EU4GREEN

GUIDANCE FOR EFFECTIVE AIR QUALITY MANAGEMENT: DEVELOPING LOCAL AIR QUALITY PLANS IN THE WESTERN BALKANS

EU4Green:
Support the implementation of the Green Agenda for the Western Balkans

WP-1.7 Air quality management – local air quality planning

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Responsible Umweltbundesamt project management:
Violeta Philippitsch, Project Director
Laura Hohoff & Fabian Kracmar, Co-Project Leader
Vlasta Nejasmic, Project Manager

Responsible thematic authors:
Depollution Air: Christian Nagl
Green Finance: Olga Zhminko

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ABBREVIATIONS

AAQD ---------------- European Union Ambient Air Quality Directive

AEI -------------------- Average Exposure Indicator

AQ -------------------- Air Quality

AQM------------------ Air Quality Management

AQP------------------- Air Quality Plan

AQS------------------- Air Quality Standard

BaP ------------------- Benzo[a]pyrene

CFD ------------------- Computational Fluid Dynamic

CO--------------------- Carbon Monoxide

ECO ------------------- Exposure Concentration Obligation

EE --------------------- Energy Efficiency

EEA ------------------- European Environment Agency

EFSE ------------------ European Fund for Southeast Europe

EU--------------------- European Union

FAIRMODE ---------- Forum for Air quality Modeling

GGF------------------- Green for Growth Fund

KfW------------------- Kreditanstalt für Wiederaufbau

LAQM ---------------- Local Air Quality Management

MS -------------------- Member State

NIPAC ---------------- National IPA (Instrument for Pre-Accession) Coordinators

NO_2 ------------------- Nitrogen Dioxide

NO_x ------------------- Nitrogen Oxides

OECD ----------------- Organisation for Economic Co-operation and Development

PAH------------------- Polycyclic Aromatic Hydrocarbon

PF --------------------- Project finance

PM -------------------- Particulate Matter

PPP ------------------- Public Private Partnership

REEP------------------ Regional Energy Efficiency Programmes

SEA ------------------- Strategic Environmental Assessment

SO_2-------------------- Sulphur Dioxide

TIF--------------------- Tax Incrementing Financing

TPF-------------------- Third party financing

UK--------------------- United Kingdom

UNDP----------------- United Nations Development Programme

WBIF ----------------- Western Balkans Investment Framework

WHO ----------------- World Health Organization

WB6 Specific Abbreviations

BiH-------------------- Bosnia and Herzegovina

FBiH ------------------ Federation of Bosnia and Herzegovina

WB6 ------------------ Western Balkan 6

2. EXECUTIVE SUMMARY

The "WP-1.7 Guidance for effective Air Quality Management: Developing Local Air Quality Plans in the Western Balkans" document is designed to support local authorities in the Western Balkans in the development and implementation of effective Air Quality Plans (AQPs) in accordance with European Union Ambient Air Quality Directives (AAQDs). Recognizing the critical need for improved air quality management in urban areas, the document outlines a comprehensive framework that encompasses legal requirements, necessary content, and structured processes for creating AQPs.

The guidance begins with an overview of the legal background, detailing the obligations set forth by the EU directives, including the need to address exceedances of air quality standards. It emphasizes that AQPs must incorporate specific information, such as the identification of pollution sources, emission inventories, and the expected impact of proposed measures. The document suggests a structured approach to developing AQPs, which includes preparation, elaboration, adoption, implementation, and ongoing monitoring and review.

A significant focus of the document is on the importance of public participation and citizen engagement throughout the planning process. It highlights essential activities such as awareness-raising campaigns and stakeholder consultations, which are crucial for ensuring community support and effective implementation of air quality measures. The guidance also stresses the need for clear indicators to assess the effectiveness of implemented actions, enabling local authorities to monitor progress and make data-driven decisions.

In addition to outlining the process for developing AQPs, the document provides practical tools and methodologies for air quality assessment, including air quality modeling, emission calculations, and source apportionment techniques. These tools are essential for understanding the current air quality situation and for evaluating the potential impact of various measures on pollutant concentrations. In addition, the document provides translations of two guidelines developed for Swedish municipalities, namely “Modelling of air quality in urban environments - Guidance for choosing a model type” and a “guidance for the use of models in the development of air quality plans”.

Furthermore, the guidance addresses funding opportunities available for local authorities to support the development and implementation of AQPs. It also showcases good practice examples from various regions, offering insights into successful strategies and approaches that can be adapted to local contexts.

Ultimately, this guidance document serves as a vital resource for local governments in the Western Balkans, empowering them to tackle air quality challenges effectively. By providing a clear framework, practical tools, and examples of best practices, the document aims to enhance air quality management, protect public health, and contribute to sustainable urban development in the region.

3. INTRODUCTION

Air quality plans are required under the European Union Ambient Air Quality Directives (AAQDs) to address air quality problems. Air quality modelling is a necessary tool for developing such an air quality plan. In addition, the effectiveness of individual measures on emissions and subsequently on concentrations of air pollutants is required to estimate the overall impact of all measures and the air quality plan on air pollutant concentrations. Monitoring of the implementation of measures is required to ensure the effectiveness of the plan. Guidance is therefore needed, especially for the local level, on how to select and finance effective measures, estimate their impact, monitor their implementation and model air pollutant levels.

The EU4Green project was therefore asked during the inception phase in 2022 of this project to develop a guidance document for developing air quality plans on local level. The necessities for such a guidance document were further discussed at a regional workshop, which took place from 31 January to 1 February 2024 in Sarajevo.[1] This guidance document therefore summarise available guidance documents, elaborate on aspects, which were named to be important for the authorities in Western Balkan economies such as indicators and funding of air quality plans, and provide good practice examples related to these topics.

The document is structured as following:

- **Chapter 4** provides the legal background for air quality management according to EU legislation.
- **Chapter 5** describes the necessary content of air quality plans.
- **Chapter 6** summarises the process for developing an air quality plan
- **Chapter 7** provides an overview of methods to support air quality planning, including modelling.
- **Chapter 8** describe funding opportunities for developing and implementing air quality plans
- **Chapter 9** shows good practice examples related to air quality planning and links to further guidance documents.

Annex 1 provides a translation of a Swedish guidance for selecting air quality models and Annex 2 for the use of models in the development of air quality plans.

[1] https://eu4green.eu/news-events/, last viewed on 22 February 2024

4. LEGAL BACKGROUND

4.1. Limit and target values

The European Union Ambient Air Quality Directives (AAQDs) 2008/50/EC and 2004/107/EC (4th Daughter Directive, 4DD) lay down objectives for ambient air quality and methods and criteria for the assessment of air quality in the EU Member States (European Parliament and the Council of the European Union, 2004, European Parliament and the Council of the European Union, 2008).

Directive 2008/50/EC lays down objectives for benzene, carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), particulate matter (PM_{10}, $PM_{2.5}$), ozone (O_3) and sulphur dioxide (SO_2), see Table 1, Table 2, Table 3.

The 4th Daughter Directive (4DD) lays downs target values for arsenic (As), cadmium (Cd), nickel (Ni) and benzo[a]pyrene (BaP) as a marker for polycyclic aromatic hydrocarbons (PAH), see Table 4.

Table 1: Limit values of Directive 2008/50/EC.

Pollutant	Averaging period	Limit value	Remark
SO_2	One hour	350 µg/m³	not to be exceeded more than 24 times a calendar year
SO_2	One day	125 µg/m³	not to be exceeded more than 3 times a calendar year
NO_2	One hour	200 µg/m³	not to be exceeded more than 18 times a calendar year
NO_2	Calendar year	40 µg/m³	
Benzene	Calendar year	5 µg/m³	
CO	Maximum daily eight hour mean	10 mg/m³	
Lead	Calendar year	0.5 µg/m³	
PM_{10}	One day	50 µg/m³	not to be exceeded more than 35 times a calendar year
PM_{10}	Calendar year	40 µg/m³	

Table 2: Provisions for $PM_{2.5}$ of Directive 2008/50/EC.

Provision	Value	Year	Remark
Exposure concentration obligation (ECO)	20 µg/m³	2015	Average Exposure Indicator (AEI)
Target value	25 µg/m³	2010	Applicable throughout the territory

Limit value stage 1	25 µg/m³	2015	Applicable throughout the territory
Limit value stage 2	20 µg/m³	2020	Indicative limit value, no changes in 2013 review

Table 3: Target values for ozone.

Objective	Averaging period	Target value
Protection of human health	Maximum daily eight-hour mean	120 µg/m³ not to be exceeded on more than 25 days per calendar year averaged over three years

Table 4: Target values of 4DD

Pollutant	Value
Arsenic	6 ng/m³
Cadmium	5 ng/m³
Nickel	20 ng/m³
Benzo(a)pyrene	1 ng/m³

In 2015, several annexes to the AAQDs were amended by Commission Directive (EU) 2015/1480 (European Commission, 2015). This Directive lays down rules concerning reference methods, data validation and the location of sampling points for the assessment of ambient air quality.

4.2. Exceedance of limit and target values

In principle, European Union Member States are obliged to ensure compliance with the relevant limit values (see above). Once compliance has been achieved, Member States are required to keep levels below the limit values in all zones and agglomerations.

Regarding target values, all appropriate measures (as long as they do not entail disproportionate costs) have to be implemented to reach compliance. In the case of limit values and the $PM_{2.5}$ Exposure Concentration Obligation (ECO), cost considerations can in principle not lead to the disregarding of measures that would enable the achievement of compliance.

When limit or target values are exceeded, Member States have to establish air quality plans for the zone or agglomeration in non-compliance within two years. The air quality plan has to include measures that aim to keep the exceedance period as short as possible. The air quality plans have to include at least the information listed in Section A of Annex XV of Directive 2008/50/EC (see section 5.1 below).

Where exceedances are due to natural sources (Article 20 Directive 2008/50/EC) or winter-sanding or –salting (Article 21 Directive 2008/50/EC) and compliance is reached after deducing the contribution of these sources Member States do not have to draw up air quality plans. The European Commission has published guidelines relating to these deductions (European Commission, 2011b, European Commission, 2011c).

4.3. Air quality plans

Provisions regarding air quality plans are laid down in several articles and annexes of Dir. 2008/50/EC:

- Article 17: Requirements in zones and agglomerations where ozone concentrations exceed the target values and long-term objectives
- Article 20: Contributions from natural sources
- Article 21: Exceedances attributable to winter-sanding or -salting of roads
- Article 23 Air quality plans:
- Article 24: Short term action plans:
- Article 25: Transboundary air pollution: cooperation with neighbouring country in case of significant transboundary contribution to pollutant levels
- Article 26: Public information: public and organisations have to be informed about the AQ plan
- Article 28: Implementing measures
- Annex XV: Information to be included in the local, regional or national air quality plans for improvement in ambient air quality, A: Information to be provided under article 23 (air quality plans)

5. CONTENT OF AN AIR QUALITY PLAN

5.1. Content according to Dir. 2008/50/EC

According to Article 2 Dir. 2008/50/EC an Air Quality Plan (AQP) "*shall mean plans that set out measures in order to attain the limit values or target values*". An AQP shall incorporate at least the information listed in Section A of Annex XV of Dir. 2008/50/EC. Reporting of air quality plans is laid down in Commission Decision 2011/850/EU and further detailed in a guidance (European Commission, 2011a, European Commission, 2018).

The following information is required to be included in an AQP (Urban Agenda for the EU, 2019, European Parliament and the Council of the European Union, 2008):

- The **localisation of excess pollution** should be described within a region or city with a map and geographical coordinates of the monitoring station(s) reporting the exceedance(s). Monitoring stations should have a unique unambiguous code that has been generated by the beneficiary and used for the reporting.
- **General information** about the environment in which the exceedance has occurred is required, such as whether the zone is in a city, rural or industrial area. This also includes an estimation of the polluted area (km^2), or km of road, and of the population exposed to the pollution. Climatic data and topography should be provided as well.
- **Responsible authorities:** names and addresses of persons responsible for the development and implementation of the AQP.
- The **nature and assessment of the pollution** should include concentrations observed over previous years and concentrations measured since the beginning of any associated air quality improvement measures.
- The **origin of the pollution** requires a list of the main emission sources (tonnes/year) responsible for the exceedance(s) and a corresponding map of the area. Contributions lower than 3% are not considered significant. Next to the total quantity of emissions from the relevant sources information should be provided on pollution imported from other regions outside the city and the country. Main emission sources should to be categorized according to the IPR guidance (European Commission, 2018).
- **Analysis of the situation:** This comprises a source apportionment (Thunis, Clappier, Pirovano, 2020). It should reflect regional, urban and local contributions from relevant sources.
- **Previous plans and programmes** on local, regional, national or international level that are of relevance for the local situation. This includes at which level of governance any measures were implemented.

- **Details of abatement measures and any associated projects adopted with a view to reducing pollution** should each be listed and described in an AQP with an accompanying timetable for implementation. This includes an estimate of the improvement due to the measures compared to the baseline scenario, thereby showing the expected timeframe required to attain the objectives of the AAQDs.
- **Any measures or projects planned or being researched for the long term**.
- **List of all publications, documents, and associated work**.

5.2. Suggested structure of the AQP

Based on the necessary information (see section above), the following general structure is suggested for the AQP:

- Introduction
  - Legal background
  - Overview of air pollutants and their health impacts
  - Overview of local air quality and the exceedance situation
- Responsible authority
- General information
  - Description of city / region
  - Climate
  - Topography
  - Exceedance area, affected population
- Sources
  - Emission sources
  - Source apportionment
- Measures
  - Plans and measures already implemented so far
  - Process of developing and selecting effective measures
  - Details of measures of the APQ
  - Long-term measures
  - Overall impact of the measures
- Other plans and programmes relevant for the AQP
- Monitoring and review of the AQP and the measures
- List of documents, publications etc.

6. PROCESS TO DEVELOP AN AIR QUALITY PLAN

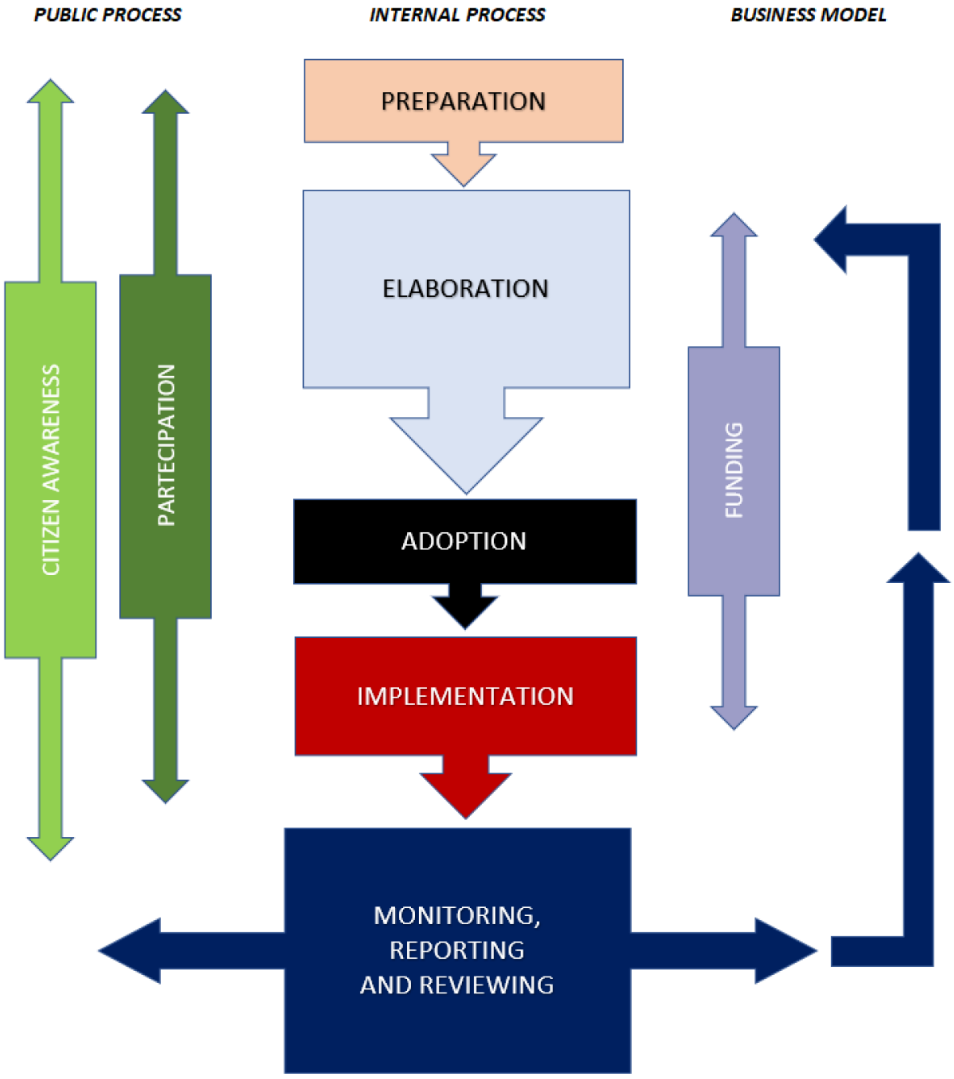
The Urban Agenda guidance describes nicely the process in general for how to develop an AQP (Urban Agenda for the EU, 2019). The process can be divided in the following steps:

1. Preparation
2. Elaboration
3. Adoption
4. Implementation
5. Monitoring, Reporting and Reviewing.

As described in the Urban Agenda guidance, there are essential activities to be undertaken in parallel to this process to ensure the success of the AQP (see section 6.8):

a) Citizen awareness raising
b) Public participation
c) Funding.

Figure 1: Main steps and activities to develop an AQP (source: (Urban Agenda for the EU, 2019).



The following sections describe the above-mentioned steps.

6.1. Preparation of an AQP

According to the Urban Agenda guidance the following steps are required for preparing an AQP:

a) Put Air Quality higher on the Municipal Agenda, raise citizen awareness, lead by example e.g. regarding procurement, environmental friendly behaviour and initiatives
b) Identify stakeholders and key actors
c) Setting up an ‘Air Quality Plan Steering Group’
d) Review internal resources

6.2. Elaboration of an AQP

The main steps for elaborating an AQP are the following ones (Urban Agenda for the EU, 2019):

a) Frame the problem (i.e. assessment of the air quality situation, including emissions and source apportionment)
b) Define targets of the AQP
c) Define the indicative deadline and time plan in line with the legal requirements
d) Define effective measures / packages of draft measures
e) Prioritizing measures
f) Screening with competent authorities if a Strategic Environmental Assessment (SEA) process is required

The elaboration of the AQP should include stakeholder involvement and especially a dialogue with other departments, public participation and consultation (see section 6.8).

This allows to define the final set of measures of the AQP, including schedules, roles and responsibilities, monitoring methodology and indicators.

Key elements of an AQP are the following ones:

- Ensure policy coordination and integrated planning with other sectors of the administration (Climate change, Transport sector, Energy sector, Agriculture, etc.).
- Define a business plan and look for funding
- Carry out citizen awareness raising campaigns and prepare effective communication strategies.

6.3. Indicators

Indicators are important to monitor the implementation and effect of individual measures and the AQP as whole. Indicators are a prerequisite for the evaluation of AQPs. The theoretical background of environmental indicators in general can be found in several studies (UNEP/RIVM, 1994, Andres, et al., 2022, ETC/ACC, 2009, Henneman, et al., 2017, CCAC, 2019). These studies allow for describing criteria for selecting appropriate indicators for AQPs:

POLICY RELEVANCE AND UTILITY FOR USERS

An indicator should:

- provide a representative picture of the air quality situation, the effect and implementation of the measures;
- be simple, easy to interpret and be able to show trends over time;
- be relevant for the policy aims/targets that they should shed light on;
- be easy to communicate towards the target audience;
- be responsive to changes in the air quality situation and related activities;
- provide a basis for comparisons;
- have a target threshold against which to compare it so that users are able to assess the significance of the values associated with it;
- be designed to highlight the context within which an organization is operating (e.g. a government/ministry is working within a set of laws) and whether this context has changed;
- be able to identify whether the project is still relevant, or whether the context has changed such that some activities are no longer relevant.

ANALYTICAL SOUNDNESS

An indicator should:

- be theoretically well founded in technical and scientific terms;
- be based on international good practice examples;
- should allow to compare the progress against baseline levels (the expected state in a scenario without an intervention);
- lend itself to be linked to forecasting and information systems.

MEASURABILITY:

The data required to support the indicator should be:

- readily available or made available at a reasonable cost/benefit ratio;
- adequately documented and of known quality; and
- updated at regular intervals in accordance with reliable procedures.

The Urban Agenda guidance document highlights the indicators described in the AQP for Madrid, which established three types of indicators (Urban Agenda for the EU, 2019):

- Impact - associated with overall objectives;
- Specific - assessing the real impact of the actions carried out as a whole
- Process - evaluating the degree of implementation of the measures.

The AQP should also describe the necessary activities to monitor the individual indicators (CCAC, 2019):

- Means of monitoring the indicator, e.g. through data collection, questionnaires, meetings?
- Frequency of monitoring the indicators
- Responsibility for monitoring the indicators

The guidance by CCAC developed a table for necessary indicator activities and responsibilities (CCAC, 2019).

Table 5: Indicator activities (source: (CCAC, 2019)).

Organisation	Indicators	Activities	Definitions and unit of measure	Data source	Method or tool	Frequency of collection / reporting	Use of information	Person responsible

In addition, there should be targets for the indicators.

Table 6: Indicator targets table (source: (CCAC, 2019)).

Indicators	Baseline (current year)	Target year 1	Target year 2	Target year 3	Target year 4	Target year 5	Target justification

Dataset K of CID 2011/850/EU requires inter alia to describe the indicators to monitor the progress of the measure, which can be downloaded from the EEA website[2] (K.2.11.8 <aqd:monitoringProgressIndicators>) (European Commission, 2011a, European Commission, 2018, ETC/ACM, 2017). The aqd:monitoringProgressIndicators is a free text description on the indicators to track progress towards implementation / full affect i.e. monitoring the effectiveness of a measure. The guidance document provides the following examples:

- have the planned parking fees been implemented [y/n] and to what extent [number of parking places affected];
- has the planned permit revision been implemented [y/n];
- how much has the traffic volume on a road gone down [% heavy duty vehicles].

The time extension applications, which have been sent to the European Commission after the implementation of Directive 2008/50/EC, provide the following good practice examples of indicators to monitor the progress of the implementation of measures:

Measure	Indicator
Speed limit at specific road sections	Average speed of vehicles
Retrofitting of diesel particle filters to construction machinery	Number of retrofitted particle filters compared to overall number of machinery suitable for retrofitting
Public transport improvements	Number of public transport users
District heating improvements	Number of connected households

Nevertheless, as described above, AQPs should interact with a number of other strategies for mobility, energy, noise etc. Usually, these strategies include frameworks for monitoring the progress. Just to name improvements for bicycle traffic, there are a number of indicators and frameworks for monitoring of quality criteria for cycling networks (see e.g. (Weikl, Mayer, 2023, Wysling, Purves, 2022):

- Safety
- Comfort
- Directness
- Coherence
- Attractiveness

Therefore, the AQP requires close interaction with the experts and responsible authorities also for monitoring the progress.

[2] https://discomap.eea.europa.eu/App/AQViewer/index.html?fqn=Airquality_Dissem.h2k.Measures, last viewed on 11.9.2024

6.4. Adoption

The final AQP should be adopted according to the legal requirements. In general, the AQP should be adopted by the highest political level responsible for the region in question and especially for the implementation of the measures.

6.5. Implementation

The AQP needs to be implemented according to the timeline foreseen in the elaboration process. Therefore, the AQP has to define responsibilities, timeframes, indicators and a process to monitor the implementation, see the following section and section 6.3 regarding indicators.

6.6. Monitoring, Reporting and Reviewing

Monitoring of the implementation of an AQP and its measures is crucial for achieving the expected improvements of air quality. The monitoring process should be reported to the AQP steering committee.

As described in the UK local air quality management (LAQM) good practices[3], monitoring is not restricted to measures described in the AQP, but to all activities in the city / region that can impact AQ. This is crucial for reviewing the effectiveness of the AQP and for adjusting the measures. Such a review should take place regularly, e.g. every three years.

Focus on planning, what is interesting: monitoring is not restricted to measures described in the AQP, but to all activities in the city / region that can impact AQ.

The UK provide useful templates for reporting the status of the AQP implementation.[4] These templates include examples of activities outside the AQP that should be taken into account as well.

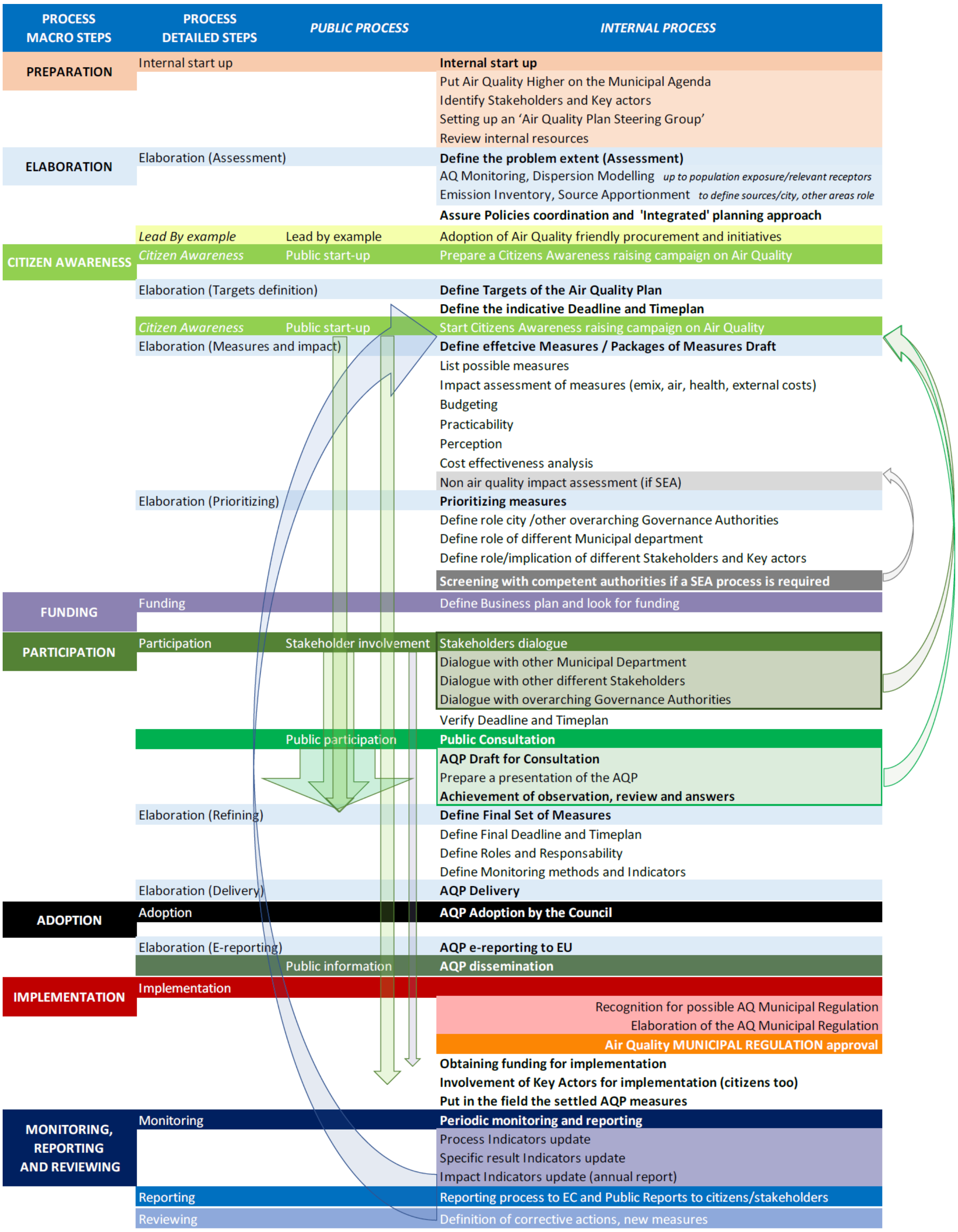
The CCAC guidance provide suggestions for an review or evaluation of the AQP (CCAC, 2019). The evaluation should check whether the implementation is on track with the help of the indicators. The evaluation should also check whether the indicators and monitoring activities included in the AQP are still appropriate.

[3] https://laqm.defra.gov.uk/air-quality/annual-reporting/annual-good-practice/, last viewed on 22 February 2024
[4] https://laqm.defra.gov.uk/annual-reporting/, last viewed on 22 February 2024

6.7. Checklist

The Urban Agenda guidance document provides the following checklist for the process of developing an AQP.

Figure 2: Checklist of the process to develop an AQP (source: (Urban Agenda for the EU, 2019))



6.8. Public participation, communication, awareness raising

Public participation and awareness raising are crucial elements of a successful AQP. Both require a strong and coherent communication, for which guidance and good practice examples are provided in the following sections.

6.8.1. Participation

The presentation provided by Chloé Déchelette shows the advantages of public participation for developing an AQP as well as good practice examples (Déchelette, 2024). The importance of public participation can be summarised as following:

- Countries have to adopt European standards but struggle to implement them effectively.
- Environmental policy needs a more comprehensive and systemic approach, which can be provided by participation processes
- Democratic values: a new state and administrative culture based on cooperation rather than confrontation, on empowering non state actors for a stronger civil society.

In addition, there are legal requirements concerning public participation:

- Aarhus Convention[5] on Access to Information, Public Participation in Decision Making and Access to Justice in Environmental Matters (see section 6.8.1.1 to 6.8.1.3 below for details)
- EU Ambient Air Quality Directive 2008/50/EC (Articles 24, 26, Annexes XV,
- EU Public participation Directive 2003/35/EC[6]
- Sophia Declaration on the Green Agenda for the Western Balkans (Regional Cooperation Council, 2020)
- National legislations

The benefits of public participation are:

- Policies more responsive to the needs of the population
- Better acceptance of the policy by the population
- Better policy implementation
- Increased credibility and legitimacy

[5] https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-13&chapter=27, last viewed on 22 February 2024
[6] http://data.europa.eu/eli/dir/2003/35/oj, last viewed on 22 February 2024

- Participants can express their views and feel heard
- Awareness is raised
- Different points of views are considered

Good practice examples can be found in the participation global network[7]:

- Clean Air for Helsinki: how we can work together to improve air quality[8]
- French citizens convention for climate[9]
- Gdansk citizen panel on reducing air pollution[10]
- Grenoble metropolitan area climate and energy plan (2020-2030)[11]

Success factors for public participation are the following ones:

- Clearly define your objectives and your public.
- Explicitly state what is open for discussion and what is not.
- Maintain transparency throughout the process.
- Provide feedback to participants.
- Monitor/evaluate the participation process

Questions to be asked before starting a public participation are the following ones:

- Has the final decision already been made?
- Will participants benefit from the consultation?
- What is the expected result? Do we have clear objectives and the means to achieve them?
- Has no one who will be affected by the issue been forgotten?
- Is the facilitator neutral?
- Will the process involve people along the way?
- Do we have the means to give participants feedback on what has been done with their proposals?

6.8.1.1. Aarhus Convention

[7] https://participedia.net/, last viewed on 22 February 2024
[8] https://www.hel.fi/static/ymk/esitteet/ilmansuojeluesite-en.pdf, last viewed on 22 February 2024
[9] https://www.conventioncitoyennepourleclimat.fr/en/, last viewed on 22 February 2024
[10] https://publicagenda.org/wp-content/uploads/Healthier-Democracies-Gdansk.pdf, last viewed on 22 February 2024
[11] https://www.citego.org/bdf_fiche-document-2228_en.html, last viewed on 22 February 2024

The Aarhus Convention[12] guarantees the public three key rights on environmental issues:

- Access to environmental information, including information on the state of the environment, policies or measures affecting the environment, public health and safety where these are affected by the state of the environment.
- Public participation refers to the public's right to participate in environmental decision-making.
- Access to justice refers to the public's right to review by a court or another independent body to ensure that public authorities respect the rights to access to information and public participation, and environmental law in general.

The Convention includes the Kyiv Protocol on Pollutant Release and Transfer Registers (PRTR)[13] for industrial sites and other sources from 2009 that can also be signed by parties, which have not ratified the Aarhus Convention.

The Aarhus Convention has been implemented into EU legislation via the Access to Environmental Information Directive (Directive 2003/4/EC), the Public Participation Directive (Directive 2003/35/EC), which both includes provisions for access and to justice, and the Aarhus Regulation (EC) 1367/2006, which contributes to the implementation of the Convention to the EU's institutions, bodies, offices and agencies (European Parliament and the Council of the European Union, 2006a, European Parliament and the Council of the European Union, 2003a, European Parliament and the Council of the European Union, 2003b). The Kyiv Protocol has been implemented via the PRTR Regulation[14] (EC) 166/2006 as amended (European Parliament and the Council of the European Union, 2006b).

The Aarhus Convention and the EU provide a number of guidance documents, studies and publications[15] to support the implementation of the Aarhus Convention, thereby enabling access to environmental information, public participation and access to justice of its citizens (UNECE, 2014, UNECE, 2015, European Commission. Directorate General for the Environment, 2018).

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[12] https://unece.org/environmental-policy-1/public-participation, https://environment.ec.europa.eu/law-and-governance/aarhus_en, see also https://www.icnl.org/resources/research/ijnl/the-aarhus-convention-and-its-practical-impact-on-ngos-examples-of-cee-and-nis-countries, last checked on 1 December 2023

[13] https://unece.org/env/pp/protocol-on-prtrs-introduction, last checked on 1 December 2023

[14] https://environment.ec.europa.eu/topics/industrial-emissions-and-safety/european-pollutant-release-and-transfer-register-e-prtr_en, last checked on 1 December 2023

[15] https://environment.ec.europa.eu/law-and-governance/aarhus_en#studies-and--publications, https://unece.org/environment-policy/public-participation/key-guidance-material, summary of the Aarhus Convention: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al28140&qid=1659457532271, last checked on 1 December 2023

6.8.1.2. Status of the ratification[16] of the Aarhus Convention in Western Balkan

Albania signed and ratified the Aarhus Convention, and accepted the amendment from 2005. Bosnia and Hercegovina, Montenegro, North Macedonia and Serbia did not sign the Convention yet, but accessed it.

The Kyiv Protocol[17] has been accessed by Albania, signed, but not ratified by Bosnia and Hercegovina, signed and ratified by Montenegro, North Macedonia and Serbia.

6.8.1.3. Aarhus Centres

The OSCE has established Aarhus Centres in all WB6 economies except Kosovo*[18].[19]

6.8.2. Communication and awareness raising

Communication of air quality related topics and awareness raising are key for successful preparation and implementation of AQPs. WHO and other trustful organisations developed a lot of material to facilitate communicated the rather technical topics related to air quality. In general, communication for raising awareness should consider the following aspects (Déchelette, Mayer, 2023):

- Link air pollution to biggest drivers: health and climate change.
- Appeal to reason by building upon scientific facts, but don't forget emotions and people's concerns.

Communication for developing the AQP and the measures should consider the following aspects:

- Be aware of the possible solutions
- Assess your current efforts and identify necessary improvements
- Use a suitable communication method for the target audience

[16] https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-13&chapter=27&clang=_en, amendment: https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-13-b&chapter=27&clang=_en, last checked on 1 December 2023
[17] https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-13-a&chapter=27&clang=_en, last checked on 1 December 2023
[18] The designation of Kosovo is without prejudice to any positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.
[19] https://aarhus.osce.org/, last viewed on 22 February 2024

When communicating it is crucial to differentiate your message to specific audiences, to define your message and think about what you want to tell and what you want to achieve.

6.8.2.1. Storytelling:

Storytelling can be an important aspect of communicating air quality issues, as stories are much better remembered by people compared to mere information and data.

Examples for storytelling can be found e.g. at the website of the American Lung Association[20], the National Centre for Atmospheric Science provide an online children's story[21].

6.8.2.2. Low cost sensors

Low cost sensors are used by citizen for various reason. The data retrieved by these sensors often require substantial communication efforts by administrations. Nevertheless, administrations can rely on a number of brochures, factsheets and reports to facilitate communication and refer to reliable sources of information:

- "An Update on Low-cost Sensors for the Measurement of Atmospheric Composition" provided by the World Meteorological Organization (WMO, 2021).
- "Integrating Low-cost Sensor Systems and Networks to Enhance Air Quality Applications" provided by the World Meteorological Organization (WMO, 2024).
- "Description of methodology for mobile monitoring and citizen involvement" by the EU-Project RI-URBANS discusses mobile measurements and sensor networks to generate high resolution exposure maps by involving citizens (RI-URBANS, 2022a).
- "Recommendations regarding modelling applications within the scope of the ambient air quality directives" are provided by the JRC of the European Commission (European Commission JRC, 2019b).
- "The Enhanced Air Sensor Guidebook" is provided by the US EPA, which is very active in field of air quality sensors since many years (US EPA, 2022).

[20] https://www.lung.org/policy-advocacy/healthy-air-campaign/share-your-story, last viewed on 23 February 2024
[21] https://grandmasfootsteps.com/, https://ncas.ac.uk/online-childrens-story-explores-changes-in-air-pollution/, last viewed on 23 February 2024

7. METHODS AND TOOLS FOR AIR QUALITY PLANNING

The elaboration of an AQP can be roughly divided into the following steps:

1. Technical assessment of situation, i.e., a background analysis of the pollutant levels, exposure of the population, main sources, contribution from sources outside the city;
2. Definition of the objectives of the AQP (for which pollutants, timeframe for reduction of pollutant levels, concentration levels to be achieved);
3. Selection of a set of proposed measures;
4. Assessment of the effectiveness and the costs of the measures (or a set of measures).

Different methods and tools are required for some of the above mentioned steps. Whereas steps 2 and 3 require merely discussions and political decisions, steps 1 and 4 require certain methods and modelling tools.

The tools for step 1, the technical assessment, are mainly monitoring, calculation of emissions, modelling and source apportionment.

Step 4, the assessment of the effectiveness of measures, is mainly covered by literature research, emission calculations and modelling.

The following sections shortly describe these methods.

However, these methods cover only the technical aspects; developing and implementing an AQP requires additionally a lot of communication and coordination, as well as participation processes. Those are described in section 6.8.

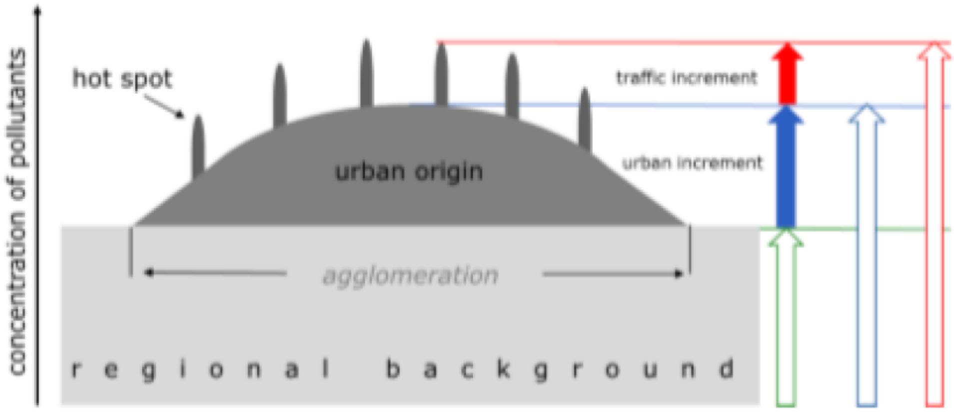
7.1. Monitoring for further assessment of the exceedance situation

The guideline by the German Environment Agency as well as the Urban Agenda code of good practice describe the assessment of the exceedance situation in detail (Urban Agenda for the EU, 2019, Umweltbundesamt Dessau, 2016).

In short, the assessment requires an analysis of the current air quality situation based on quality assured monitoring results and on modelling, if available. The assessment should describe the current levels and the trends.

The assessment should distinguish between contributions from outside the city or region and from contributions of the city itself and of local sources. Contributions from outside can be determined by suitable regional background stations or in case no such station is available, by large scale modelling results, e.g. by EMEP[22]. The contribution by the city is the difference between concentrations at regional and urban background stations. Local contributions can be determined by hotspot stations, such as urban traffic stations or industrial stations. Such an assessment helps to estimate the effectiveness of measures on different (administrative) levels.

Figure 3: Scheme of different contributions to air pollution in a city.



Source: (Urban Agenda for the EU, 2019)

In addition, the assessment should include an estimate of the exposure of the population, and, if appropriate, the km of roads along which the limit value is exceeded.

In case that the existing air quality monitoring network is not sufficient to assess the air quality situation in the whole city or region, further monitoring campaigns should be undertaken. For gaseous pollutants, this can be done with the help of passive samplers. For PM, mobile stations can be used.

The openair package for the R programming language allows for a swift analysing and visualising of air quality data (Carslaw, Ropkins, 2012).[23]

[22] https://www.emep.int/mscw/index.html, last visited on 8 September 2023
[23] https://www.r-project.org/, https://bookdown.org/david_carslaw/openair/, last viewed on 22 February 2024.

7.2. Emission calculation

An extensive framework is available for the calculation of emissions on national level under the UNECE, laid down in the EMEP/EEA air pollutant emission inventory guidebook (EEA, 2019b). In addition, guidance is available and a toolbox is currently developed especially for WB6 within the SEPA and SMHI project[24] (Ministère de la Transition écologique et solidaire, 2018, ETC/ACM, 2014, van Dongen, et al., 2024).

Urban emission inventories are part of the EU project RI-URBANS, where a "Methodology to improve European urban emission inventories" was developed; the project LIFE REMY[25] provides recommendations that can support modelling teams in reducing modelling uncertainties by improving urban emission inventories (LIFE-REMY, 2024, RI-URBANS, 2022b).

7.3. Air quality modelling

Dispersion modelling requires on the one hand a lot of expertise and reliable input data, on the other hand, the model application to be used depends on the specific situation. Therefore, in the following only some general guidance can be provided.

FAIRMODE[26], the Forum for Air Quality Modelling has developed a number of guidance documents, which can be used a starting point (EEA, 2011, ETC/ACC, 2010, European Commission JRC, 2019a, FAIRMODE, 2017, FAIRMODE, 2020). In addition, FAIRMODE has developed a tool for validating model performance against observations, the so-called DELTA tool.[27]

The Swedish Meteorological and Hydrological Institute (Sveriges meteorologiska och hydrologiska institut, SMHI) hosts a reference laboratory for air quality models where guidance material is provided.[28] This includes a step-by-step guidance on how to model air quality[29] as well as a guidance for how to choose an urban air quality model[30] (SMHI, 2022a). A translation of the guidance can be found in the Annex.

Further guidance is available by US EPA (US EPA, 2018, US Government, 17 Jan. 2017).[31] This guidance is especially helpful for modelling of ozone and $PM_{2,5}$, which require chemical

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[24] https://www.naturvardsverket.se/en/international/cooperation/bilateral/western-balkans/, last viewed on 22 February 2024.
[25] https://liferemy.eu/, last viewed on 17 May 2024
[26] https://fairmode.jrc.ec.europa.eu/, last viewed on 8 September 2023
[27] https://aqm.jrc.ec.europa.eu/Section/Assessment/Background, last viewed on 15 February 2024
[28] https://www.smhi.se/reflab, in English: https://www-smhi-se.translate.goog/reflab?_x_tr_sl=sv&_x_tr_tl=en&_x_tr_hl=sv&_x_tr_pto=wapp,
[29] https://www-smhi-se.translate.goog/reflab/guider/guider/steg-for-steg-sa-gor-du-en-luftkvalitetsberakning-1.28409?_x_tr_sl=sv&_x_tr_tl=en&_x_tr_hl=sv&_x_tr_pto=wapp, last viewed on 29 December 2023.
[30] https://www-smhi-se.translate.goog/reflab/guider-och-verktyg/guider/vagledning-for-val-av-modelltyp-for-spridningsmodellering-i-tatortsmiljo-1.182830?_x_tr_sl=sv&_x_tr_tl=en&_x_tr_hl=sv&_x_tr_pto=wapp, last viewed on 29 December 2023.
[31] https://www.epa.gov/state-and-local-transportation/project-level-conformity-and-hot-spot-analyses#dispersionmodel,

transport models. In addition, the guidance describe the building blocks required for air quality modelling.

The guidance by the German Environment Agency describes in detail the different objectives of models and well established models for different spatial scales including the necessary input parameters (Umweltbundesamt Dessau, 2016).

The Government of Alberta, Canada, developed a helpful guidance document, especially for regulatory purposes, i.e. industrial facilities (Alberta Environment and Parks, 2021).[32] A similar guidance is provided by British Columbia (British Columbia Ministry of Environment and Climate Change Strategy, 2022a, British Columbia Ministry of Environment and Climate Change Strategy, 2022b).[33]

The city of Hong Kong provides an online guidance for local-scale air quality assessment using models.[34]

7.4. Source apportionment

In order to select measures for the main sources responsible for the exceedance, it is necessary to assess the impact of these sources on pollutant levels and their spatial distribution. Source apportionment is also required to distinguish between sources from within the city or region and from outside. A recent guidance by FAIRMODE provides the theoretical background for different approaches of source apportionment (Thunis, Clappier, Pirovano, 2020). Recommendations were prepared within a research project (RI-URBANS, 2023).

Comment: Within FAIRMODE, the so-called SHERPA tool (Screening for High Emission Reduction Potential on Air) was developed.[35] This tool allows for a quick assessment of the contribution of different sectors on different geographical scales; however, this tool is not available for WB6 cities.

The main methods for source apportionment are the following ones:

- Expert estimate, based on data from air quality monitoring data, emissions and meteorology. For PM, the expert estimate can be supported by chemical analysis of PM samples.

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https://www.epa.gov/scram/modeling-guidance-and-support, last viewed on 29 December 2023.
https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models, last viewed on 4 October 2023.
[32] https://open.alberta.ca/publications/air-quality-model-guideline-2021, last viewed on 4 October 2023.
[33] https://www2.gov.bc.ca/gov/content/environment/air-land-water/air/air-quality-management/modelling, last viewed on 4 October 2023.
[34] https://www.epd.gov.hk/epd/english/environmentinhk/air/guide_ref/guide_aqa_model.html, last viewed on 4 October 2023.
[35] https://aqm.jrc.ec.europa.eu/Section/Sherpa/Background, last visited on 11 September 2023

- Chemical analysis of PM samples and receptor modelling;
- Air quality modelling.

Receptor modelling uses chemical fingerprints of air pollutant sources to identify and apportion their contribution to PM levels (Esmaeilirad, et al., 2020). Such receptor models use measured data of PM chemical composition and their corresponding uncertainty to calculate the contributions of different emission sources based on statistical calculations. Common receptor models can be categorized into univariate models, such as chemical mass balance (CMB), and multivariate models, such as principal component analysis (PCA), positive matrix factorization (PMF), and the US EPA's Unmix model. A user guide for the Unmix model is available by US EPA; however, the software itself is no longer available at the EPA's website.[36]

The PMF method was used for a source apportionment study for the city of Skopje (University Goce Delcev, AMBICON Lab, 2022).[37]

Chemical mass balance (CMB) models use mathematical methods to relate chemical source profiles to measured concentrations of different PM constituents. The accuracy of a CMB modelling result depends strongly on the availability of the chemical source profiles. A more detailed description of the CMB method can be found in the literature (Mircea, et al., 2020, US EPA, 2004). US EPA provides a CMB model.[38]

Positive matrix factorisation (PMF) models use the results from chemical analysis of PM samples to identify factors that contribute to observed concentrations. Chemical source profiles can be used to interpret the results of the PMF model.

A more detailed descriptions of PMF and the underlying mathematical concepts can be found in the literature, especially in the user guide of the US EPA PMF model (Mircea, et al., 2020, US EPA, 2014). US EPA also provides a PMF model, which is however no longer being updated.[39] Nevertheless, PMF is one of most commonly used receptor models.

A Swedish project conducted a source apportionment study for various cities in BiH, which used both PMF and air quality modelling with the help of the so-called MATCH model[40] (SMHI, 2022b).

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[36] https://www.epa.gov/air-research/epa-unmix-60-fundamentals-user-guide, last viewed on 11 September 2023.
[37] https://cistvozduh.mk/en/publikacii/analysis-for-share-determination-of-different-pollution-sources-in-skopje-urban-area/, last viewed on 19 February 2024.
[38] https://www.epa.gov/scram/chemical-mass-balance-cmb-model, last viewed on 11 September 2023.
[39] https://www.epa.gov/air-research/positive-matrix-factorization-model-environmental-data-analyses, last viewed on 11 September 2023.
[40] Multi-scale Atmospheric Transport and Chemistry (MATCH) model, https://www.smhi.se/en/research/research-departments/meteorology/match-transport-and-chemistry-model-1.6831, last viewed on 5 October 2023.

7.5. Selection of measures and their effectiveness

Air quality plans have been implemented in EU MS since two decades. These plans and the measures are reported to EEA (ETC/ATNI, 2021).[41] Therefore, a large number of air quality measures have been analysed, implemented, monitored and evaluated. A more detailed analysis of implementation challenges cities are facing was conducted by EEA (EEA, 2013, EEA, 2018).

There have been attempts to collect measures in databases[42]; however, these databases are not always up-to-date and regularly updated.

In addition, the time extension for compliance with limit values exercise resulted in a further vast set of air quality measures.[43]

Under FAIRMODE, WG5 "Efficient and robust AQ measures" has recently published "Best practices for local and regional Air Quality management" (Pisoni, et al., 2022). Furthermore, the Urban Agenda code of good practice includes recent good practices as well (Urban Agenda for the EU, 2019). In addition, WHO has published a report supporting the implementation of the WHO air quality guidelines, which includes resources and tools for air quality policies, plans and emission reductions by sectors (WHO Regional Office for Europe, 2023).

Urban access regulations and low emissions zones for traffic are collected in an online database, which is kept up-to-date.[44] Effects of low emission zones on health outcomes has recently been reviewed (Chamberlain, et al., 2022, Chamberlain, et al., 2023). Planning of low emission zones and congestion charges has been summarised in a recent paper (ICCT, 2023).

Therefore, local authorities can select suitable measures from this vast number of data and literature. However, it has to be noted that in many cases essential data is missing on costs and effectiveness of the measures related to the impact on emissions and air quality for a number of reasons (EEA, 2013, EEA, 2018, ETC/ATNI, 2021). In addition, even if available, this data is dependent on the specific circumstances and thus cannot used for different situations in most cases. Nevertheless, local authorities are advised to liaise with other communities to exchange information, to learn from each other and to avoid repeating mistakes.

[41] https://aqportal.discomap.eea.europa.eu/index.php/users-corner/, last viewed on 4 October 2023.
[42] https://aqm.jrc.ec.europa.eu/measure-catalogue/, last viewed on 4 October 2023.
https://www.bast.de/DE/Verkehrstechnik/Fachthemen/v3-MARLIS/Hinweise_mit_Bestaetigung/Hinweise.html?nn=1817946, last viewed on 4 October 2023.
[43] https://environment.ec.europa.eu/topics/air/air-quality/time-extensions_en, last viewed on 4 October 2023.
[44] https://urbanaccessregulations.eu/, last viewed on 4 October 2023.

8. FUNDING FOR AIR QUALITY PLANNING

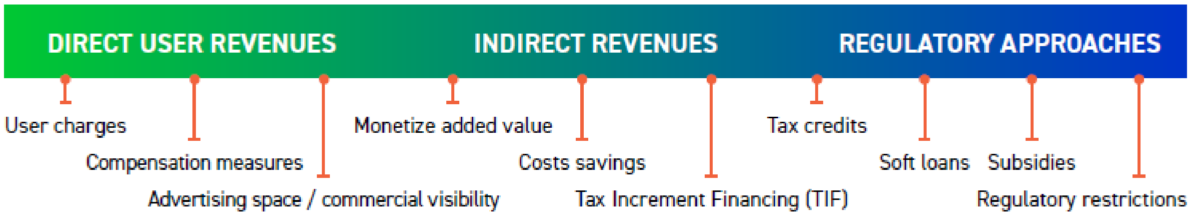
The improvement of air quality is in need of the deployment of significant financial resources. In this chapter we seek to lay down which resources can be employed to financially support the implementation of air quality measures. To do so, we provide a high level overview on potential sources of air quality measures, elaborate on different financing and funding options as well as identify EU and dedicated WB6 programmes, that are available for implementing national, regional and local air quality policies.

8.1. Potential source of finance and financing tools for air quality measures

In the first step, we aim at creating a common understating of key financial terms: Whereas funding generally refers to the capital that is provided without the expectation of repayment (e.g., government grants), financing is defined as capital (equity or debt), which is to be repaid in time (and mostly with interest). When discussing sources of finance, we generally differentiate between public and private sources of finance. Public sources may include the municipal, national or regional budget, fiscal initiatives or EU funds and programmes. In opposition, private sources of finance can come from commercial banks, private companies and retail or institutional investors (The European Investment Bank Advisory Hub & AMAT, 2018).

In the next step, we take a look at different financing options for air quality measures. They can be grouped according to whether they involve direct user revenues, indirect revenues or regulatory approaches (The European Investment Bank Advisory Hub & AMAT, 2018).

Figure 4: Financing options for air quality measures



Source: The European Investment Bank Advisory Hub & AMAT, 2018

- **User charges**: *E.g. Private vehicle owners can be forced to pay when entering a pollution-restricted area.*

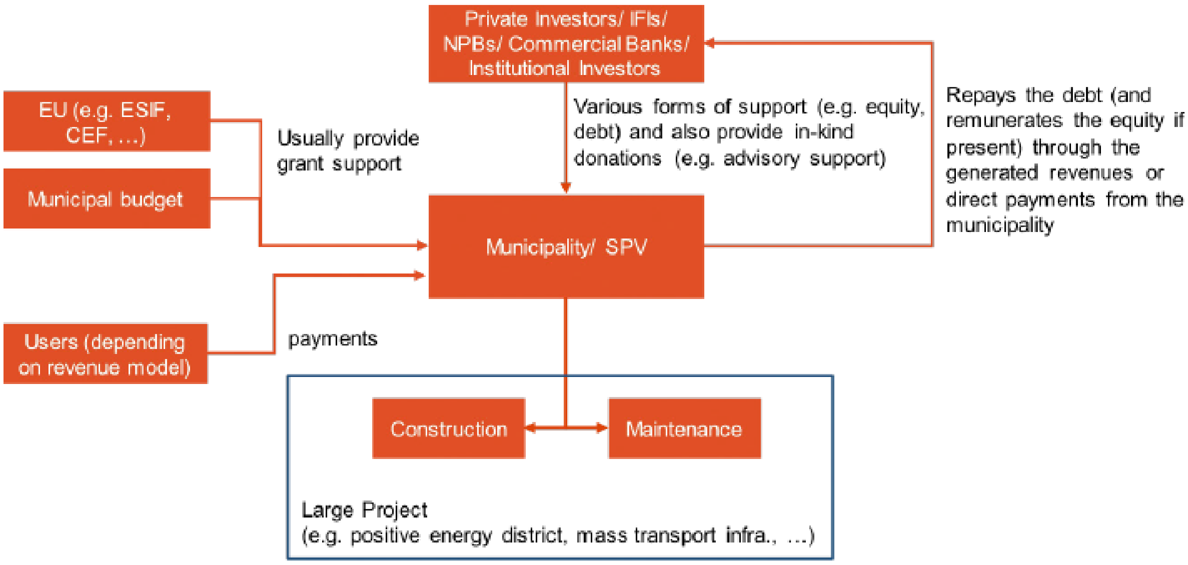
- **Compensation measures**: *Developers can be forced to pay a surplus costs for the construction of buildings subtracting agricultural areas.*
- **Advertising spaces/commercial visibility**: *Private companies are encouraged to invest in charging stations infrastructure when they have the possibility to display their logo or brand.*
- **Monetized added value:** Revenues come directly generated by the development or improvement of the goods or services offered. *E.g. Investment in eco districts would allow to improve buildings and infrastructure in the area, increasing the real estate economic value.*
- **Cost savings**: *Energy efficiency interventions allow to save costs of energy consumption.*
- **Tax Incrementing Financing (TIF):** TIF is a financing method by means of an investment, usually directed to the development or re-development of a specific area, whose repayment is anticipated from capturing the uplift in value via an increase in the tax base in the area directly affected by the intervention during operation. *E.g. TIF provides means for cities to gain approval of redevelopment of blighted properties or public projects such as city halls, parks, libraries etc.*
- **Tax credits** (for local authorities): Tax credits allow taxpayers to save costs by subtracting the amount of the credit they have accrued from the total they owe. *E.g. Member states may provide tax credit mechanisms in order to incentivize homeowners to develop energy efficiency interventions.*
- **Soft loans**: public authorities have the possibility to access loans made available at favorable conditions by int. financial institutions, national promotion banks etc. *E.g. Loans can be channeled through state owned banks at interest rates ranging from zero to just marginally below commercial interest rates for pollution abatement investments.*
- **Subsidies:** a measure to ensure that a certain category of users is incentivized to perform a specific action in line with the objectives of the provider of the subsidy. As cash-out, they are usually not related to any revenue or cost reduction, if not in the very long run (i.e. as the effect of the result of the incentive policy). *Private vehicle owners can be exempt from paying vehicles fees and taxes if they buy green vehicles.*
- **Prohibitions or restrictions:** provided by authorities without charges for users. The only source of funding could be provided by non-compliance charges/penalties fees for surpassing regulatory limits. *E.g., Municipalities and road transport authorities can deny permission to certain categories of polluting vehicles to enter certain areas.*

We have further common multiple financing mechanism for air quality measures, which include:

- Traditional loans and leases
- Revolving financing instruments
- Project finance
- Third party financing (TPF)
- Direct investment
- Project finance (PF)/Public Private Partnerships (PPP)/Concessions

Overall, the success of the financial project implementation depends on multiple criteria. When seeking to finance singular measures, one has to ensure that project characteristics match the eligibility criteria and investment conditions of the source identified. Further, the project needs to be monitored in coordination with the AQP as well as requires the local and municipal authorities to manage the procurement process and manage contractors. Finally, sufficiently developed legal frameworks (e.g., for PPPs and concessions) at the national level are required. In regards to multi-sector investment programs, a profound technical and administrative preparation of all the actors involved is needed. Coordination and cooperation across different municipalities and departments are necessary to avoid conflict. Informed project management plays a key role in the successful implementation. The graph below displays an example for PPP project management (The European Investment Bank Advisory Hub & AMAT, 2018).

Figure 5: Example of project management in a PPP



Source: The European Investment Bank Advisory Hub & AMAT, 2018

8.2. Identifying sources of finance for the Western Balkans

To identify suitable sources of finance for the Western Balkan countries in regards to air quality measures, we began by evaluating the potential of the Western Balkans Investment Framework (WBIF) considering its financing instruments as well as affiliated organisations before looking at EU funds and programmes that are open to the Western Balkans.

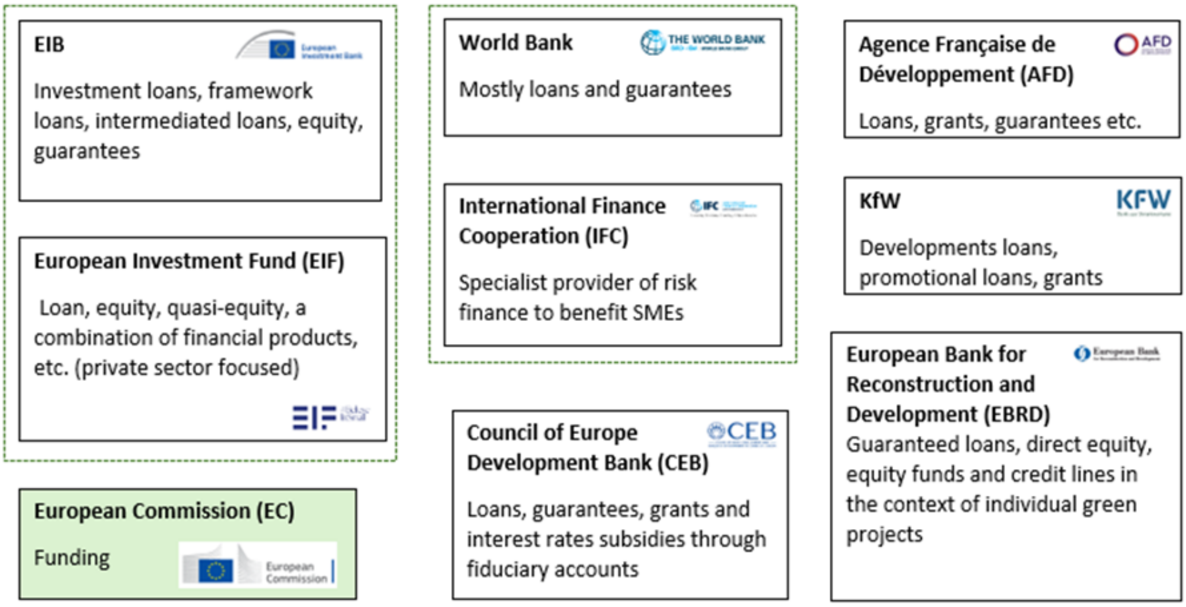
8.2.1. WBIF

WBIF was founded in 2009 and is a joint initiative of the EU, financial institutions, bilateral donors and beneficiaries, aimed at enhancing harmonization and cooperation in investments for the socio-economic development in the Western Balkans. It constitutes a donor investment platform that pools funds from various sources (also referred to as blending). It facilitates grants, guarantees and loans for energy, environment, social, transport and digital infrastructure as well as for private sector development projects, following annual or bi-annual calls for proposals. The Intervention areas of WBIF evolve around sustainable transport, clean energy environment and climate, digital future, private sector, human capital (WBIF, 2024a). In particular, the WBIF covers the following areas related to air quality measures (WBIF, 2022):

- Energy efficiency (e.g., for public and private buildings, construction of district heating systems)
- Clean energy (including e.g., solar, wind farm, hydropower, biomass, electricity and heat generation)
- Sustainable transport
- Climate-smart technologies and techniques in the field of solid waste management
- Pollution prevention measures
- Sustainable agriculture

The WBIF has nine partner organizations, which different sources of funding and financing mechanisms as listed below:

Figure 6: WBIF partner organizations



Source: WBIF, 2024a, own display

WBIF employs four different financial instruments of which we found three to be potentially relevant for supporting the implementations of air quality measures. These instruments are grouped according to the type of financial instruments they employ, types of projects the support and potential beneficiaries.

Table 7: WBIF instruments

Name of instrument	Financial instrument employed	Types of projects (selection)	Beneficiaries
Regional Energy Efficiency Programmes (REEP)[45]	Loans, grants	Financial assistance to those wanting to invest in energy efficiency and small-scale renewable energy projects. WebGEFF focuses on residential sector energy efficiency and small-scale renewable investments implemented by individuals and housing associations.	Households, businesses, public authorities (municipalities)
Green for Growth Fund (GGF)[46]	Blended finance structure (PPP) to substantially increase investment volumes to regions and sectors that do not normally attract such flows, sub-loan investments	Investments are conducted in measures that reduce energy consumption, resource use and CO_2 emissions	Households, Businesses
European Fund for Southeast Europe (EFSE)[47]	Financing provided to financial institutions	investing in the success of micro, small and medium enterprises (MSMEs) as well as improved living conditions for private households	Households, MSMEs (via financial institutions)

Source: WBIF, 2024c, Green for Growth Fund, 2024, EFSE, 2024

In addition to the above mentioned, WBIF provides grants for energy, environment, social, transport and digital infrastructure as well as for private sector development. Private sector development grants may also be allocated to specific initiatives which complement infrastructure projects and help achieve the WBIF's goals and objectives. Grants are allocated following annual or bi-annual calls for proposals. In order for grants to be allocated, project applications must meet the eligibility criteria set forth for a specific call as well as respond to the requirements detailed in the Guidelines relevant for the type of grant support - technical assistance or investment grants[48]. As defined by the WBIF Steering Committee, only projects submitted and/or endorsed by the National IPA Coordinators

[45] Useful information: Advice for Small Businesses (ebrd.com) (EBRD and KfW are the implementing IFIs for REEP)
[46] Options for technical assistance
[47] Options for technical assistance: EFSE: The Development Facility
[48] Useful information can be found here: WBIF Guidelines for Applicants_Dec2023.pdf; Annex 1_WBIF Strategic Orientation.pdf; wbif-cv-guidelines-and-plan-2023-24-web-version.pdf

(NIPACs) are eligible for consideration (WBIF, 2024b). The NIPACs obtain the project applications from line ministries.

8.2.2. EU funds and programs

Out of the multiple EU funding programs[49] made available for WB6 upon payment of the respective entry tickets, we argue that Horizon Europe as well as the Programme for the environment and climate action (LIFE) could potentially best support the implementation of air quality measures in the Western Balkans.

Table 8: EU funds and programs

Name of program/fund	Financial instrument employed	Types of projects (selection)	Beneficiaries
Horizon Europe[50]	Mostly grants complemented with dedicated financial instruments	Pillar II: supports research relating to societal challenges and reinforces technological and industrial capacities through clusters Pillar III (innovative Europe) supports all stages of innovation, from research and development on the scientific underpinnings of breakthrough technologies, to the validation and demonstration of breakthrough technologies and innovations to meet real-world needs, to the development and scaling up of start-ups and SMEs.	Businesses, public authorities, NGOs, research institutions
Programme for the environment and climate action (LIFE)[51]	Mostly grants (broadly constituting about 85 % of the total budget). They can co-finance up to 95 % of project costs,	LIFE funds environment-specific and environment-integrated projects (including nature and biodiversity, circular economy and quality	Public and private authorities

[49] The indicative list of Union programmes where the beneficiaries can participate includes (but it is not limited to): Erasmus+6 , Horizon Europe, Single Market Programme, Creative Europe, Customs, Fiscalis, EU Programme for Employment and Social Innovation (EaSI), EU4Health, Civil Protection Mechanism, Citizens, Equality, Rights and Values (CERV), Justice, European Solidarity Corps, LIFE, EU Anti-fraud programme, Digital Europe Programme (European Commission (2023a)).
[50] Options for technical assistance: Apply for funding
Further resources: Work programmes
[51] Further resources on LIFE: https://cinea.ec.europa.eu/programmes/life_en

	as outlined below, depending on the type of projects. Other forms of funding include procurement contracts, prizes and technical assistance for investment operations.	of life, climate change mitigation and adaptation, clean energy transition) It may also finance technical assistance for investment operations.	

Source: European Commission, 2024b, European Union, 2024, European Commission, 2024a, European Commission, 2023b

8.3. Interventions from international financial institutions

Throughout the workshop we received presentations from two international financial institutions, namely KfW and the World Bank (KfW, 2024a, KfW, 2024b, World Bank, 2024). [52]

8.3.1. World Bank

The World Bank's contributions to the workshop focused on an air quality improvement project they are currently implementing in the FBiH as well as certain Cantons (project extension further Cantons is possible). Overall, the project aims at strengthening mechanisms at all levels for AQM and improve existing mechanisms by increasing efficiency, knowledge and technology availability. Quantitative goals of the project are reducing emissions from domestic heating and reduced emissions from urban transport in Canton Sarajevo. In addition, World Bank referred to the implementation of an air quality report they conducted in BiH, North Macedonia and Kosovo in 2019 as well as a regional trust fund work that allowed for e.g., revising the intervention plan for times of excessive air pollution in Sarajevo (World Bank, 2024).

8.3.2. KfW

KfW reported on their energy efficiency programs in Bosnia and Herzegovina as well as district heating project in Prishtina, Kosovo (KfW, 2024a, KfW, 2024b). In Bosnia and Herzegovina, one part of the project is concerned with increasing energy efficiency in residential housing. More precisely, KfW supports Raiffeisen Bank Bosnia and Herzegovina in introducing a new Credit Program for energy efficiency improvements in residential housing with the program goal to contribute to the climate and environment protection and improvement of living conditions by improving energy efficiency (EE) in residential housing and SMEs and reducing air pollution. Moreover, the project shall contribute to a sustainable

[52] https://eu4green.eu/air-quality-management-hybrid-workshop/, last checked on 10.5.2024

incorporation of EE financing products into product portfolio of local commercial banks in Bosnia and Herzegovina. The program implementation runs in coordination with the Regional Energy Efficiency Program REEP+. The second part of the project promotes energy efficiency and improvement of public services in schools and kindergartens including higher education institutions by investing into EE measures including energy audits, preparation and revision of design documentation, energy certification, energy consumption metering equipment, supervision and other related activities. This resulted e.g., in the rehabilitation of 15 to 20 schools in FBiH and RS (KfW, 2024b).

KfW's district heating project in Prishtina, which started in 2010, has resulted in the provision of 24/7 service as winter and a significant cost reduction for costumers when compared to before the project. The district heating company does not rely on subsidies anymore and has started operating with profits. The consequent solar district heating project "Solar4Kosovo" foresees the implementation of a solar district heating plant becoming one of the largest solar thermal plants in Europe over the implementation period 2022-2027 (KfW, 2024a).

9. FURTHER READING, GOOD PRACTICE EXAMPLES

As described in section 7.5, a large number of air quality plans and an even much larger number of measures is available. A selection of good practice examples can be found in the following literature. In addition, under the Swedish “Partnership for Improving Air Quality in the Western Balkans” good practice examples are currently collected and should soon be available.[53]

9.1. Air quality management

- Best practices for local and regional Air Quality management (Pisoni, et al., 2022)
- Air Pollution Management in a World under Pressure (Nordic Council of Ministers, 2023)
- Protecting health through ambient air quality management (WHO Regional Office for Europe, 2023)
- Code of good practices for cities air quality plans (Urban Agenda for the EU, 2019)
- Air implementation pilot - Lessons learnt from the implementation of air quality legislation at urban level (EEA, 2013)
- Europe's urban air quality - re-assessing implementation challenges in cities (EEA, 2018)
- Air Quality and urban traffic in the EU: best practices and possible solutions (Nagl, et al., 2018)
- Implementation of the Ambient air quality Directive (Nagl, Schneider, Thielen, 2016)
- Good Practice Guide for Air Quality Monitoring and Data Management 2009 (Ministry for the Environment, 2009)

[53] https://www.smhi.se/en/services/international-development-cooperation/projects/partnership-for-improved-air-quality-in-the-western-balkans-1.206508, https://www.naturvardsverket.se/en/international/cooperation/bilateral/western-balkans/, last viewed on 11 September 2024

9.2. Guidance for air quality planning

Guidance for air quality planning is inter alia available in the following literature:

- Code of good practices for cities air quality plans (Urban Agenda for the EU, 2019)
- Guideline on Air Quality Plans (Umweltbundesamt Dessau, 2016)
- Local Air Quality Management[54] (DEFRA, 2009)

9.3. Information about initiatives and platforms

In addition, a number of websites provide material and information about initiatives and platforms:

- UNEP BreatheLife: a global campaign for clean air, including good practice examples: https://breathelife2030.org/
- C40 global network of mayors to confront the climate crises and to clean the air of their cities: https://www.c40.org/accelerators/clean-air-cities/
- Collection of urban traffic access regulations: https://urbanaccessregulations.eu/

9.4. Participation

A recent scoping studies provides a review of different approaches to engage communities to address air quality (Ward, et al., 2022).

Further information, studies and examples can be found here:

- EU projects to support municipalities in participation processes, e.g. URBAN ACT IV (URBACT)[55]
- Sharing of experience:
    - CITEGO: promotes the exchange of experiences and knowledge sharing between practitioners, researchers, elected officials, associations and citizens[56]

[54] https://laqm.defra.gov.uk/guidance/, last viewed on 4 October 2023.
[55] https://urbact.eu/
[56] http://www.citego.org/index_en.html, last viewed on 22 February 2024

    - Wiki for participation (European Institute for Public participation)[57]
    - Aarhus Clearinghouse includes good practice examples[58]
    - International Observatory on Participatory Democracy[59]
    - Balkan Civil Society Development network[60]
- Guidance documents for public participation
    - Guide to public participation and facilitation (Lisode, 2017)
    - US EPA online public participation guidance[61]
    - OECD Guidelines for Citizen Participation Processes (OECD, 2022)
    - UNDP selected case studies for promoting sustainability development through more effective civil society participation (United Nations Development Programme, 2016)
    - The public participation handbook (Creighton, 2005)

9.5. Communication

Further information can be found in a number of reports:

- "Communicating the health impacts of air pollution". This guidance was developed through focus groups, online message testing, and consultation with key organisations working on air pollution in order to uncover the best ways to engage and drive public action on improving air quality (Clean Air Fund, 2019).[62]
- "Communicating Air Quality and Health: A media toolkit for health professionals in India." This toolkit address health professionals as advocates for solutions and raising awareness (HEAL, 2020).
- "Toolkit: Communicating on air quality and health - Inspiring practices, challenges and tips": The toolkit shares examples of successful measures to trigger participation and to coproduce solutions (Urban Agenda for the EU, 2018).
- "How to talk about air quality and environmental health". The guidance provides effective communication strategies for designing policies and practices, improve public understanding and motivate people to act and support policies (The Workshop, 2020).

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[57] https://participedia.net, last viewed on 22 February 2024
[58] https://aarhusclearinghouse.unece.org/, last viewed on 22 February 2024
[59] https://oidp.net/en/, last viewed on 22 February 2024
[60] https://balkancsd.net/, last viewed on 22 February 2024
[61] https://www.epa.gov/international-cooperation/public-participation-guide-introduction-guide, last viewed on 22 February 2024
[62] https://www.cleanairfund.org/resource/communicating-the-health-impacts-of-air-pollution/, last viewed on 23 February 2024

- “Personal interventions and risk communication on air pollution: summary report of WHO expert consultation”: Even though individual interventions should complement – and certainly not substitute for – AQPs, WHO has published this report to provide the health sector with sound, reliable guidance on mitigating the risks of air pollution. It includes a review of the current scientific literature on individual interventions to reduce exposure to air pollution. The guidance also discussed the best ways to communicate (WHO, 2020). Recently, WHO published a further study on “Personal-level actions to reduce air pollution exposure in the WHO European Region” (WHO Regional Office for Europe, 2024).
- “Public awareness and efforts to improve air quality in Europe”: This report on behalf of EEA describes examples of public information, research on perception of air quality and successful examples of communication (ETC/ATNI, 2020, EEA, 2019a).
- The resource package “Protecting health through ambient air quality management” by WHO includes a number of international resources for communication and awareness raising (WHO Regional Office for Europe, 2023).
- The State of Global Air website provides a factsheet for air pollution and health to facilitate communication.[63]

9.6. Funding

KfW’s district heating project in Prishtina can be considered a good practices case as it resulted in significant emissions reductions as well as the district heating company to operate with profits (Lugavić, 1 Feb. 2024). The continuation of the project is promising.

9.7. Clean Air Regions Initiative - CARI

Nine Western Balkans municipalities within the Energy Community have started the Clean Air Regions Initiative (CARI) to inter alia develop, adopt and maintain AQPs, and to share experiences.[64]

[63] https://www.stateofglobalair.org/resources/factsheet/air-pollution-and-your-health, last viewed on 23 February 2024
[64] https://www.energy-community.org/regionalinitiatives/Transition/CARI.html, last viewed on 22 February 2024

Within the first phase of the initiative, seven trainings took place.[65] Within the second phase, local AQPs will be developed, and regional and international exchange will be strengthened. Municipalities can build on these experiences.

9.8. Source apportionment Skopje

The source apportionment study for the city of Skopje by the University Goce Delcev on behalf of UNDP is a good practice example for applying well established methods to identify the main sources for PM in a city (University Goce Delcev, AMBICON Lab, 2022).

9.9. Air quality sensors

Next to brochures and reports described in section 6.8.2.2, further information can be found here:

- The EU project VAQUUMS (Various Assessments of air QUality Measurement methods and their policy Support) investigated the quality of various measurement methods and assessed which methods can be a valuable addition for reference measuring stations.[66] Furthermore, it provides an online guideline and webinars for air quality sensors.[67]
- FAIRMODE WG6 - Sensors and data-fusion discusses regularly the strengths and weaknesses of the different ways low-cost sensors can be used in conjunction to modelling.[68]

[65] https://www.energy-community.org/regionalinitiatives/Transition/CARI.html#7ky558-accordion, last viewed on 22 February 2024
[66] https://www.vaquums.eu/, last viewed on 23 February 2024
[67] https://www.vaquums.eu/news/a-tour-of-our-outcomes-guidelines-on-using-air-quality-sensors, last viewed on 23 February 2024
[68] https://fairmode.jrc.ec.europa.eu/activity/ct6, last viewed on 23 February 2024

10. ANNEX 1 – MODELING GUIDANCE SMHI

The following guidance for **choosing a model type** was machine translated from the modelling guidance document of the modelling reference laboratory of the Swedish meteorological and hydrological institute (SMHI, 2022a).

Modelling of air quality in urban environments - Guidance for choosing a model type

2022-04-26 – Updated 2022-10-12 [Version 1.1]

Referenslaboratoriet för luftkvalitet – modeller (SMHI)

10.1. Content

10.2. Introduction

The extensive construction of mainly new housing means that cityscapes are changing, often towards more enclosed street spaces and thus poorer ventilation of traffic-generated air pollution. Therefore, the need for model calculations at ground level has increased. Modelling of air quality is needed to ensure that current environmental air quality standards (AQS) for outdoor air are followed even after construction is completed and in the work to achieve the environmental goal fresh air. There are a large number of different simulation models, and it can be difficult to know which type of simulation model is most appropriate in different situations.

So far, there has been a lack of general guidance on appropriate model selection for different building structures. The purpose of this guide is to create a better understanding in the choice of model type. The guidance is based on the results and literature study from a modelling project (Haeger-Eugensson et al., 2019). It is primarily aimed at municipalities and other model users, as well as clients and developers to, among other things, facilitate model selection for users and specification of requirements when procuring air quality investigations.

The dominant source of pollution levels in our urban areas is in most cases road traffic, and the highest levels thus occur in street spaces. With buildings on both sides, the local contribution to pollutant concentrations is often significantly higher compared to an open road. In some cases, especially in metropolitan municipalities, it can also be a nearby major road that gives rise to relatively high concentrations and which spreads over and around buildings to nearby smaller streets. The models compared in this guidance are thus those that are clearly focused on simulating road traffic emissions and their distribution.

In order to do an air quality modelling, in addition to the dispersion model itself, you also need:

- ✓ background air quality levels
- ✓ calculations of exhaust and non-exhaust emissions (e.g. road wear) from different vehicle types
- ✓ traffic data (such as number of vehicles, proportion of heavy traffic, posted speed and, if relevant, proportion of vehicles with studded tyres)
- ✓ locally adapted meteorology
- ✓ quality assurance of input data
- ✓ if it is not already included in the model, a base map containing buildings and their height, road surface and other objects in the area is also needed.

Urban background concentration needs to be added to the calculation of local contribution to get the total concentration of the air pollution. Depending on the selected model, data processing in the form of conversion from NOx to NO_2 may also be added as well as calculation of relevant percentiles. Some model systems include necessary steps regarding input handling and processing of calculation results, while other individual models require the user to do these steps himself. This is described in more detail under 10.4 Input data to models.

As a supplement to this guidance for choosing a model type, the website for Reflab - models (Reference laboratory for air quality - models) provides more detailed information on individual models and model systems as well as advice in general on modelling air quality, see section 10.5.

10.3. Air quality modelling – which model to choose?

The section first provides a brief introduction to the history and the problem around air quality modelling. This is followed by an overall description of three common model types, a guide with guiding questions to help in the choice of model and finally a number of examples of buildings situations and advice on the choice of model.

10.3.1. Densification requires dispersion modelling

Urbanization and densification of cities can create air quality problems and discussions about what kind of models should be used in that kind of environment have been going on for a long time. Traditionally, mainly Gaussian and/or Eulerian models have been used and great focus has also been on building up databases with input data for dispersion models for both urban areas and entire countries with sufficiently relevant input data. In Sweden, the concept has been further developed by the Swedish Environmental Protection Agency, the Swedish Transport Agency and SMHI having financed the development of SIMAIR, which includes a semi-empirical OSM (Operational Simulation Model) street space model. This gave municipalities an opportunity to more easily carry out calculations even in street rooms and thus be able to improve the monitoring of air quality.

The building has a major impact on the mixing of the air at ground level and thus the spread of air pollution. Depending on how the building structure looks, winds and dispersion are affected to varying extents. In line with increased densification, questions now arise more and more often about how new buildings affect air quality. An example is the physical planning of new buildings, where account must be taken of the AQS, but since it usually applies to future situations, a comparison should also be made with the air quality targets. If there is a risk of exceeding the AQS, the plan can be cancelled or changes can be demanded.

Today's urban development often means densification in central parts and with nearby high traffic loads. A large part of the new development will be residential, which means that more people are at risk of being exposed to the levels that will occur after the planned areas are built. Detailed calculations of traffic emissions and their spread in the street space then become a necessary tool to produce relevant data. It enables well-thought-out planning right from the start, as in this phase there is a greater opportunity to influence the design through well-thought-out planning of both the building and surrounding green areas.

In many cases, the densification therefore places increased demands on the degree of detail of the results when modelling the air quality. In practice, this means that models are required that can explicitly take into account the building structure and its variation within the street space in 3D, for several levels above the ground and also be able to include transport between street spaces, e.g. over roof.

There have previously been no recommendations on model selection for air quality modelling in urban environments either nationally or, to our knowledge, internationally.

10.3.2. Overview of model types included in this guide

Below is a brief overview of the three most common model types for air quality calculations and their general calculation principles. They are presented in increasing degree of complexity and level of detail.

Gaussian models have a long history of use and were created to be able to calculate concentrations from elevated chimney emissions. They are based on the assumption that the concentration in a cross-section of a smoke plume is Gaussian (normally distributed) in horizontal and vertical directions. The Gaussian assumption often works well when calculating hourly average concentrations on a local scale (≤ 10 km). Gaussian models do not take buildings into account and are therefore not suitable for calculating concentrations at ground level in street spaces. A Gaussian model is normally two-dimensional and the slope is calculated for a certain height above the ground where the buildings are only included through a roughness parameter.

Examples of model systems: SIMAIR intersection, Airviro Dispersion, ADMS, AERMOD

Operational dispersion model for street environments (OSM - Operational Simulation Model) calculates the local contributions from the vehicles that use the street in question. The emissions consist of two concentration contributions, partly direct emission from exhaust pipes to a receptor point, partly pollutants that circulate in the more or less closed street space. The latter is simulated with a so-called box model, where the pollution is considered to be evenly distributed in a volume determined by the width of the street space (the distance between the houses on either side) and the building height along the street. Resulting concentrations are obtained on both sides of the street, but the description of air flows around buildings is simplified. For particles, there is a third concentration contribution in the form of turbulence from accumulated road dust.

In Figure 7, the wind sectors used in the OSM model are visualized. The dispersion calculations are affected by the geometry of the street space and the height of nearby buildings affects the circulation. The result is presented in the two receptor points on each side of the street.

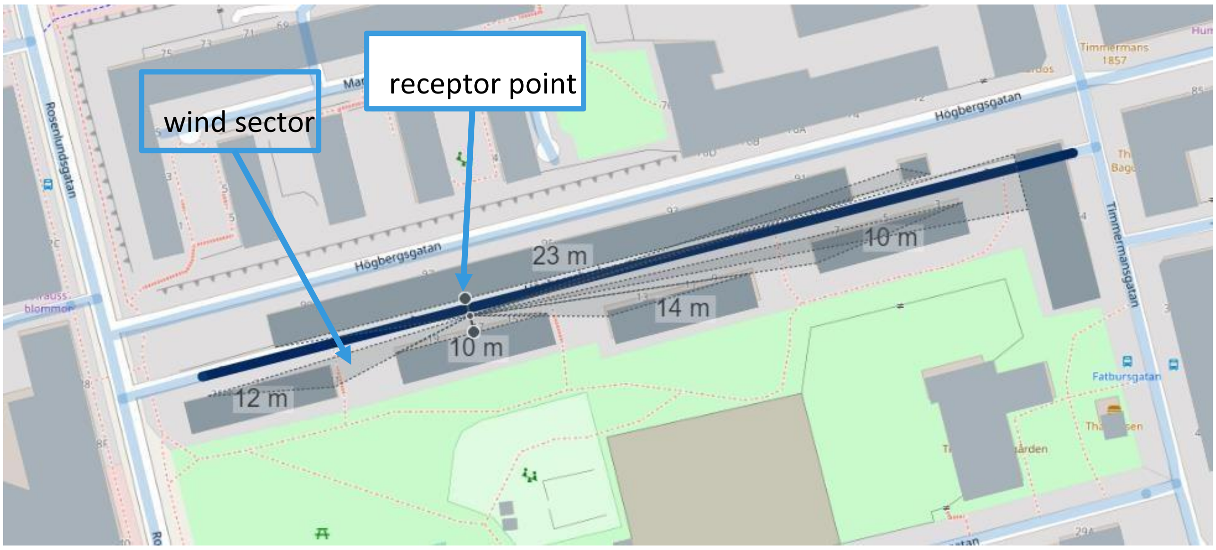


Figure 7. ***Visualization of wind sectors (the grey shaded triangles from buildings to the receptor points) used in an OSM calculation. The height of nearby buildings affects the circulation pattern.***

Dominant modelling systems of this type are user-friendly and have well-developed methodology for handling input data such as calculation of air pollution levels for each hour over a year, based on meteorological input data with the same time resolution. Even background levels can be provided with high time resolution. The model type is relatively easy to use.

Examples of model systems: SIMAIR pathway, Airviro Dispersion, OSPM

Flow simulating models (CFD - Computational Fluid Dynamics) is a numerical flow and dispersion model that describes in detail wind flows and concentrations in a three-dimensional calculation grid. Flow conditions are calculated for, for example, about a hundred different combinations of wind speed and wind direction and thus the spread of air pollutants at these wind conditions. The typical spatial scale is in the order of magnitude from single street canyons (streets with buildings on both sides of the road) to several city blocks but is not suitable for larger overall mapping as the modelling time can be long. In the vertical direction, the calculation is made from ground level up to a height of several hundred meters. The model type can also take into account interaction with emissions from/to surrounding streets through its possibility of import/export to/from adjacent roads or other emission sources via dispersion over and around buildings, thus providing concentration values over the entire calculation area.

The model type requires post-processing of calculation results to obtain concentrations that can be compared against, for example, AQS. It requires a relatively high level of knowledge and skills associated with the calculations and is generally more time-consuming than Gaussian models and OSM models. Examples of model systems: OpenFOAM, MISKAM

10.3.3. Guiding questions before model selection

Before choosing a model, the primary purpose of the modelling needs to be determined. Most of the time, it is monitoring or planning issues that are the main current purposes, but there may also be other issues that require dispersion calculations. The purpose of the exposure calculation must be decisive for which model resolution is used. Calculation with coarse resolution of population data and coarse model resolution risks giving an incorrect picture of the exposure in e.g. street room.

In order to facilitate reasoning about how one should think when choosing a calculation model, a number of questions have been identified that can provide guidance before the decision. These questions are linked to the purpose of the dispersion calculation and the physical conditions of the area. The main purposes are, as mentioned above, usually:

1. **Monitoring** – often against the background of the obligation each municipality has to monitor and report on its air quality.
2. **Planning issues** – usually in connection with planned new construction in an urban environment, often directly related to the preparation of a new detailed plan. This may also apply to new roads within densely built-up areas.

If *monitoring* is the primary purpose of the dispersion calculation, this purpose often makes somewhat less demands regarding the degree of geographic detail of the results. The primary question here is of a more comprehensive nature, to get a general picture of the concentration contributions from all sources – vehicle emissions, industries, etc. – and their distribution over a larger area. The purpose can also be to identify areas with high levels and assess whether the AQS is being followed or is at risk of being exceeded. For this type of question, Gaussian models in combination with a street space model (e.g. OSPM) can provide good enough information. Gaussian models provide levels at roof level or 2 m above ground in open terrain, while street space models are suitable for use in the more densely built-up areas of a municipality to take into account the impact of buildings on air pollution levels. A combination of these two model types can provide a good overview of the concentration distribution in a municipality and is used today by a number of municipalities and cooperation areas as an important part of their control strategies for air quality.

If *planning issues* are the primary purpose, there may be a need for detailed information regarding the spatial distribution of pollution levels in street spaces, especially if there is a risk of high air pollution levels. Here there are more parameters that the model must be able to take into account, which increases the degree of complexity. For example, it may be necessary to describe the dispersion conditions in the street space using building heights and the width of the road. In such cases, at least a semi-empirical modelling such as OSPM or a model where a three-dimensional wind pattern needs to be calculated, i.e. a CFD model, is required. However, it is not always obvious which type of model is most suitable for an air quality investigation. As the demand for both input data and knowledge on the part of the user often increases with increasing model complexity, the choice of model often becomes a trade-off between the effort required to use an advanced model and requirements for the level of detail in the specific case. In Figure 8, support for model selection is visualized based on a number of guiding questions.

When it comes to a fairly regular building structure with more or less closed street spaces, or when expected levels are relatively low, an OSM model is often the most appropriate choice in planning matters.

In some cases, it may be justified to use a CFD model. This concerns, for example, situations where planned development is complex and especially if critical concentrations can be feared in relation to AQS and evaluation thresholds.

Even in complex environments, simpler flow approaches than CFD can sometimes suffice, namely if the concentration level is relatively low. If it is found with the help of other model types that the content level is by a margin below AQS levels, a CFD modelling can be judged as redundant. Higher resulting concentrations, on the other hand, can lead to the conclusion that one needs to proceed with CFD calculations. Sometimes it may be appropriate to use more than one model type, or sometimes to first use a simpler model type and then, depending on the outcome, possibly proceed with a more advanced variant, such as a CFD model.

However, when it comes to areas close to roads without nearby buildings, it is usually sufficient to use a Gaussian model. Regardless of which model is chosen, it is important to use local meteorology and other quality-assured input data as described in section 10.3.

In the end, the various advantages and disadvantages of different model types must be weighed together. The decisive factor may then be how in the individual case there is reason to place more or less weight on the various factors.

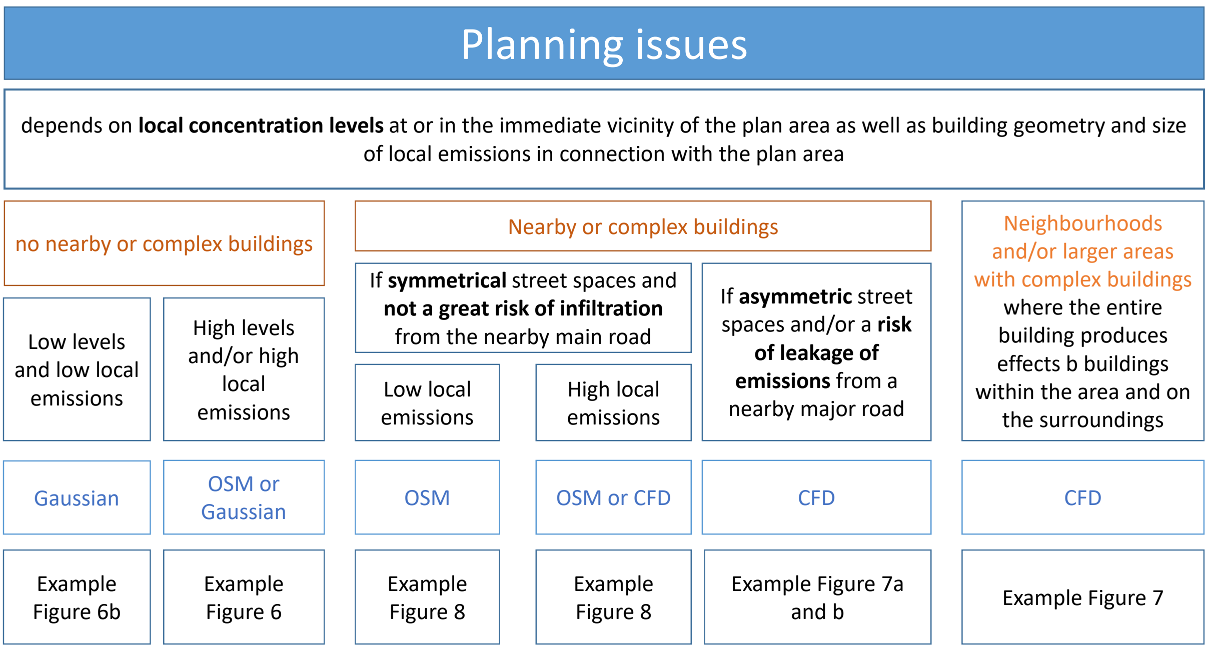


Figure 8. ***Methodology for model selection for calculations in different types of street environments and more or less complex urban environments, with examples from this study (see also Haeger-Eugensson et al. 2019).***

The workflow in Figure 8 works so that in the case of a current planning issue - define first whether or not there are nearby complex buildings or whether there are blocks and/or larger areas with complex buildings. The next selection is below the respective overall selection. If, for example, "Nearby complex building" is selected, there are several further underlying choices to be made. Is it a symmetrical street space without a high risk of significant infiltration from surrounding sources? If there are low emissions in the street space in question, OSM is preferably chosen. If, on the other hand, there are high emissions, either OSM or CFD can be chosen, depending on the purpose and the need for detailed information within different parts of the street space.

If it is instead a very asymmetric street space and/or there is a risk of significant leakage, a CFD model is generally recommended as the complex wind field generated in these cases is difficult to simulate in a realistic way with another model.

10.3.4. Examples of building situations and choice of model

There are thus some important factors to take into account when choosing a suitable calculation model: the local concentration level, the building geometry and the local emissions.[69] In the following section, some examples of built-up, concentration and emission-related factors that are important in model selection and the effect on the calculated concentration level are illustrated and briefly discussed.

10.3.4.1. No nearby or complex buildings

When air pollution spreads from an open street/road without nearby buildings, there are no obstacles in the form of buildings that control or modify the wind and thus the spread takes place more "freely", which Gaussian models can describe. In Figure 9a, an environment with "open road" without nearby buildings is visualized. In Haeger-Eugensson (2019), such an example has been calculated both with a Gaussian model and compared with the results from a CFD model. The comparison is shown in Figure 9b and c. Here it appears that there is very little gain from using a CFD model both on the main road but also on the crossroads, compared to a Gaussian model.

[69] The difference between emissions and levels is that emissions are the emissions themselves from, in this case, road traffic. It is thus the emission from the internal combustion engine (particles and nitrogen dioxide) and wear particles from tires, brakes and swirled particles from the road surface. Local levels refer to total pollution levels in the street space, which is affected by background levels from the area as well as long-distance transported air pollution.

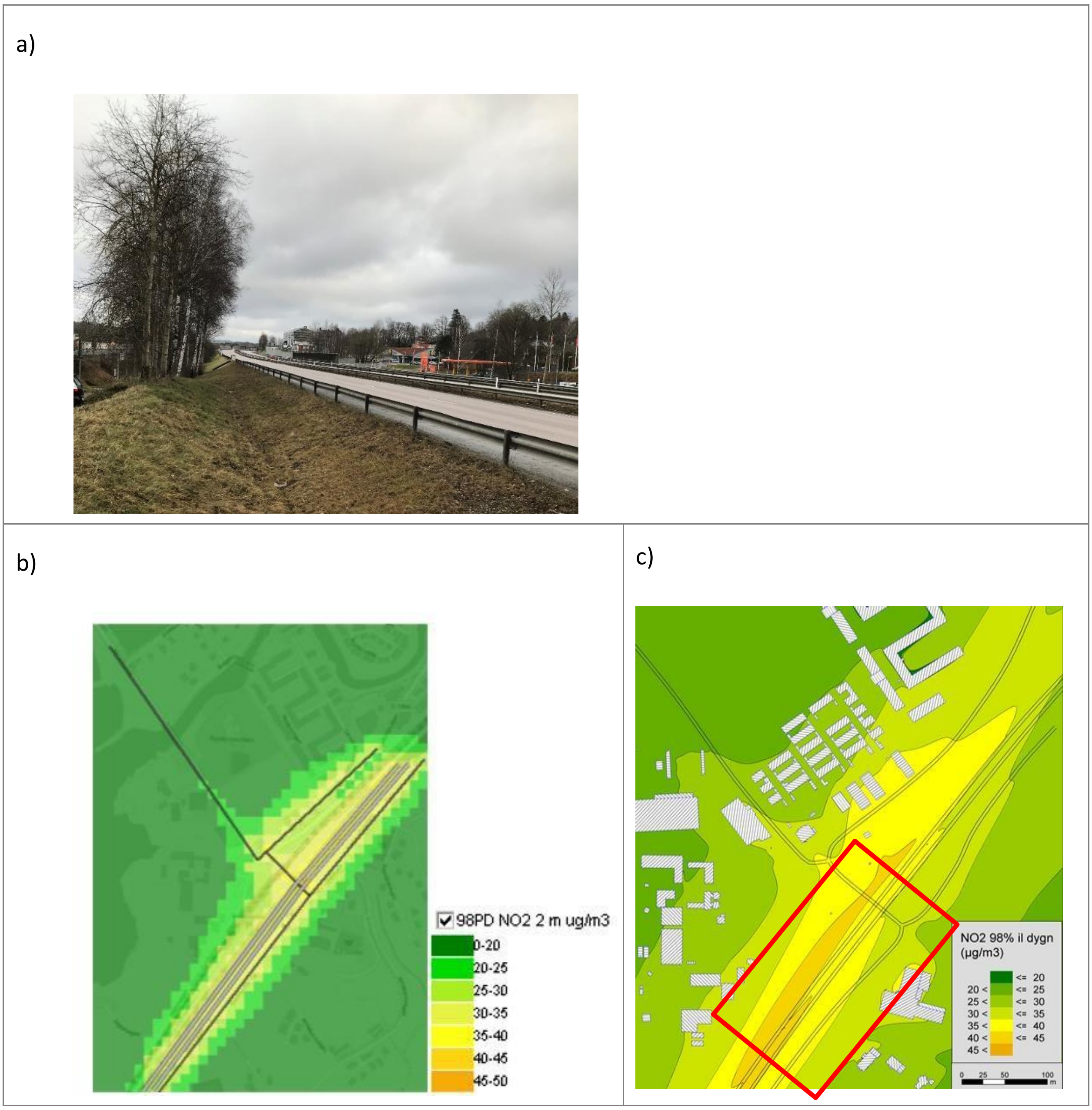


Figure 9 ***a) Illustration of an open road (approx. the area in red box in figure c) and dispersion calculations with b) Gaussian model (ADMS) and c) CFD model (Miskam).***

10.3.4.2. Nearby irregular buildings

In Figure 10, two different types of street space are exemplified, partly a larger traffic route with single-sided irregular buildings, and partly double-sided street space with dense and irregular buildings. Both are shown in all the figures below marked with a and b respectively.

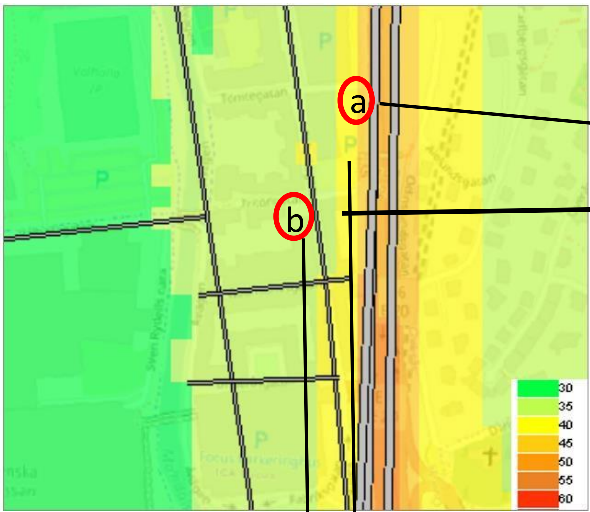
In street space/section (a) the emissions are very high. Emissions are also relatively high in street room (b).

Important factors when choosing a model in this type of area is to, in addition to the built-up structure, also take into account the level of both local emissions and the urban background level. High local emissions may justify the use of the CFD model if there is a risk of export/import of air pollution between surrounding sources, such as nearby streets/routes with high emissions. If, on the other hand, the concentration level falls below the critical comparison levels by a margin, a CFD modelling can be deemed redundant. Then OSM is completely sufficient.

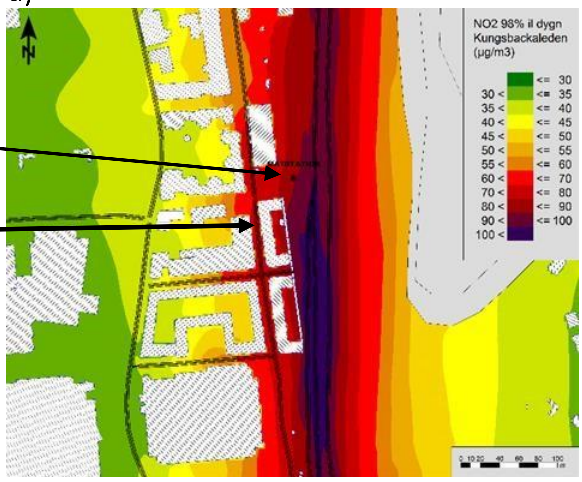
a) Street room/path

b) Street room

c)



d)



e)

Figure 10*. Illustration of two types of street space, a) highly trafficked road, partly single-sided street space and b) double-sided street space with complex buildings and relatively high traffic. In c) the result calculated with Gaussian modelling, d) with CFD modelling and e) with OSM model is shown. The location of the photos is indicated in the gradient maps with a and b respectively.*

For the traffic route (location a above): The result in Figure 10c and Figure 10d shows that the percentage differences are large between the Gaussian and CFD model results (Figure 10d). The reason is that there are no buildings included in Gaussian models that limit the dispersion, so the dispersion pattern becomes unrealistic both near and at a distance from the source. A Gaussian model is not appropriate here.

The difference is also large between the CFD (Figure 10d) and the OSM model (Figure 10e). The reason for the relatively much higher concentrations in the CFD modelling is likely that there is a more detailed transport over and around the shielding building from the adjacent joint compared to the more simplified handling of the OSM model. Depending on the size of urban background concentrations and/or the size of the emission, either an OSM or CFD model is required.

For the local street (location b above): Here, too, the difference in level is very large between Figure 10c, Figure 10d and Figure 10e. Here, too, a Gaussian model is unsuitable because it cannot take into account the built-up in 3D.

The OSM model also greatly underestimates the content in the street space in this example, which could be due to both the limited possibility of inbound transport from adjacent roads and also that consideration of the variable built-up area is not included with the same degree of detail, which affects the spread internally in the street space.

10.3.4.3. Nearby regular buildings

Figure 11 shows an example of a street room with double-sided (also called closed) and relatively even height buildings. Here, the difference between OSM and CFD modelling is shown, but also the difference if surrounding streets with little traffic are also included in the CFD modelling.

The result shows that the OSM model can identify the concentration level in the street space, which the CFD model also does, but if it is to be investigated if AQS is followed in the street space, the OSM model is fully sufficient. When comparing the effect of transport contributions from surrounding streets, this is minimal as the emissions here are very low. If the purpose is monitoring, the use of CFD modelling is not justified. If there is a planning purpose where detailed concentration levels might be needed along the street space, a CFD model may be needed. In this example, there is no Gaussian modelling as it is excluded to use for this type of situation.

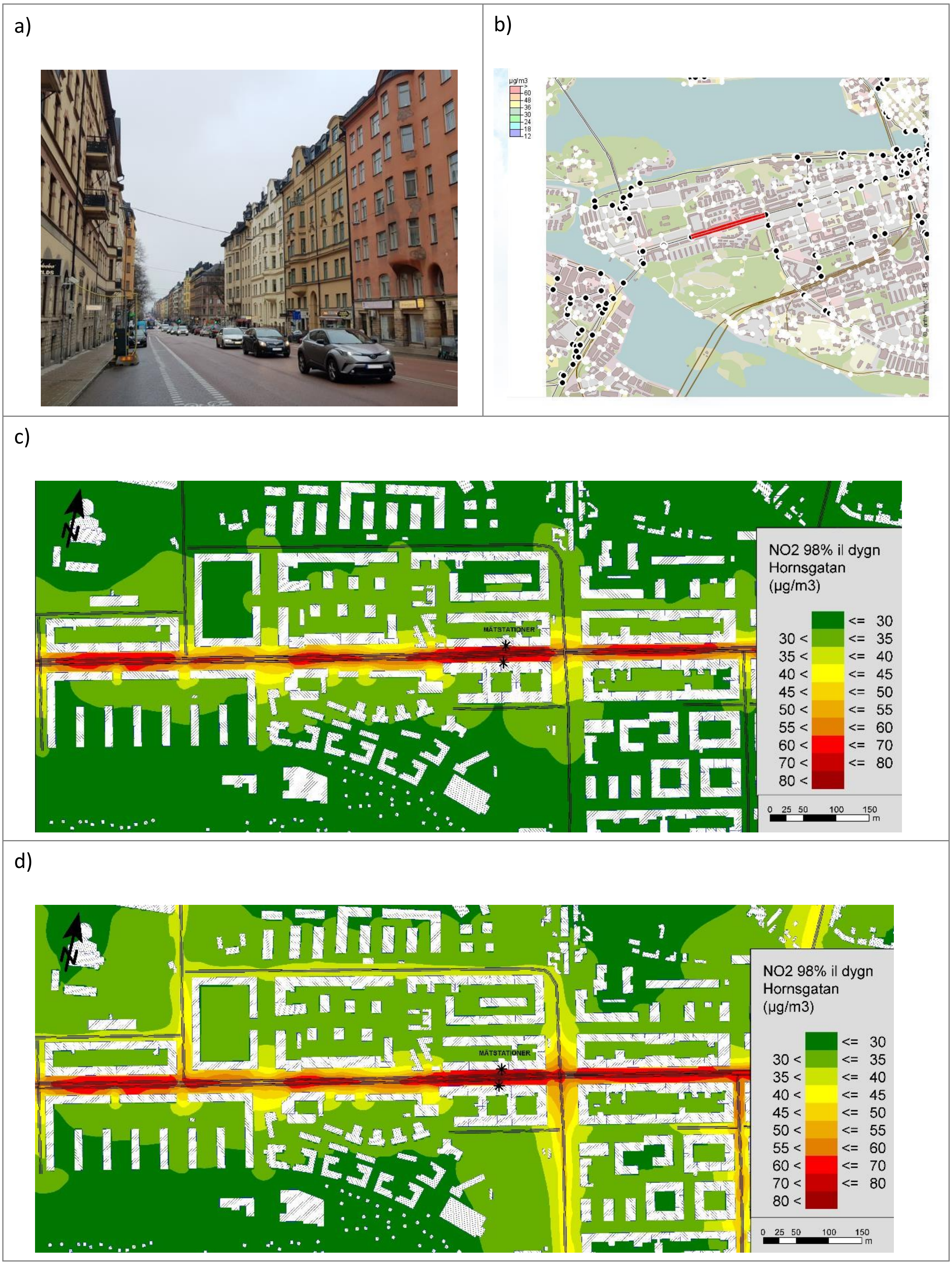


Figure 11 ***a) Illustration of a partially double sided/enclosed street room with a lot of traffic. Calculation with only emissions from the street space calculation with b) OSM***

model c) CFD model, d) corresponding calculation with CFD model but here also with emissions from surrounding low-traffic streets.

10.4. Input data to models

In the following section, information is given on the basis that may be needed for dispersion calculations.

10.4.1. Background levels

The curb contributions from all sources except the calculated street itself, need to be included in the calculations in some way. These are called background levels and include contributions from emission sources on the larger geographic scales (urban, regional, international) that affect the levels in the area being studied. If the background levels are not already included in the model or model system to be used, it is important that they are added to the calculation.

If the dispersion model has pre-calculated background concentrations, it is important to ensure that the calculations agree with real conditions. This can be done, for example, by comparison with measured levels. If measurements are missing, a general comparison can be made with measurements from a similar location. When comparing with measurement data, however, it is important to consider that it is not completely trivial to compare calculated surface-covering concentrations with point measurements – the concentration variation within a calculation box can be large.

In some cases, calculated background concentrations are missing, and in order to estimate total concentrations, measurement data of urban background concentrations can be added to the local concentrations. Consider using measurements from a nearby and representative area. If local calculations for, for example, a road are representative of an area on the outskirts of the built-up area, it may often be inappropriate to use background concentrations from measurements at a centrally located point in the built-up area, as the variation in urban background levels can be large within the built-up area. Measurement data can be downloaded from the data host for Air Quality[70].

10.4.2. Meteorological data

Using high-quality and representative meteorological data is important to describe the distribution of air pollutants.

[70] national and regional air quality data provider, EEA AQ portal: https://eeadmz1-cws-wp-air02-dev.azurewebsites.net/

The majority of air quality model systems include meteorological data for the whole of Sweden. It is recommended to read through the model documentation and review which meteorological data is used. A big advantage is if the meteorological data is available on an hourly basis and not based on statistical classification (such as a number of combinations of wind direction and wind speed), then the distribution and thus the level of air pollution is very sensitive to the meteorology, and for example the wind can change quickly in a couple of hours. High spatial resolution of the meteorology also generally improves dispersion calculations.

Some models require that the model user himself has meteorological data available. Then it is important to use data that is representative of the area and the question being investigated. Most often, the meteorology needs to be produced in one of the following ways.

1. Just one meteorological station/mast: Data collection of all the necessary meteorological parameters to produce all the data needed for a dispersion calculation. The entire model range gets the same values. This approach works well for smaller model areas, provided the mast is positioned representatively.
2. Multiple meteorological stations/masts: Measured parameters can be used as input to process fields of meteorological parameters, such as winds and temperature etc. It is required that some method be available to go from point measurements to fields, such as simple interpolation or a diagnostic wind model. Such methods can be implemented in different model systems.
3. Use of gridded meteorological data, for example from SMHI's analysis model MESAN or calculated via a meteorological model such as TAPM[71]. These data can then be used as fields of parameters or as single-point time series, depending on how the dispersion model works.

10.4.3. Emission data and traffic data

The quality of emission databases and traffic data are central to the quality of the calculation results from a dispersion model.

Below are some different types of emission sources and examples of which input data should be produced, reviewed and modified before detailed model simulations are made (when focusing on traffic environments, the local contributions of point sources are sometimes ignored and instead handled as contributions to urban background concentrations).

[71] TAPM: http://tools.envirolink.govt.nz/dsss/the-air-pollution-model/

LINE SOURCES (STREETS AND OPEN ROADS)

- Traffic flows (24-hour traffic), proportion of heavy traffic and traffic composition, use of studded tyres, sanding/salting, possible queuing situation and time variations over the day and year.
- Signed speed, street width, road width, number of lanes
- Any building heights on each side of the street

LOW POINT SOURCES (E.G. SMALL-SCALE WOOD BURNING)

- Coordinates
- Energy requirements
- Type of wood boiler or local fireplace
- Type of fuel (wood, pellets, oil, etc.)
- Possible accumulator tank and its volume
- Chimney height
- Height and width of nearby buildings

HIGH POINT SOURCES (EG INCINERATORS)

- Coordinates
- Emissions and their time variation
- Movement flow and temperature
- Chimney height
- Height and width of nearby buildings

Exhaust emissions need to be calculated with an emissions model that is adapted for the right geographical area (regarding car fleet, fuel, etc.). For Swedish (and Austrian, Swiss and German) conditions, the emission model HBEFA[72] is constantly updated and suitable to use.

When it comes to particles in urban air, road dust and wear particles from road traffic are a very important aspect in the Nordic climate, with a high percentage of studded tyre use and anti-slip. When modeling particles from road traffic, non-exhaust emissions of particles must thus be handled. An emission model for road dust and wear particles has been developed within the framework of the Nordic cooperation project NORTRIP[73]. The emissions model

[72] The Handbook Emission Factors for Road Transport (HBEFA): https://www.hbefa.net/e/index.html
[73] NORTRIP-model: https://www.diva-portal.org/smash/get/diva2:674122/FULLTEXT01.pdf

describes the number of processes that are linked to road dust, via for example salting, sanding and sweeping the road surface. For example, NORTRIP is implemented in SIMAIR.

10.4.4. Management of NO_X chemistry

As a result of high temperatures in combustion processes (from e.g. road traffic vehicles and industry), the air's nitrogen (N_2) and oxygen (O_2) react with each other, which leads to the formation of nitrogen oxide (NO) and nitrogen dioxide (NO_2). Together, these substances are called NO_x, whereby the NO part is counted by weight as if it were also NO_2 (ie molecular mass: 46.01 g/mol). The reason for this is that the NO emitted from the exhaust pipe or chimney quickly reacts further with the air's ozone (O_3) and forms successively more NO_2[74].

Air quality models need to take these chemical reactions into account because air quality standards and air quality targets refer to levels of NO_2. It can be solved either by calculating the chemical conversion from NO to NO_2, which takes into account the background content of ozone and its variations during the calculation year, or by general or local relationships between NO_X/NO_2. Some models use background data for ozone in each time step to calculate the proportion of NO_2 in NO_X via a chemical formula, other models use rougher empirical relationships. How this is done varies from model to model. The user/consumer is advised to visit the website of the respective model to seek information on this.

10.4.5. Quality review of input data

The importance of input quality, regardless of model, cannot be overemphasized. There are often opportunities for the user to influence and improve the quality of the input data. An example is if the model has pre-set values that can be exchanged for higher quality values. Another is that the user himself produces current data to be used for the modelling, perhaps with a scenario for future emission levels, at e.g. modelling of the future relationship before a planning process.

Guidance on input review is provided on the Reflab - models website.[75]

10.5. References and reading tips

This guidance is largely based on a study carried out by the University of Gothenburg and SMHI on behalf of the Swedish Environmental Protection Agency (Haeger-Eugensson et al., 2019 N.B. not publicly available).

[74] More on NO_2 on Reflab's website: https://www.smhi.se/reflab/omluftfororeningar/luftfororeningar/kvavedioxid-1.19620
[75] Reflab – modeller: http://www.smhi.se/reflab/kvalitetssakring/kvalitetssakring/indata-och-sparbarhet

Haeger-Eugensson, M; Andersson S och Kindell S (2019): Modellering av luftkvalitet i markplan i tätbebyggda områden – Jämförelse mellan en CFD- och OSM-modell samt två Gaussiska modeller.

(Haeger-Eugensson, et al., 2021)

http://www.smhi.se/reflab

http://www.smhi.se/reflab/luftkvalitetsmodeller

Kvalitetskontroll av indata i luftkvalitetsberäkningar | Referenslaboratorium för tätortsluft - modeller vid SMHI

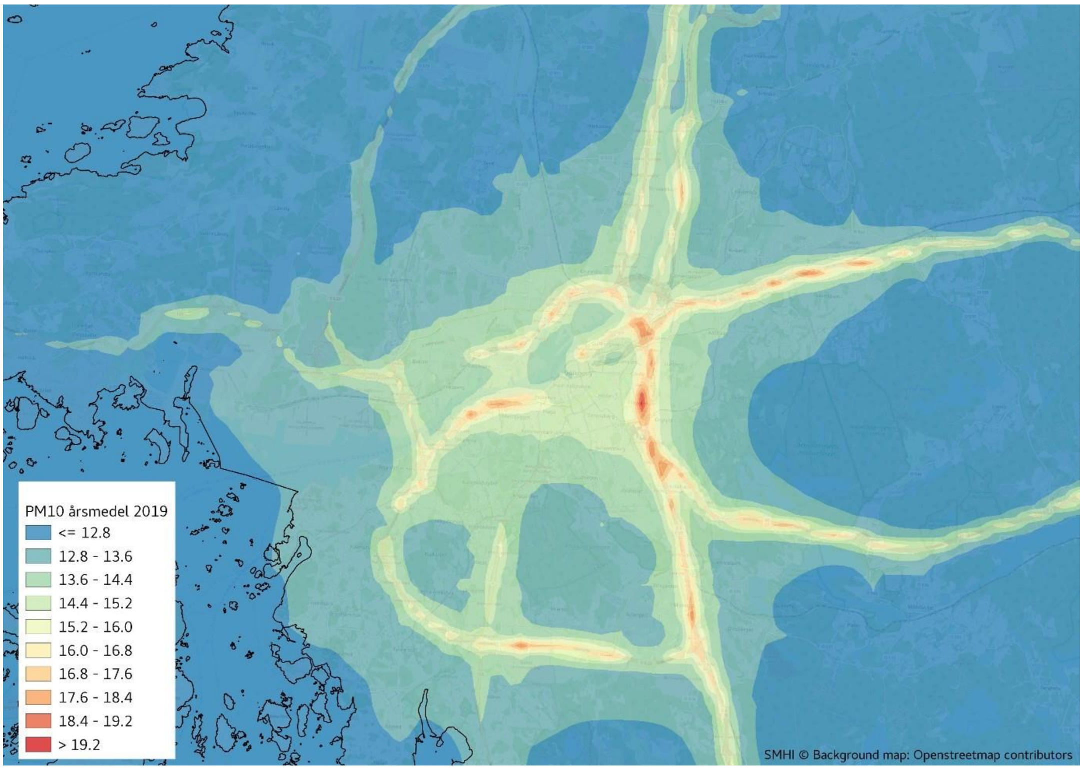
11. ANNEX 2: GUIDANCE ON THE USE OF MODELS IN THE DEVELOPMENT OF AIR QUALITY PLANS

The following guidance for **the use of models in the development of air quality plans** was machine translated from the modelling guidance document of the modelling reference laboratory of the Swedish meteorological and hydrological institute (SMHI, 2023).

Air Quality Reference Laboratory - Models

2023-11-27

Guidance on the use of models in the development of air quality plans



Cover image.

The picture shows the modelled annual average concentration in µg/m³ of PM_{10} in Gothenburg in 2019.

Content

11.1. Introduction

If an air quality standard for outdoor air is exceeded or is at risk of being exceeded, the municipality must notify the Swedish Environmental Protection Agency, which then makes an assessment of the need to establish an air quality plan. The concerned county board or municipality must then draw up one (Naturvårdsverket, 2019).

Modelling is a necessary tool to obtain information and data about the air pollution situation in an urban area, which must be formally included in the action programs and in the reporting to the European Commission. Requirements for the content of air quality plans can be found in ch. 5. Section 9 of the Environmental Code and Section 33 of the Air Quality Ordinance (SFS 2010:477). These requirements are specified in more detail in the requirements for reporting the data on established action programs found in Appendix 7 of the Swedish Environmental Protection Agency's Regulations on Assessment of Air Quality control (NFS 2019:9). Detailed guidance on the content and reporting of air quality plans can also be found in the Luftguiden (Air Guide) (Naturvårdsverket, 2019).

This guide is intended to be a supplement to the Air Guide and to provide more detailed and technical guidance with practical examples on the preparation of input data for models and how model results can be used in the work with air quality plans. The focus of this document is on the pollutants PM_{10} and NO_2 with specific focus on traffic sources in urban areas. The focus is thus also on the use of models on the local scale. Based on the requirements of the legislation and the Swedish Environmental Protection Agency's guidance, the Reference Laboratory for air quality - models (Reflab - models) has produced this guidance on how modelling can be a good support in the work with formulating measures in air quality plans.

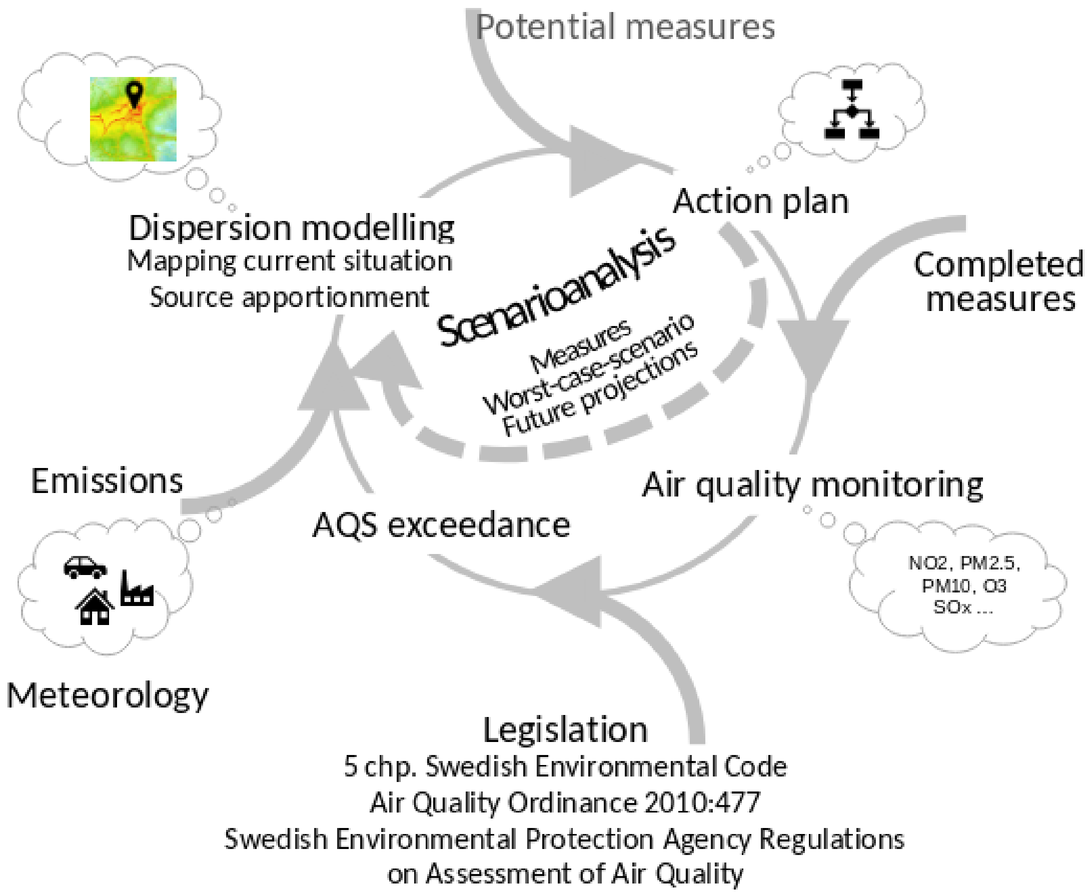


Figure 12 ***: The evaluation cycle of air quality and connections between dispersion modelling and development of air quality plans where modelling is an important tool for assessing the effect of various measures to reduce air pollution levels in, for example, a municipality.***

Air quality management can be seen as a continuous process with recurring activities and evaluations regarding air pollution levels and measures. These steps are summarized in Figure 12. The work to bring forth air quality plans is most often triggered by the fact that air quality measurements have registered high concentrations that exceed or risk exceeding air quality standards in a certain location and therefore measures need to be taken to improve the air quality. To explore whether high levels occur more widely and in several locations, a mapping of air pollution concentrations over a larger area, such as a city, needs to be carried out and is suitably done through dispersion modelling. To carry out these concentration simulations, input is required for emission amounts from all sources and meteorology (which controls the dispersion conditions). The mapping provides information on the current state of the air quality situation over a city and shows whether there are more locations with high levels (so-called hotspots). After mapping, a source apportionment must be made, which aims to find the emission sources that are dominating the contribution to the high levels. With this information, concrete measures should be proposed that can reduce emissions from the dominant sources and thus effectively improve air quality. Dispersion modelling can then be used to test the effect of the measures' emission changes on the concentrations, as well as to make future forecasts and various scenario analyses. This guide focuses on the activities that directly link to dispersion modelling. These are mapping air quality over cities and larger urban areas, source apportionment, scenario analysis and gathering or producing of input data (emissions and meteorology) to the model and are treated in more detail in different sections throughout.

11.2. Current air quality situation

11.2.1. Mapping of concentrations in an urban area

Mapping the air quality in an urban area aims to identify the places where AQS is at risk of being exceeded or exceeded. In Swedish urban areas this usually occur in streets with high traffic loads. If the street canyon is narrow and enclosed with dense surrounding buildings, the risk of high air pollution levels increases due to limited ventilation. It is therefore very important to map the air quality situation over the entire urban area, partly in places where it is known that the traffic load is high, but also in places where street spaces are narrow and high levels can become a problem despite a lower traffic load. Mapping with model calculations therefore usually requires a model that can calculate the concentration in a street canyon. There are a number of different models that calculate levels in street canyon and that require the model user to produce input data for e.g. traffic emissions, street canyon geometries, meteorology and background levels.

Which model type is best suited for the current mapping depends on several factors. Reflab - models has produced a guide for support in choosing a model[76], among other things with regard to the extent of the exceedance and building structure. It is important to choose a model that can take into account the influence of the street canyon geometry on the pollution levels in the event that exceedances occur in less well-ventilated environments.

The scope of the mapping depends on how widespread the air quality problems are. If exceedances are expected to occur only very locally, for example on specific streets with very high traffic loads, the focus should be placed to the vicinity of these streets. If the extent of exceedances is unknown or is believed to be a problem in larger areas of the agglomeration, the mapping should cover a larger area. The size of the model area can also affect the model selection, as some model types are computationally intensive or impractical to run for several streets. The more streets to be mapped, the greater work effort is needed, partly to produce up to date input data of roads and traffic for calculation of emissions, partly to carry out all the calculations required to map whether evaluation thresholds and AQS are at risk of being exceeded.

To produce calculations of air pollution concentrations with a model, it is very important to acquire input data that describe the emission sources in the current situation as well as possible. A large amount of work required in modelling is precisely the preparation of emission data itself. Models also need input in the form of meteorology and background concentrations. Data for these are usually available through measurements or through models. However, for emissions, for example from traffic, there are usually no measured quantification of emissions, but these must instead be calculated.

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[76] https://www.smhi.se/reflab/guider/guider/vagledning-for-val-av-modelltyp-for-spridningsmodellering-i-tatortsmiljo-1.182830

To be able to carry out a model calculation of the air pollution level in a street canyon, the steps described below in brief are required. In some model systems, some of these steps are included automatically, which makes it easier for the user.

1. Prepare emission data for the road(s) to be investigated.
2. Retrieve information about the physical environment that the model requires, e.g. the geometries of the street space.
3. Retrieve the meteorology required by the dispersion model as input.
4. Retrieve background levels for the air pollutant under investigation.
5. Calculate the air pollution level at the locations to be investigated.
6. Compare the calculated annual average levels and percentiles with current evaluation thresholds and AQS.

These steps are described in more detail in the sections below.

11.2.1.1. Preparation of traffic-related exhaust emissions

Exhaust emissions from traffic can be calculated by combining road information, traffic data, vehicle types and emission factors.

Road information and traffic data can be retrieved from the national road database NVDB managed by the Swedish Transport Administration[77]. However, the quality of traffic data varies depending on the type of road. There is well-updated data for state roads, while the quality is usually markedly worse for municipal roads. For municipal roads, the municipality's traffic office may have better information. If the information is still insufficient, a traffic consultant may need to be hired to produce more detailed information.

Emission factors, i.e. an estimate of the amount of emissions per amount of fuel used, for different pollutants and vehicle types can be obtained from the emission model HBEFA[78] (Handbook emission factors for Road transport). HBEFA has a database that contains emission factors for different vehicle categories, roads and traffic situations. Traffic situations have several dimensions; urban/rural, functional road class, speed limit and traffic flow classes describing accessibility and congestion. The vehicle composition is adapted to each country's vehicle fleet and is updated on an annual basis in Sweden. Emission factors are updated periodically with no particular frequency for when updates take place. The latest version (HBEFA 4.2) is from January 2022. The next planned version is 5.1 but has no set release date.

To calculate the emission on a certain road in a built-up area, you therefore need information on, for example, road type, speed limit, vehicle composition, traffic flow conditions and year-round traffic. Below is a list of examples of input data that affect how big the emissions will be from traffic on a certain road:

- Traffic volume (average number of vehicles per day, annual daily traffic (ADT))
- Vehicle composition (shares car, bus, truck, motorcycle)

[77] https://www.nvdb.se/sv/
[78] https://www.hbefa.net/

- Fuel parts for different vehicle types (diesel, petrol, ethanol, electricity, biogas)
- Share of heavy traffic (% heavy traffic)
- Studded tyre shares (% studded tyre use)
- Time variation, i.e. how the amount of traffic varies over the day, week and month
- Traffic flow (free, stop and go)
- Driving speed (signed speed)
- Number of lanes
- Road type
- Road width

In some models, where the emission is calculated in connection with the concentration calculation, users have the option of entering data for traffic, vehicles and road information, etc. in an interface, which makes it relatively easy to quickly update input data and calculate emissions at a road section. In other models, the user needs to calculate the emissions separately and read the emission data into the model in a certain file format, which depends on the structure and structure of the model. As a user, you should therefore consult the model's manual for further guidance on what format and unit the emissions should have. It can be anything from a simple csv file to a rasterized format. It can be good to investigate the model's emission management in advance, as it is an aspect that can influence the choice of dispersion model.

HBEFA contains developed emission factors for around a hundred different traffic situations as well as vehicle types (passenger cars, two-wheelers, city buses, trucks with trailers, trucks without trailers, etc.) and fuel types for various air pollutants. Here follows a simple example of how the emission of NOx from all passenger cars with different fuels on a municipal road can be calculated using HBEFA's emission factors (Table 9) for the traffic situation: Urban (URB) municipal highway (MW-City) with speed limit 70km/h (70) and free traffic flow (Freeflow):

Table 9*: NOx emission factors from HBEFA for passenger cars with different fuels and the traffic situation URB/MW-City/70/Freeflow.*

Vehicle type	**Fuel**	**Traffic situation**	**EF_NO_X (g/km)**	**ÅDT**
Passenger car	Diesel	URB/MW-City/70/Freeflow	0,06097	10000
Passenger car	Petrol	URB/MW-City/70/Freeflow	0,40059	9000
Passenger car	Electric	URB/MW-City/70/Freeflow	0	1000
Passenger car	Electric hybrid/diesel	URB/MW-City/70/Freeflow	0,05283	400
Passenger car	Electric hybrid/petrol	URB/MW-City/70/Freeflow	0,00307	300
Passenger car	Ethanol	URB/MW-City/70/Freeflow	0,07849	100
Passenger car	Biogas	URB/MW-City/70/Freeflow	0,05120	100

The total emission for all passenger cars ($Emission_{pb}$) for a road section is thus calculated by summing all emissions for the specific traffic situation and the vehicle types and fuels observed.

$Emission_{pb} = EF_{traffic\ situation\_pb\_diesel} \times ADT_{pb\_diesel} + EF_{traffic\_situation\_pb\_petrol} \times ADT_{pb\_petrol} + EF_{traffic\_situation\_pb\_electric} \times ADT_{pb\_el} + EF_{traffic\_situation\_pb\_\ electric\ hybrid/diesel} \times ADT_{pb\_\ electric\ hybrid/bensin} + EF_{traffic\_situation\_pb\_ethanol} \times ADT_{pb\_ethanol} + EF_{traffic\_situation\_pb\_biogas} \times ADT_{pb\_biogas}$

In addition, we will also calculate (according to the same principle as above) and sum the emissions for all other vehicle types with different fuels to obtain the total NOx emission for all traffic on the road section in question. All information on emission factors for road traffic can be found in HBEFA. Information on state roads' ADT and vehicle composition can be obtained from the Swedish Transport Administration. For municipal roads, such information can often be deficient or missing and, as mentioned earlier, it is recommended to contact the municipality's traffic office or alternatively a traffic consultant to retrieve traffic data through measurements or modelling. A rather large effort is thus required to calculate the traffic emissions, especially if they are to be done on many road sections. If updated information about e.g. vehicle composition and the amount of traffic on a road are missing, this needs to be produced using traffic measurements (Burman et al., 2020) or traffic modelling.

11.2.1.2. Traffic-related non-exhaust emissions

A large part of particle emissions linked to traffic is made up of the interaction between vehicle and road, which generates wear particles and falls within the category of non-exhaust emissions. Such emissions are of great importance in Sweden, where observed exceedances of AQS for PM_{10} are largely caused by wear particles. Even anti-slip methods such as salting and sanding road surfaces can generate particle emissions. Wear particles are also generated from a vehicle's brakes. At a local level, it may be precisely wear particles that give rise to high particle concentrations. Models that can calculate these particulate emissions are important and research in this area has been going on for many years, but there are still relatively large uncertainties in these emissions.

Examples of important inputs for calculating non-exhaust-related particulate emissions are:

- Studded tyre shares
- Winter tyre shares
- Selection and extent of anti-slip measures, such as sandblasting, salting or the use of dust binding agents.

To calculate wear particles in particular, it is important that the dispersion model used supports this. The NORTRIP model[79] is specifically designed to calculate particulate emissions (Denby et al., 2012).

11.2.1.3. Meteorological input

To describe the transport and mixing of the air and thus also the spread of air pollution, models need to take the prevailing meteorology into account. Different models take into account different parameters in calculating the dispersion pattern, but generally input data such as wind speed, wind direction, temperature and precipitation are required to be able to calculate the air mixing in, for example, a street canyon. Meteorological data can either be retrieved from measuring stations or calculated using meteorological models. Consult the model's manual to ensure which meteorological variables are needed as inputs, time resolution and in which file format they need to be loaded. SMHI provides services for open data where meteorological data can be downloaded from a number of measuring stations all over Sweden[80]. Municipalities may also have access to their own meteorological data which may be relevant to use if these are located near the areas being investigated and thus represent the prevailing meteorology in the areas to a greater degree than a measuring station at a greater distance.

11.2.1.4. The physical environment

In a street canyon, special mixing conditions can arise due to its design and surrounding buildings. A street canyon model therefore needs information about street canyon geometry and building heights in order to calculate mixing and airflow in a street canyon. Depending on which model is used, different amounts of input about the building are required. A simpler model requires fewer input parameters while a more advanced model may need more. See Reflab - models' website[81] for a compilation of different diffusion models, as well as separate guidance on which model can be chosen for different purposes (SMHI, 2022).

11.2.1.5. Input data for background levels

The calculated street canyon air pollutant levels from the model are based in many models only on the emissions that occur from the road section in the street canyon itself. However, the air pollutant levels do not only consist of contributions from the specific road section, but also from the emissions from the larger surrounding area, the so-called background levels. The background concentrations thus need to be added to the local concentrations. Information on the background levels can, for example, be obtained from measurements carried out at so-called urban background stations, if such data is available for the urban area being analysed. It is important that the urban background station is representative of the urban area. If there are no measurements, an urban-scale model can be used to calculate urban background levels. Urban-scale models often specify concentrations over a

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[79] https://www.nilu.no/wp-content/uploads/dnn/23-2012-BDE-IS_NORTRIP-model-description.pdf
[80] https://www.smhi.se/data
[81] https://www.smhi.se/reflab

surface at ground level. A model that calculates the urban levels needs input in the form of emissions, meteorology and background levels in order to be able to calculate levels over a larger area where all emission sources should be found.

Reported results from completed measurements, including at urban background stations, can be downloaded from the database for Air Quality[82].

11.2.1.6. Description of the current air quality situation – extent of exceedance and baseline scenario

When all the necessary input data have been produced and loaded into the model, the calculations are carried out. The calculations need to produce results in the form of annual average values, as well as percentiles/number of exceedances of the current air quality standards. The results are conveniently presented in table format and as a map image to illustrate the geographical extent of the exceedance. It is important to map all critical locations (e.g. where the traffic load is high) in the entire urban area and possibly also in other areas of a municipality where the AQS may be at risk of being exceeded. This is to obtain the necessary information about the extent of the exceedance and thus where measures need to be taken. The extent of the exceedance must be reported in an air quality plan according to § 33 of the Air Quality Ordinance (SFS 2010:477) and at a later stage reported when reporting the air quality plan according to § 43 of the Swedish Environmental Protection Agency's Regulations on Assessment of Air Quality (NFS 2019:9). Information on the extent of the exceedance is also necessary to be able to investigate the number of people exposed to concentrations above the AQS (see further section 2.2).

It is also important to analyse the concentration variation over the year through time series analysis, e.g. with a simple line plot of hourly average concentrations over the year. High levels of air pollution are often strongly linked to the season, and various air pollutants most often show both a typical seasonal variation and diurnal variation. It may therefore be appropriate, based on the analysis, to place greater focus on measures to reduce concentrations during the times and periods when the lowest concentrations occur.

[82] www.smhi.se/datavardluft

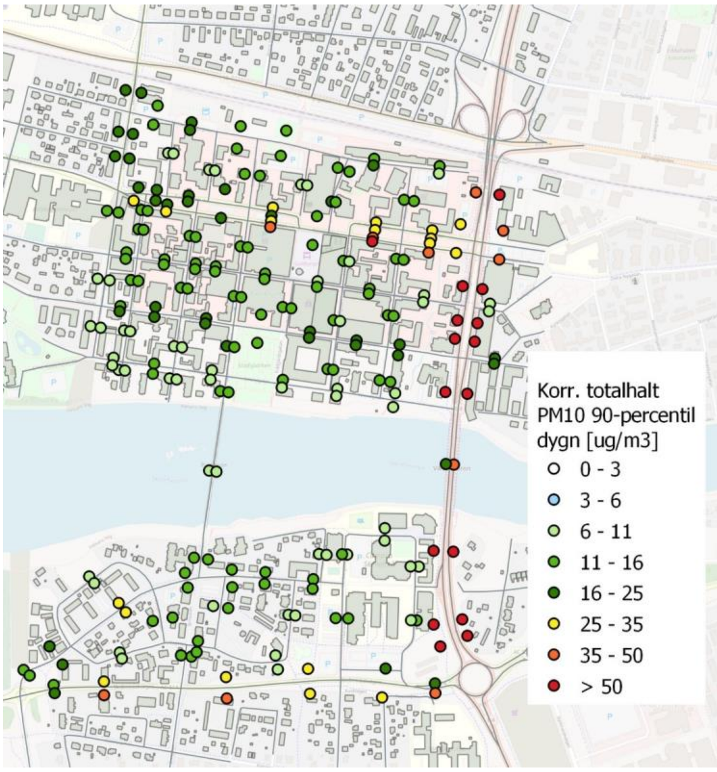

Figure 13*: Example of a modeled mapping of air quality in Skellefteå municipality using a local-scale model. Several hot spots are visible for the air quality standard of PM_{10} daily average value with yellow (lower evaluation threshold), orange (upper evaluation threshold) and red marked (air quality standard) circles.*

The mapping with input data for the current year constitutes a so-called base scenario, which is a description of the current prevailing air quality situation. Figure 13 illustrates an example of a mapping of particle concentrations produced in central Skellefteå. High levels are observed over a larger area at a number of traffic-laden roads where evaluation thresholds and the air quality standard for PM_{10} daily average value are exceeded (90 percentile > 50 µg/m³). A survey is thus the basis for and is the starting point in the development of an air quality plan. To assess the effectiveness and impact of planned and implemented measures on improving air quality, it is important to be able to compare different scenarios against the original base scenario. More about this is described in section 4.

11.2.2. Population exposure

While it is important to identify the places where concentrations are high, it is also important to know how many people are estimated to be exposed to high concentrations. The mapping of an urban area's air pollution concentrations can be combined with population data to calculate the number of people exposed to high concentrations in the areas where the AQS is exceeded or at risk of being exceeded. Statistics Sweden provides surface population data of 100 × 100 m and can be purchased for a fee. If there is other data for how many people stay in a specific area (at workplaces and hubs for public transport), this is also very valuable to include in an exposure analysis. In order to calculate how many residents are exposed to high concentrations of air pollution, in this case it is required that the concentrations are described over an area, so it is recommended to use a model that can specify surface-covering concentrations. In an exposure calculation, population data are often divided into different age groups (e.g. 0-15, 16-20, 21-30, 31-50, 51-65 and over 65 years) and content ranges based on limit values for air quality standards and environmental targets. For each surface coverage area, the number of people exposed to that concentration range is calculated and summed up over the model's domain to give answers to e.g. how many people are exposed to concentrations above the air quality standard. If you have access to population data (number of residents in a certain property) at a certain road section where high concentrations occur, population exposure can also be calculated here. Figure 14 shows an example of how to illustrate the number of people exposed to a certain concentration.

The calculation must at least be able to provide information on the number of people who are exposed to concentrations above the standard concentration as well as objects worthy of protection (e.g. preschools, schools, healthcare facilities) in the area. This information must be included in an air quality plan according to § 33 of the Air Quality Ordinance (SFS 2010:477) and must also be reported when reporting an air quality plan according to § 43 of the Swedish Environmental Protection Agency's Regulations on Assessment of Air Quality (NFS 2019:9).

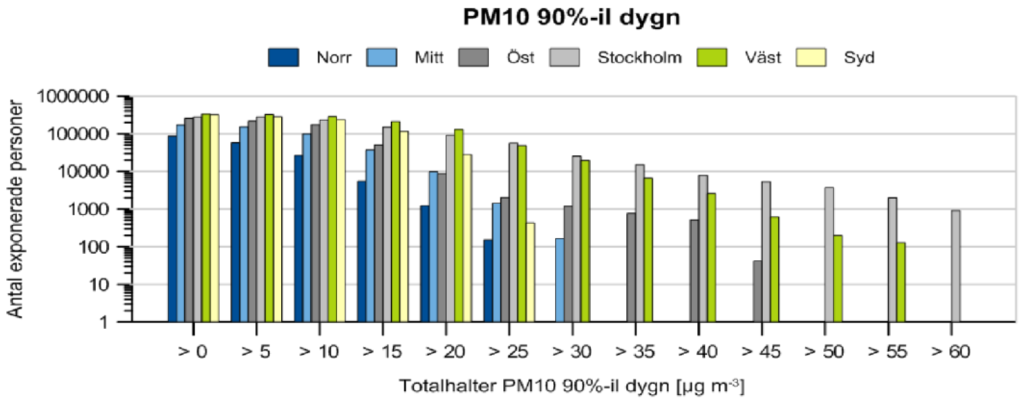

Figure 14*: Number of people exposed to PM_{10} daily average values where the 90th percentile exceeds various concentration ranges on state roads in different parts of Sweden.*

11.3. Source apportionment – identification of dominant emission sources

To create effective measures with good precision, it is important to both identify and quantify the source or sources in an area that largely contribute to the high levels observed in the mapping of air quality in an agglomeration. With a so-called source apportionment, the emissions of the sources in an area are linked to the levels in the air. This is done most easily with simulations in a dispersion model. It does not always have to be the largest emissions that contribute most to high levels, although this is often the case. Factors that are important for how high the levels are, are of course the size of the emission, but also the height above ground of the emission and the properties of the pollution such as e.g. lifetime in the atmosphere and volatility (propensity to react with other substances) and atmospheric processes controlled by meteorology that have a strong effect on the dispersion of air pollutants.

As mentioned in previous sections, air pollution levels at a certain location depend on many different emission sources which can be located at different distances from the site, partly very close (local), partly at a longer distance such as in nearby areas, for example the own urban area (urban) or at longer distances (regional). Concentration contributions must therefore be described on a local, urban and regional scale to gain an overview of whether problems with elevated concentrations are mainly caused by local sources or if source contributions on a larger scale are significant for the total concentrations. If it turns out that the rate contribution is large at, for example, an urban level, there may be a need to implement measures on a larger scale instead of solely focusing on measures on the most congested streets.

In general, it can be mentioned that particles have a relatively long lifetime in the atmosphere and can thus be transported from other distant areas. High particle concentrations in an agglomeration can thus be episodically driven by regional sources. Urban areas in southern Sweden can occasionally, for example, have a fairly large transport of particles due to its proximity to continental Europe, while this is less often seen in northern Sweden. Nitrogen dioxide, which has a relatively short lifetime in the atmosphere (~ 1 day) is known to be a local-scale air pollutant and is largely linked to emissions from local traffic in urban areas. In a narrow street canyon, the level is often strongly linked to the traffic emissions of the local roads.

A source apportionment study needs to be carried out at an early stage when developing an air quality plan and there are established requirements for which sectors are to be included in a source apportionment[83]. For a municipality, the source apportionment covers urban and local scale and must then, according to the reporting regulations, contain content contributions from the source sectors;

1. Road traffic
2. Industry
3. Agriculture
4. Heating
5. Shipping
6. Work machines
7. Natural sources
8. Transboundary sources
9. Other sources

[83] Luftguiden - handbook on environmental quality standards for outdoor air

10. Total

In Sweden, the focus of air quality measures is often on road traffic, which is usually the dominant sector, as well as measures at the urban and local scales. In the subsections below, there are a number of examples of how a source apportionment can be carried out with a focus on road traffic, as well as a section on spatial measures (urban and regional).

11.3.1. Detailed local source apportionment of traffic

To make a source apportionment, it is necessary to have good knowledge and up-to-date information about the emissions from different sources, how big the emissions are and what time of the day they occur (time variation) as described in section 11.1. The most common method for making source apportionment is called "Brute force”. The methodology is based on several simulations being carried out, a first (the base case) in which all emissions are included without having changed. A further simulation is then carried out where a single emission source is reduced by a certain amount (percentage). The levels between the simulations are compared and the difference can be used to calculate the source contribution to the total levels. For each source to be included in the source apportionment, a new simulation with the same steps needs to be performed. This may seem like a complicated procedure but there are explanations for why it needs to be done this way and it is most simply illustrated with the example in section 11.3.1.1.

More detailed information on the brute force methodology (and the concept of potential level change/source contribution used in the subsections below) can be found in a guidance document on source apportionment developed by the EU air quality modelling network, FAIRMODE[84] (Clappier et al., 2022).

11.3.1.1. Source apportionment of road traffic with a local-scale model

Example 1 - Source apportionment NO_2

Below is an example of the steps that need to be carried out in a source apportionment with the so-called "brute force" methodology. For the sake of simplicity, it is assumed in the example that the emission sources on a road only consist of passenger cars with diesel or petrol as fuel (in reality, of course, all vehicle types must be included in a source allocation) and heavy traffic.

- Sim_1 = Calculation of air pollution levels where total emissions for all vehicle types are included
- Sim_2 = Calculation of air pollution levels where the ADT for diesel-powered passenger cars is reduced by 25%

[84] https://publications.jrc.ec.europa.eu/repository/handle/JRC130562

- Sim_3 = Calculation of air pollution levels where the ADT for petrol-powered passenger cars is reduced by 25%
- Sim_4 = Calculation of air pollution levels where the ADT for heavy traffic is reduced by 25%
- Potential change in diesel-powered passenger cars = ($Halt_{Sim\_1}$ – $Halt_{Sim\_2}$) / 0,25
- Potential change in petrol-powered passenger cars = ($Halt_{Sim\_1}$ – $Halt_{Sim\_3}$) / 0,25
- Potential change in heavy traffic = ($Halt_{Sim\_1}$ – $Halt_{Sim\_4}$) / 0,25

The potential change in concentration is thus an estimate of how large the concentration contribution is for a specific source to the total concentration, in this case three sources; diesel-powered passenger cars, fuel-powered passenger cars and heavy duty vehicles. In the example (Table 10), we see that a reduction of diesel cars has the greatest effect on the NOx emission and the NO_2 concentrations, which decrease by 8.4 µg/m/s and 1.5 µg/m³, respectively. They also account for the largest potential source contribution (6 µg/m³). Diesel-powered passenger cars thus potentially account for 47% of the local NO_2 content (6 of 12.8 µg/m³). Even for gasoline-powered passenger cars, a relatively large local reduction in concentration and potential local concentration change of 4.8 µg/m³ is seen, which constitutes 38% of the local NO_2 concentration.

Table 10*: Example of a calculation of NOx emission and NO_2 content in a street canyon with a local-scale model for different scenarios (Sim2-Sim4) where ADT for passenger cars and heavy traffic has been reduced by 25% from the current situation (Sim1). Potential level change is calculated with the so-called The "Brute Force" methodology.*

	Emission NO_X (µg/m/s)	Total level [NO_2] (local+background) (µg/m³)	Local level [NO_2] (µg/m³)	Potential change local level (”Brute force” method) (µg/m³)
Sim1	57,9	26,5	11,8	-
Sim2 – pb_petrol-25%	56,7	26,6	10,6	4,8
Sim3 – pb_diesel-25%	49,5	25	10,3	6
Sim4 –heavy traffic-25%	53,2	26	11,3	2
Sum	-	-	-	12,8

Measures focused on reducing traffic by passenger car, especially diesel-powered passenger cars, should therefore be effective according to the information from this source apportionment. The sum of the three sources' calculated potential concentration changes should be the same as the total content from simulation 1. If it is not, the source apportionment is incomplete, which is the case in this example (11.8 vs. 12.8). This is a known problem in modelling and is often the outcome if source apportionment is done for non-linear air pollutants (air pollutants that are chemically reactive and thus have a non-linear relationship with variation in emissions). This can be handled by calculating the percentage share of the apportioned source sectors (in this case the three vehicle types). The proportions obtained are then applied to the actual total local concentration contribution and a concentration value can be obtained which represent the sources' potential concentration contribution. It must be borne in mind that this value is however uncertain as the source apportionment in the example is incomplete because additivity is not fulfilled. Even with the absolute concentration contributions being somewhat uncertain, the source apportionment provides valuable information about which sources are dominant (see Figure 4) and provides a basis for constructing measures that include the most suitable sources.

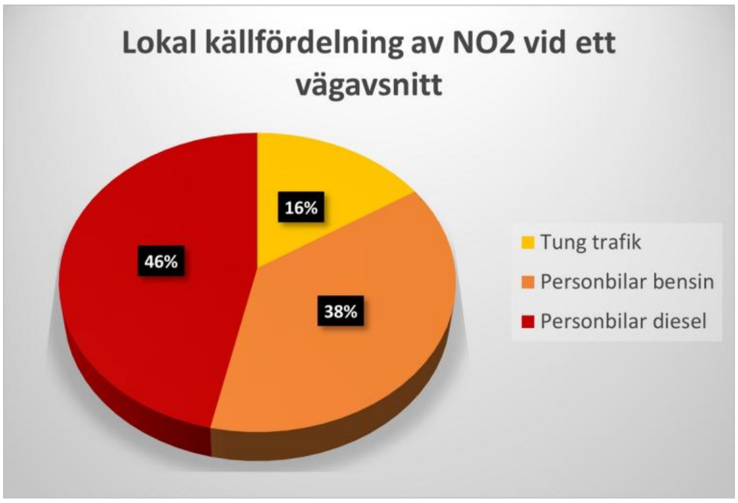

Figure 15*: Source* apportionment *of local content contribution based on three vehicle types (petrol-powered passenger cars, diesel-powered passenger cars and heavy traffic) for the NO_2 content at a road.*

There is a general recommendation from FAIRMODE to make only small emission reductions in source apportionment so that the sum of the individual concentration contributions remain additive and thus agree with the concentration total obtained when calculating without any emission changes (the concentration for the first simulation in example 1 above). You can read more about this in a guidance document on source allocation methodology from FAIRMODE[84].

Example 2 – Source apportionment PM_{10}

Below is another theoretical example of the steps required to source apportion PM_{10} from light and heavy vehicles using a local scale model.

- Sim_1 = Calculation of PM_{10} levels where total emissions for all vehicle types are included
- Sim_2 = Calculation of PM_{10} levels where light vehicles are reduced by 25%
- Sim_3 = Calculation of PM_{10} levels where heavy vehicles are reduced by 25%
- Potential change of levels light vehicles = $(Halt_{Sim\_1} – Halt_{Sim\_2}) / 0,25$
- Potential change of levels heavy vehicles = $(Halt_{Sim\_1} – Halt_{Sim\_3}) / 0,25$

Table 11*: Example of a calculation of PM_{10} emission and PM_{10} concentration in a street canyon with a local-scale model for different scenarios (Sim2-Sim3) where the ÅDT for light and heavy vehicles has been reduced by 25% from the current situation (Sim1). Potential level change is calculated with the so-called The "Brute Force" methodology. In the base case, ÅDT is 40,000 vehicles, half of which are light and heavy vehicles. The reduction of 25% in the various vehicle types thus corresponds to 5,000 vehicles. The speed on the road is 80 km/h.*

	Emission PM_{10} (µg/m/s)	Total level [PM_{10}] local+background (µg/m^3)	Local contribution [PM_{10}] (µg/m^3)	Potential local level change ("Brute force" methods) (µg/m^3)
Sim1 – base case	141	21,2	15,1	-
Sim2 – light-25%	124	19,6	13,5	6,4
Sim3 – heavy-25%	118	19,2	13,2	7,6
Sum	-	-	-	14

In the example above (Table 11) we see that a reduction of heavy vehicles has the greatest potential effect on the local level (13.2 µg/m³) compared to light vehicles (13.5 µg/m³), although the differences are very small. The sum of the potential concentration contributions is here 14 µg/m³, thus quite close to a complete source apportionment when compared to the local concentration from the first simulation which has no emission reductions. As there is not a particularly large difference in the potential change in concentrations for heavy and light traffic in this example, it can be concluded that both sources are of great importance for the concentrations on the road in question and that measures to reduce emissions for both sources should be effective to reduce PM_{10} levels.

11.3.1.2. Source apportionment of road traffic with traffic measurements and emission calculations

In Swedish urban areas, it is often the traffic that has historically constituted the largest urban and local source contribution to the AQS for NO_2 being exceeded. The traffic consists of many different vehicle types and fuels, so it is therefore justified to do a more detailed source apportionment analysis on a local scale where the air pollution level in a street canyon can be derived from the prevailing vehicle composition. In a study from Uppsala, this has been done by combining emission calculations with traffic measurements to identify vehicle types and its speed (Burman et al., 2020). Emissions were calculated using HBEFA for different traffic flow classes, which were determined by the measured speed of each vehicle passage. Emission shares for traffic were thus calculated by vehicle and fuel type, where 86% of NOx emissions were from diesel-powered vehicles (especially buses). The gasoline-powered vehicles accounted for only 5% of NOx emissions. Using the emission shares divided by vehicle and fuel type, it was then calculated how much different traffic measures affect the local air pollution level of NO_2. The results show that a total replacement of diesel and gas buses with electric buses would have the greatest reduction effect on NO_2 levels. The measured vehicle composition with information on the prevailing traffic situation reflects at a high level of detail the actual current state of the emission contributions, which makes it clear which sources may need targeted measures to ensure good air quality.

11.3.2. Contributions on different spatial scales

In addition to identifying and quantifying the contribution of different sources to the total concentrations at a certain location, contributions must also be quantified on different geographical scales. A measured concentration at a certain street not only represents the concentration contributions from emission sources on the street but also from source contributions located at a greater distance, partly sources within the urban environment (urban concentration contribution) but also from sources at a greater distance, so-called regional contributions. Contributions from distant sources are usually quite small, but can of course vary depending on proximity to regions with high emissions.

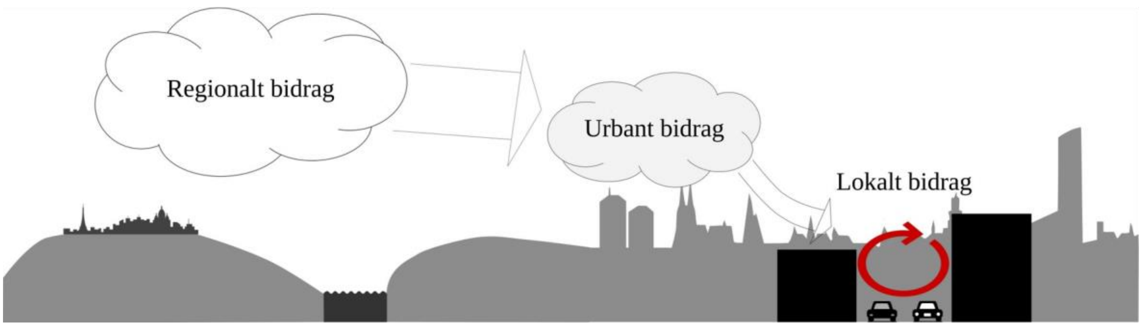

Figure 16*: Air pollution levels at a certain location are affected by sources located at different dis-tances from the location. The amount thus consists of contributions from these sources and is usually divided into a regional, (Regionalt bidrag), urban (Urbant bidrag) and local (Lo-kalt bidrag) contribution.*

In Swedish conurbations, urban and local concentrations often have a great impact on how high the concentrations will be in a street canyon. In smaller urban areas, exceedances of the AQS can be clearly linked to a single street or a few streets with high traffic loads. In larger urban areas, where emissions from various sources are often greater, the urban concentration contribution may, on the other hand, have greater significance for exceeding the AQS. For measures to be effective, it is therefore important to also calculate source apportionments of the urban and regional contributions to ensure that the measures are introduced on the same scale as the air pollution problem.

11.3.2.1. Urban contribution

An urban concentration contribution is conveniently calculated with a surface coverage model that calculates concentrations for areas that cover the urban area. The dispersion calculation should, as far as possible, include all emission sources within the specified geographical area so that the calculated concentration then represents the general urban background concentration for the area. The geographical resolution is usually between 250 × 250 m² and up to one or a couple of km².

Modelling air pollution levels at an urban scale follows the same principle of bringing in all the necessary inputs of emissions, meteorology and background levels. In an urban-scale modelling, all emissions must be calculated from all potential emission sources (industry, heating, traffic, shipping, etc.). Emission data is available from the consortium SMED, which includes official statistics on annual total emissions from 55 different sectors throughout Sweden (SMED, 2019). These national totals are distributed geographically in the national emissions database and for each individual municipality it is possible to download emissions data from the national emissions database[85] at 1 × 1 km² resolution. A municipality that lacks data from a specific source can, for example, retrieve such information to use in a dispersion modelling.

Detailed emission databases for urban areas can involve a very large amount of work and are possibly easiest to do with the help of modelling experts.

If it turns out that the urban contribution is of great importance for the total level, according to the reporting regulations, a source apportionment on the urban scale must be made, where emissions from all sectors are included and where the same source apportionment principle as illustrated in section 3.1.1 is followed. In a recently published study, urban concentrations have been produced for the whole of Sweden, where source apportionment was also carried out on the urban scale for four Swedish cities in 2019 (Alpfjord Wylde et al., 2023). The study used geographically distributed emissions from SMED (Sveriges Miljö emissions data), which are Sweden's official statistics on total emissions from 55 different sectors (SMED 2019). In the three large cities, for example, the urban source apportionment of particles showed to be strongly driven (between 50-70%) by traffic-related non-exhaust gas emissions, while for Umeå, small-scale heating was also a significant source of urban contribution to particle concentrations and made up approx. 40% of urban the contribution to PM_{10}. For nitrogen oxides, it was the traffic sources that dominated a significant

[85] https://www.smhi.se/data/miljo/nationella-emissionsdatabasen

proportion of the pollution levels in all the cities studied. In the coastal cities, shipping also accounted for a significant proportion of the urban pollution contribution. It is thus traffic, small-scale heating and shipping, as well as a machinery, which often represent the significant urban contributions to nitrogen dioxide and particles in Swedish urban areas.

11.3.2.2. Regional contribution

Regional concentration contribution is conveniently calculated with a regional-scale model, which calculates the concentration for a relatively large area and includes emissions from sources in a model domain that also covers larger areas outside of Sweden, often the whole of Europe. Gridded national and international emissions are available from CAMS[86] and EMEP[87] and are produced in a similar way to SMED emissions.

A regional level contribution is thus conveniently calculated with a grid-based model that takes into account input data for gridded emissions and meteorology. It is common to use an Eulerian chemical transport model to calculate air pollution levels on a regional scale. The input data required are mainly emissions, meteorology and physiography. Simplified, the model calculates the content of a box, fixed on a certain grid. The air mass flows through the space and the model calculates the amount of air pollution transported into (emissions within the domain and transport from outside the domain) and the amount transported out of the space. Atmospheric processes such as advection and convection (horizontal and vertical transport), wet deposition, dry deposition and chemical reaction mechanisms are included. The grid resolution in a regional scale model is coarse (often around 10×10 km^2 or more) and represents the regional scale. Because the grid resolution is coarse, the sources' emissions are distributed over a relatively large area, which means that gradients of the calculated concentrations over an area cannot be reproduced in detail.

On a regional scale, the concentrations contribution should be reported from national and cross-border anthropogenic sources as well as natural sources. This requires that the emission inventories also include natural sources and that the model itself has support for calculations of, for example, natural fires, volcanic eruptions, sea salt and sandstorms. In Sweden, the air quality during certain episodes can be affected by, for example, sea salt and sandstorms. The regional concentration contribution has been shown to be of great importance for particle concentrations in Swedish cities and in southern Sweden where the concentrations are higher compared to the north (Alpfjord Wylde et al., 2023).

11.3.2.3. Options for obtaining spatial contributions

If you do not have the opportunity to model spatial contributions, there are alternatives. For regional background levels of NO_2, modelled levels within the program for environmental monitoring with the MATCH Sweden system[88] are available for download. For regional and urban background concentrations, it is possible to use measurements from a nearby

[86] https://atmosphere.copernicus.eu/anthropogenic-and-natural-emissions
[87] https://www.ceip.at/webdab-emission-database
[88] https://luftwebb-miljoovervakning.smhi.se/SMHI-luftwebb-miljoovervakning-app/

background station and this data can be downloaded from the Database[89] for Air Quality for concentrations in air. For particulates, modelled data from CAMS at a regional scale is available for download, and also separate particulate contribution from different sources for different cities[90].

11.4. Improvement measures - impact analysis

One of the biggest advantages and strengths of a model is to use it in so-called scenario analyses where you change the input data and test what effect it has on the simulated concentrations. Simplified, the emissions can be reduced according to the purpose of a measure and the air pollution levels simulated again. In this way, one can investigate how effective and how big an impact potential measures can have on the resulting concentrations. This is an important step in the action program work as it provides an important basis for the selection of effective measures.

11.4.1. Action scenario

A municipality can take many different measures to reduce direct emissions from traffic, for example a ban on studded tyres, reduced base speed, environmental zones, congestion tax etc.

The change in air pollutant levels linked to the measures can be tested with the help of a model by creating a scenario where you change the input parameter(s) that the measures aim to change. If the measure involves lowering the base speed on a road, the parameter in the emission calculation for speed (or the traffic situation according to HBEFA) must be changed and a new emission calculated for the road in question. The same applies to studded tyre bans where the parameter for the use of studded tyres is either reduced or the emissions are recalculated without wear from studded tyres. Depending on which model is used, the user either needs to change the parameter setting in the model or create a new emission database where the emissions have been recalculated according to the intended action and read them back into the model to make a new concentration calculation.

When developing an action scenario where a studded tyre ban is to apply, the checklist can generally look like this:

1. Create a new emissions file (starting from the emissions calculations from the baseline/current situation described in the sections of Chapter 11.2) and give it an appropriate name that reflects the emissions change associated with the action.
2. Change the studded tyre parameter to the desired value in the new emissions file and recalculate the emissions for the road section(s) where the studded tyre ban is to apply.
3. Read the new emissions into the model for the action scenario.
4. Simulate the levels and evaluate and compare the effect on annual average levels and percentiles with the levels from the base scenario.

[89] https://datavardluft.smhi.se/portal/concentrations-in-air
[90] https://policy.atmosphere.copernicus.eu/yearly_air_pollution_analysis_chemical_species.php?dmin=2023-01-01&dmax=2023-12-31

Note that the same background content and meteorology used in the base scenario should be used here. This ensures that only the effect of the local measure on the content is analysed.

Below is an example of how a result for PM_{10} can look in the event of a studded tyre ban compared to a current situation from a simple street canyon model (Table 12). The example is a theoretically set up test case with a rather narrow street canyon (19 m wide) and a traffic load of 26,000 vehicles per day, the studded tyre usage in the base scenario is 56% and in the action scenario 0%.

Table 12*: Comparison of emission and concentration (PM_{10}) between a base scenario and an action scenario where studded tyre shares have been reduced from 56% to 0%.*

	Base scenario (current state)	Action scenario (studded tyre ban)
Emissions PM_{10} (µg/m/s)	47,1	17,7
PM_{10} annual mean (limit value 40 µg/m^3)	27	20,5
PM_{10} 90-percentil day (limit value 50 µg/m^3)	57	31

The results here show that the emission from the street is more than halved and that the annual average level at the street is reduced by 6.5 µg/m³. The percentile for daily average values decreases significantly more, and the air quality standard for daily average levels (50 µg/m³) is not exceeded in the action scenario. The conclusion here is that a studded tyre ban on the street in question can therefore be a highly relevant and effective measure to lower the level locally and meet the air quality standard.

In the EU Commission's proposal for a revised air quality directive, a new limit value for PM_{10} annual average content of 20 µg/m³ is proposed. In the example above, this level is exceeded despite the local studded tyre ban, and it becomes clear that further measures would therefore be needed to bring the particle levels down below the proposed standard for annual averages. Here it becomes clear that the contribution from other local or urban sources is also important for how high the levels are in the area where the norm is exceeded. Particulate matter is an air pollution problem that is not only due to studded tyre use and acts on more than just a local scale, as it has a relatively long lifetime in the atmosphere and can be transported over long distances.

In other words, for each measure that is examined, the emissions need to be recalculated according to the effect that the measure is expected to have on emissions in order to assess what improvement the measure would bring. According to the requirements in Chap. 5 Section 9 of the Environmental Code, air quality plans must, in addition to information on the effect of individual measures on concentrations (as above), also contain information on how all selected measures together contribute to compliance with the standard. An important approach is therefore both to create separate emission files for each individual planned measure, but also to have an additional emission file where the emissions are calculated for all measures that are supposed to be introduced. If, for example, there are two proposals for measures (studded tyre ban and reduced base speed), there should therefore be two emission files representing these. In the end, there will also be two more emission datasets, one where no measures have been implemented (the base scenario) and one where all measures are included. Thus, you have a total of four emission files:

1. emissions_basescenario (current description of emissions)
2. emissioner_studded_tyre_ban (emissions according to the studded tyre ban)
3. emissioner_reduced-base speed (emissions according to reduced speed)
4. emissioner_studded_tyre_ban_speed_reduction (emissions according to all measures; studded tyre ban and reduced speed)

The results from the four emission scenarios are presented in Table 13 and analysed further in chapter 11.5 with the addition of a future scenario that takes into account forecasts for future traffic volumes.

Table 13*: Comparison of emissions, annual averages and percentiles for PM_{10}, NOx and NO_2 between the base scenario and different action scenarios with a studded tyre ban and reduced base speed.*

	Base scenario (current state))	Action scenario (studded tyre ban)	Action scenario (reduced speed)	Action scenario (studded tyre ban + reduced speed)
Emission PM_{10} (µg/m/s)	15,5	6,9	9,8	5,2
PM_{10} annual mean (µg/m³)	21,2	18,4	19,6	18,1
PM_{10} 90%il daily mean (µg/m³)	38,7	31,4	33,6	31,4
Emission NO_x (µg/m/s)	57,9	57,9	73	73
NO_2 annual mean	26,5	26,5	29,9	29,9
NO_2 percentil daily mean	47,7	47,7	50,1	50,1
NO_2 percentil hourly mean	59,6	59,6	65,6	65,6

Which actions are possible to model the effect of depends on the type of model used. If only local measures are implemented, e.g. traffic reduction, use of studded tyres, physical changes (number of lanes, etc.) for a certain or a few individual roads or a small block, local scale models are practical to use. For measures aimed at changing the traffic load on a larger scale, e.g. congestion tax, or a generally reduced base speed in a larger area that affects the entire inner-city traffic volumes, models that have pre-calculated emissions on an urban and regional scale are not recommended for use. An alternative is to contact the consultant or the model developer for the recalculation of traffic emissions for the larger area and produce an updated urban concentration contribution that can be combined with the local concentration calculation. The other option is to use an urban-scale model that covers a larger geographic area from scratch. However, what you have to bear in mind when using an urban-scale model is that the local-scale content in a specific street canyon is not obtained explicitly because several roads and sources are included in the urban-scale calculation. For this, a more advanced model chain is required where the urban contribution is calculated with a suitable model and the local contribution with a local-scale model. Double counting of emissions included in both the local-scale and urban-scale contribution must be handled. In other words, the local-scale emissions must be subtracted from the urban concentration calculation before the urban concentration contribution is added to the total concentration.

11.4.2. Worst-case scenario

In addition to examining the effect of the measures on air quality, it is also important to take into account how the annual variation in meteorology affects. Weather conditions vary from year to year, some years can be very unfavourable with, for example, a high frequency of dry, cold and stable weather conditions which can cause air pollution levels to be higher than normal (Grundström et al., 2015). It is therefore recommended to test the effect of the measures in different meteorological years to capture a so-called worst-case scenario. For particle concentrations, this could for example be a year with a high frequency of low-precipitation conditions such as an unusually dry spring, such as the spring of 2022[91]. In the case of NO_2, high levels can be linked to cold and stable weather conditions, especially during the winter months, when air quality standards are commonly exceeded.

The years 2010 and 2011 were years when Sweden experienced very cold winters with poorer air quality (NO_2) as a result (Pleijel et al. 2015). Running the model with meteorology from these years can thus provide information on how levels can be expected in an unfavourable year compared to the current year or in a favourable year with a high frequency of more windy and rainy weather conditions.

11.5. Projections for air quality

It is important to include projections for future emission conditions in the analysis of the air quality plan's future effect on air quality, partly in a shorter perspective (1-5 years) but also in a longer perspective. In the work for constructing air quality plans, future emission

[91] https://www.smhi.se/klimat/klimatet-da-och-nu/arets-vader/varen-2022-overvagande-torr-utom-ilapplandsfjallen-1.182232

scenarios are most interesting and relevant to look at in the shorter perspective as an air quality plan aims to keep the period of exceeding the air quality standard as short as possible. The Swedish Transport Administration produces traffic forecasts every two years for how traffic is expected to develop.[92] These forecasts are based on statistics and information on, for example, economic development, surveys on travel habits, means of transport and population development, etc. (Traffic Agency, 2020). Commonly car travel is assumed to increase in the future. The vehicle fleet is also expected to change, where diesel and petrol-powered passenger cars are expected to gradually decrease in favour of electric vehicles (Traffic Agency, 2020). It is important to also take this into account in scenario analyses for future years, and additional emission calculations therefore need to be made for 1, 2 and 5 years ahead with regard to emission forecasts. In the example below (Table 14), two new emission calculations have been developed which include the expected ADT on a road section if the annual traffic growth increases by 1.5% including the measures on studded tyre ban and reduced base speed limit.

Table 14*: Emission and level comparison (PM_{10}, NOx and NO_2) between base scenario, action scenario and future traffic forecasts for a street canyon.*

	Base scenario (current situation) (ADT =10 000)	Action scenario (studded tyre ban + reduced speed)	Action scenario + traffic projection 1 year (ADT ~ 10 150)	Action scenario + traffic projection 5 years (ADT ~ 10 800)
Emission PM_{10} (µg/m/s)	15,5	5,2	5,4	5,8
PM_{10} annual mean (µg/m^3)	21,2	18,1	18,1	18,2
PM_{10} 90-percentil daily mean (µg/m^3)	38,7	31,4	31,5	31,6
Emission NO_x (µg/m/s)	57,9	73	74,4	80,2
NO_2 annual mean (µg/m^3)	26,5	29,9	30,1	30,8
NO_2 98-percentile daily mean (µg/m^3)	47,7	50,1	51,7	52,6

[92] https://bransch.trafikverket.se/for-dig-i-branschen/Planera-och-utreda/Planerings--och-analysmetoder/Samhallsekonomisk-analys-och-trafikanalys/gallande-forutsattningar-och-indata/

NO_2 98-percentil hourly mean ($\mu g/m^3$)	59,6	65,6	65,9	67,3

When comparing the action scenario and the current situation in the example above, it can be stated that the emission decreases for PM_{10} (5.2 vs. 15.5 ug/m/s) while it increases for NOx (73 vs. 57.9 ug/m/s). NOx emissions from diesel and gasoline-powered vehicles are generally lowest at speeds of around 50-70 km/h. However, at higher and lower speeds, NOx emissions can increase, which is, among other things, linked to the higher engine load. Furthermore, the action scenario in turn leads to somewhat lower particle concentrations and somewhat higher NO_2 concentrations. We see here that certain measures have a positive effect on one pollutant while the situation worsens for another. It is therefore important to make an overall assessment of the effect of the measures on all the possible pollutants associated with the emission source. If we also include traffic forecasts in the impact analysis, we see that future increased car travel can in turn lead to increased emissions of both particles and NOx and also affect the levels, especially for NO_2. The traffic forecast does not include any change in the vehicle fleet, but if diesel and gasoline-powered vehicles, for example, were to decrease in favour of electric-powered vehicles, then the increasing NOx emissions and NO_2 levels should be counteracted to some extent.

Future projections are uncertain but important to consider when working with air quality plans. It is important to understand which trends are expected to affect air quality, both in terms of technology development and traffic volumes, and the effects they have on emissions and pollution levels. This is because it can affect the choice and extent of the measures required to comply with the air quality standards.

11.6. References

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