other specific needs for guidance and capacity and measures to be strengthened that were identified by the city representatives. A number of the participating cities highlighted the need for better guidance on the use of cost-benefit analysis tools (emissions, modelling, health impact analysis) and public communication (e.g. how to effectively communicate complex information, as discussed earlier, as well as on specific issues, e.g. the appropriateness of citizen science air quality sensor measurements) and how to best coordinate measures on air quality with other measures addressing, for example, local climate change mitigation and energy measures, noise and health, and well-being.

The need for improved collaboration and coherence of action across different administrative levels was again highlighted as an area requiring further improvement, as it was in the 2013 Air Implementation Pilot project, as well as greater clarity in defining responsibilities at city level and access to expert input for selecting and implementing specific mitigation measures.

The category of 'better regulation' largely refers to a perceived implementation gap concerning the enforcement of certain EU and national requirements that lie outside the competency of local authorities to define and manage. This includes the issue of real-world driving emissions, highlighted earlier in this report, for which vehicle standards are agreed

Figure 3.4 Other specific identified guidance and capacity needs



at EU level. However, much higher than anticipated real-world driving emissions, especially of NO_2, have arguably led to reduced effectiveness of measures limiting vehicle access in city areas. In some instances, the city participants stressed the usefulness of introducing EU legislation, including stricter product standards, as tools that can help drive lower emissions at the local scale. However, in other cases the opposite perspective was put forward, namely that simplifying some EU and national regulations would be helpful, e.g. in the case of off-road machinery. Complex text formulations and numerous exemptions in the regulations are sometimes perceived to limit their effectiveness once measures are implemented by air quality managers. EU regulation is also sometimes considered to hinder local initiatives for city development through associated local and national bureaucracy and requirements (e.g. competition rules, block exemptions, public procurement of clean vehicles), which frequently stop or delay development projects within cities.

Finally, the value of coordination and sharing best practice was regularly highlighted by participants throughout the project. Many cities are currently developing their air quality action plans not knowing what other cities have already developed. It was noted that this can often lead to inefficiencies, as the knowledge and experiences from front-runners is often not available, and this can lead to less efficient use of the funding and human resources available.

In this context, there remains a clear need for streamlining and providing guidance on processes and practices in air quality action planning at the local scale. Urban air quality managers do miss having a single dedicated and endorsed platform for communication among cities and central governance on urban air quality. While there are many EU initiatives and research initiatives designed to support EU cities with information on air quality issues and to support local air quality implementation, often many local air quality managers are not aware of their existence. They express the need for a more coherent approach across Europe to allow better and regular exchange of knowledge and experiences concerning, for example, good practice and capacity building. This could be delivered through an information platform at EU level, summarising effective management approaches and helping to support the sharing of experience and best practice.

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Annex 1 Summary of the findings of the EU Urban Agenda Partnership on Air Quality

Table A.1 Summary of concrete measures to improve air quality management in cities in the framework of the Urban Agenda

	Specific problem	Action needed	How to implement the action
Action 1. Identifying gaps in regulation and implementation	• Air quality mitigation requires common air quality standards and effective implementation at national and local levels • For some pollutants and sources there is no regulation or it is limited, e.g. black carbon, nanoparticles, international shipping, construction sites	• Better implementation: • Continuous improvement approach to NO_x and PM • Focus on measures for low- and zero-emission vehicles, zero-emission modes of transport and ITS solutions • Improve coherence of LEZs' implementation and improve regulation • Provide input to EU-level policy discussions • Multilevel governance working group to provide input to the Commission • Collaboration with Partnership on Urban Mobility and Covenant of Mayors for Climate and Energy	• Studies and consultations to formulate recommendations and policy inputs • Organise public workshops to stimulate dialogue between city leaders, Member States, EU policymakers and the relevant industries • Cross-sector and multi-governance solutions
Action 2. Better air quality planning (governance)	• Air quality planning in the EU is not always under the responsibility of cities • Access to knowledge and experiences from front-runner cities should be improved • Knowledge of best practices to facilitate the choice of the relatively most effective measures should be improved	• Develop a code of good practice for cities' air quality action plans • Assemble and keep updated a register of examples of best practice	• Develop a code of good practice in cooperation with experienced cities • Promote the dissemination of best practice. Cooperation with Fairmode (WP5. Management practices)
Action 3. Better targeted funding for air quality	• Lack of specific programmes dedicated to funding of projects aimed at reducing air pollution • Air quality policy is often treated as a stand-alone effort. More effective when integrated with other policies • More possibilities to integrate existing EU/Member State/regional funds for implementing air quality measures	• Assess funding needs and develop an appropriate business model to fund air quality measures • Improve the targeting of existing funding instruments • Promote better accessibility and dissemination of funding opportunities	• Define funding needs and assess sources of funding • Develop a pilot business model • Draft recommendations for improving the targeting of existing funding instruments on air quality • Share draft recommendations through internet-based public consultation

Table A.1 Summary of concrete measures to improve air quality management in cities in the framework of the Urban Agenda (cont.)

	Specific problem	Action needed	How to implement the action
Action 4. Better focus on protecting and improving citizens' health	• Air quality planning in cities focuses on 'exceedances of limit values' but it will benefit from having an additional focus on 'health protection of citizens' • Introducing additional indicators for measuring air quality health impacts would also contribute to boosting the effectiveness of communication with the general public • Increased awareness would improve citizens' support for urban measures aiming to improve air quality	• Give more emphasis to air quality-related impacts on health • Request to indicate the impact of air quality on health	• Map and assess existing (health) impact tools (e.g. cost-benefit analysis) • Conduct empirical case studies • Pilot projects • Evaluate and disseminate results through events, the internet and social media
Action 5. Awareness raising and knowledge sharing	• The general public is little engaged in air quality policy initiatives and knowledge of the effect of poor air quality on health is not widely available • The public has a low appreciation and acceptance of the measures adopted to improve air quality • Public (lack of) awareness represents a barrier to the effectiveness of measures	• Improve cities' communication strategies. Focus on well-being, positive side-effects. • Develop a communication toolbox • Bring together educational and information models. Bottom-up awareness-raising/ knowledge-sharing initiatives • Educational campaigns; citizen science; participatory design and implementation of air quality policies	• Select examples of best practice in education, information and awareness-raising • Develop a communication toolbox for awareness-raising strategies
Action 6. Outreach	• Involve more Member States and cities in developing and implementing pilots in which models and best practices could be tested	• Organising local/national/ European air quality events to exchange experience	• Organise a series of events (i.e. workshops, round-tables or webinars)

Notes: ITS, intelligent transport system; LEZ, low-emission zone; NO_x, nitrogen oxides; PM, particulate matter.

European Environment Agency

Europe's urban air quality
— re-assessing implementation challenges in cities

2019 — 47 pp. — 21 x 29.7 cm

ISBN 978-92-9480-059-6
doi:10.2800/214599

TH-AL-19-003-EN-N
doi:10.2800/214599

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