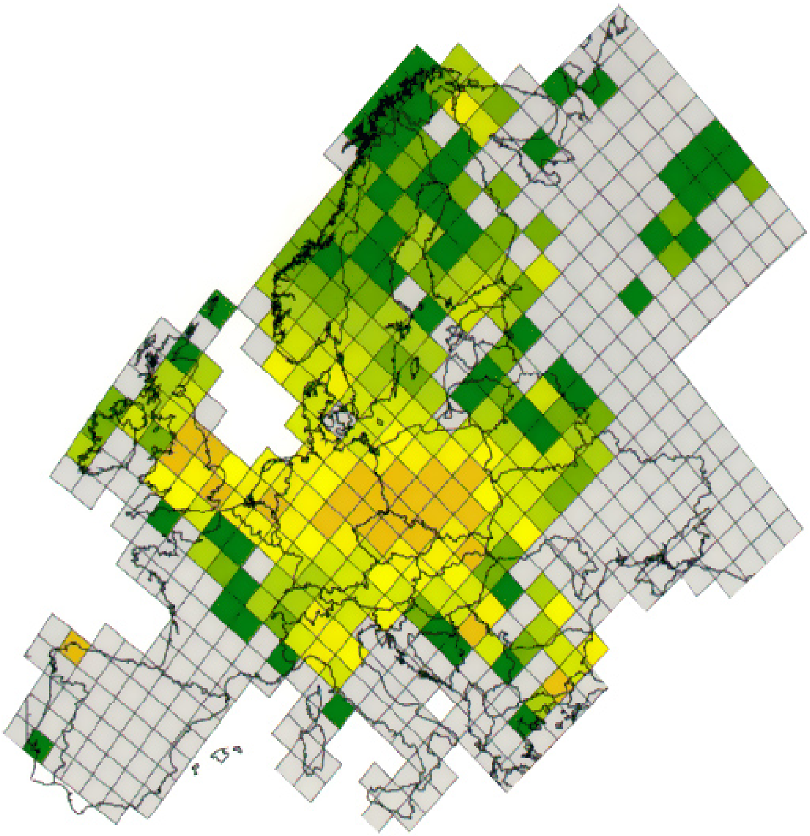
# Air Implementation Pilot:

# Assessing the modelling activities



## ETC/ACM Technical Paper 2013/4

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European Topic Centre on Air Pollution and Climate Change Mitigation

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***Cover page:***
*Representation of a grid model output for Europe.*

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# Air Implementation Pilot Description

In his address to the European Environment Agency (EEA) Management Board on 23 June 2011, Commissioner Potočnik stated the following:

*… [W]hile I don't think the EEA is equipped for such a role* [in inspections]*, we do need to strengthen our knowledge base on implementation. We cannot continue to have a situation on implementation where the Commission and Member States are looking at different data. We both need a body we trust to provide us with accurate data and state of the art, science-based assessments. We need an independent assessor if needed. This neutral and common information base for compliance monitoring should in my view be provided by the Agency. I suggest we develop a joint analysis of what such a reinforced role would imply, on the basis of one or two pilot cases e.g. on waste and on air. We need to start this process as soon as possible and I will be looking forward to develop it together with you.*

The Commissioner subsequently invited the European Commission's Directorate General for Environment (DG ENV) and the EEA to explore an enhanced EEA role in support of EU environment policy implementation, by way of pilots on air and waste.

To provide a public profile for the air implementation pilot and to prepare for the Integrated Projects proposed for air under the new LIFE+ regulation, EEA and DG ENV has mobilised a sample of cities (12) across the EU to take part in the pilot actions. Through 2012/2013 the air pilot actions have be taken forward with close involvement of these "sample" cities for the purpose of sharing both "successful" and "unsuccessful" experiences and to develop proposals for improved implementation that can be shared with a wider set of cities potentially via the LIFE+ mechanism.

The work has involved EEA, DG ENV, the European Thematic Centre for Air pollution and Climate change Mitigation (ETC/ACM), and the cities themselves, under the coordination of Alberto González Ortiz, EEA project manager for air quality data and policies assessments.

The present report refers exclusively to one of the tasks that were conducted under the Air Pilot. The complete list of key actions agreed upon by DG ENV and EEA and that were presented to the cities are described below:

1. Selection and engagement of cities
2. Assessing the emission inventories at the local level
3. Assessing modelling activities
4. Assessing monitoring station density and location
5. Assessing air quality trends
6. Assessing management practices
7. Assessing public information practices
8. Coordination, overall management and follow up

# 1 Introduction

The aim of this document is to examine the model practices (if models have been applied at all) in the twelve cities in Europe taking part in the Air Implementation Pilot, to assess the strengths and weaknesses of such applications and to further to identify needs for guidance in the use of air quality models.

The European Air Quality Directive (2008/50/EC) states that “where possible modelling techniques should be applied to enable point data to be interpreted in terms of geographical distribution of concentration. This could serve as a basis for calculating the collective exposure of the population living in the area”. Moreover, the Air Quality Directive sets limit and target values for the concentration of several pollutants, including $NO_2$ and $PM_{10}$. It is a requirement that all air quality zones and agglomerations assess the levels of these pollutants and report these to the European Commission. If concentrations are found to exceed these limit values then the Member States are obliged to take appropriate steps to reduce these concentrations. In order to do this effectively, air quality management plans must be developed and possible measures assessed. Air quality modelling then becomes an essential tool for local and national authorities to manage their air quality[1].

The document provides a description of the model applications addressed by twelve cities across Europe, illustrating the type of models applied, the input data employed and the strong and weak points encountered in the application of air quality models. This document does not provide precise recommendations on the application of models but focuses on the experiences of these cities when applying these models.

# 2 Description of the modelling questionnaire

In order to examine model practices in the 12 cities a questionnaire was prepared addressing the modelling activities in the cities (see Annex A). The questionnaire was sent to the contact persons in each city (see Table 2 in Annex A). In the year 2012 the questionnaire was sent to eight cities and in 2013 four new cities joined the Air Implementation Pilot project. The document compiles the answers of the twelve cities.

The questionnaire aimed to give answers to the following main questions:

a. What types of models have been used?
b. Which particular models?
c. Which input and other data (e.g. emissions, meteorology, monitored concentrations, boundary conditions, etc.) have been used or considered?
d. For what purposes are models used?
e. How are models validated?
f. Are the model results considered to be ‘fit for purpose’?

[1] Denby, R.B. 2011. Guide on modelling Nitrogen Dioxide (NO2) for air quality assessment and planning relevant to the European Air Quality Directive. ETC/ACM Technical Paper 2011/15.

The questionnaire was structured in four sections:

1. Overview and Contacts
2. Use of models
3. Modelling activities
4. Cooperation activities

The first section 'Overview and Contacts' presents a brief aim of the task and lists the responsible persons in each city, as well as the contact persons at EEA and ETC/ACM for this task.

The second section 'Use of models' tries to obtain an overview of the applications for which models are used and the responsible institution for running the models, if models have been applied. If models are not used then the reasons why they have not been applied should be indicated.

Section 3 of the questionnaire goes into more detail about how the model has been applied for each of the purposes. It requests a model description (setting configuration, input data, validation method, etc.) for each of the applications that have been outlined in the second section. This section also contains a subsection dedicated to get feedback from the cities about their particular experience in the application of models.

Finally, section 4 asks for other cooperative activities in the application of air quality models that have been undertaken by or in cooperation with other institutions (regional or national administrations, scientific institutions, etc.). The questions asked in this section are the same as in section 3.

# 3 Use of models for air quality activities

As mentioned before the questionnaire was sent to 12 cities, which have different sizes and population. For example Ploiesti is the smallest city with 229.258 inhabitants and an area of 58 km$^2$, whereas Berlin is the largest city, with 3.442.675 inhabitants and a surface of 892 km$^2$, followed by Madrid with more than 3 million inhabitants in a area of 604 km$^2$ (Table 1).

**Table 1: Summary of the inhabitants and area of the cities in the Air Pilot project.**

| City name | AQZ name | AQZ code | City population | City Surface |
|---|---|---|---|---|
| Berlin (Germany) | Ballungsraum Berlin | DEZBXX001A | 3.442.675 | 892 km$^2$ |
| Dublin (Ireland) | Zone A | IE001 | 527.612 | 115 km$^2$ |
| Madrid (Spain) | Madrid | ES1301 | 3.237.937 | 604 km$^2$ |
| Malmö (Sweden) | Malmö | SW6 | 302.000 | 155km$^2$ |
| Milan (Italy) | Milan Agglomerate | IT0306 | 1.307.495 | 182 km$^2$ |
| Ploiesti (Romania) | Ploiesti | RO0302 | 229.258 | 58 km$^2$ |
| Prague (Czech R.) | Praha | CZ010 | 1.257.158 | 496 km$^2$ |
| Vienna (Austria) | Wien | AT_09 | 1.731.444 | 415 km$^2$ |
| Paris (France) | Ile-de-France | FR04A01 | 2.234.105 | 105 km$^2$ |
| Plovdiv (Bulgaria) | Agglomeration Plovdiv | BG0002 | 338.153 | 102 km$^2$ |
| Antwerp (Belgium) | Port of Antwerp + Antwerp + Hoboken | BEF01A + BEF02A + BEF07S | 565.000 | 205 km$^2$ |
| Vilnius (Lithuania) | Vilnius | LT0100 | 534.000 | 400 km$^2$ |

All the cities with the exception of Dublin have applied models for air quality assessment or management. The city of Dublin despite its wish to use air quality models has encountered several problems of a different kind. Some of the problems pointed out in their reply to the questionnaire are at the administrative level, for instance the effort to bring together the various stakeholders to develop an air quality model and cooperate has not been successful. Another problem is the current economical situation. Finally, they have the perception that this is an area where there is a lack of the required skills and experience to develop a robust model. Despite this, the air quality management plan for the city of Dublin includes, as one of the actions, to build an air quality model for the region, however this action remains unfulfilled. The city of Dublin would benefit from guidance in this area, as well as from the communication and experiences from other cities, particularly from the difficulties they encountered and how they managed to overcome them. The city also highlights that it will also be important to learn about the economic aspects and budgeting from the other cities.

The other 11 cities that have employed air quality models have used them for different purposes. In the survey they were asked about 8 specific applications and a description of other applications where they had used models (see list of applications in Table 2). None of the cities have used models for other applications than the ones suggested in the survey. The applications of the models differ from city to city. Table 2 shows the summary of the purposes the cities have used models for. All the cities except Antwerp and Ploiesti have used models for assessment of source contributions. Vilnius has not employed models for long term planning and scenario calculations, and Madrid is the only city that has not used models for assessing air quality in general (see chapter 5 for further details).

**Table 2: Summary of the purposes the cities have used air quality models for.**

| | **Model application** | **Cities** | **Total number of cities** |
|---|---|---|---|
| 1 | Assessment of air quality in general (including evaluating the environmental (AQ) impact of new infrastructure like highways, airport, etc.) | Malmo, Milan, Vienna, Prague, Berlin, Paris, Plovdiv, Antwerp, Vilnius | 9 |
| 2 | Reporting of air quality compliance assessment | Malmo, Milan, Vienna, Madrid, Prague, Paris, Vilnius | 7 |
| 3 | Assessment of source contributions | Malmo, Milan, Vienna, Madrid, Prague, Berlin, Paris, Plovdiv, Vilnius | 9 |
| 4 | Long term planning and scenario calculations | Malmo, Milan, Vienna, Madrid, Prague, Berlin, Paris, Plovdiv, Antwerp | 9 |
| 5 | Short action plans | Malmo, Milan, Vienna, Madrid, Prague, Plovdiv, Vilnius | 7 |
| 6 | Air quality forecasting | Milan, Vienna, Madrid, Paris, Vilnius | 5 |
| 7 | Assessment of population exposure | Malmo, Milan, Vienna, Prague, Berlin, Paris, Plovdiv, Antwerp, Vilnius | 9 |
| 8 | Supplement measurements | Milan, Vienna, Berlin, Plovdiv, Antwerp, Vilnius | 6 |

Table 3 summarizes the different models that have been used by the cities, the purposes for which the models have been used, which cities have used them, and (when available) a link to the Model

Documentation System[2] (MDS). The city of Ploiesti has not provided information about the air quality model employed. Almost all the models employed are documented, with the exception of STREET (Paris) and POLTRAN (Plovdiv) and the majority of them (all but six) are in the Model Documentation System. The types of models employed are Gaussian, Lagrangian, Eulerian, Street canyon, Box model and Statistical model.

The cities of Malmö and Milan run the models themselves, while in the other cities the models are run by other institutions as research institutes, universities or independent consultants. The cities are aware of other specific and independent modelling studies, although only Malmö, Prague, Paris, Antwerp and Vilnius give a detailed description about their cooperation with other institutes. Malmö cooperates at regional level with Lund University, Prague cooperates at the national level with international institutions as NILU and VITO in the framework of EU research projects, Paris cooperates at two national and interregional levels with INERIS and ESMERALDA, respectively; Antwerp cooperates at regional level with LNE and Vilnius collaborates at regional level with the Lithuanian Environmental Protection Agency in the exchange of information and data as well as consultation in general. The cooperative activities are not always conducted on an operative basis or employed for air quality reporting.

**Table 3: Summary of the type of model and applications and model documentation**

| Name of the model | Type | Applications | City | Documentation |
|---|---|---|---|---|
| AERMOD | Gaussian | 1;3;4;5;7 | Malmö | http://pandora.meng.auth.gr/mds/showlong.php?id=128 |
| OSPM | Street canyon | 2;5<br>1;4;7;8 | Malmö, Madrid<br>Antwerp | http://pandora.meng.auth.gr/mds/showlong.php?id=74 |
| FARM | Eulerian | 1;2;4;5;7;8 | Milan | http://pandora.meng.auth.gr/mds/showshort.php?id=130 |
| SPRAY | Lagrangian | 3 | Milan | http://pandora.meng.auth.gr/mds/showshort.php?id=87 |
| CALPUFF | Gaussian | 3<br>1 | Milan<br>Paris | http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#calpuff |
| CBM | Chemical mass balance | 3 | Milan | http://www.epa.gov/scram001/receptor_cmb.htm |
| GRAL modified | Lagrangian | 1; 2; 3; 4; 7; 8 | Vienna | http://pandora.meng.auth.gr/mds/showlong.php?id=133 |
| CAMx | Eulerian | 5; 6;7 | Vienna | http://pandora.meng.auth.gr/mds/showshort.php?id=177 |
| SERENA | Statistical Neural Network | 6 | Madrid | http://www.mambiente.munimadrid.es/opencms/opencms/calaire/SistIntegral/SistPrediccion.html |
| CMAQ | Eulerian | 2; 3; 4; 5 | Madrid | http://www.cmaq-model.org/ |
| WRF-Chem | Eulerian | 2; 3; 4; 5 | Madrid | [http://www.acd.ucar.edu/wrf-chem/] |
| ATEM | Gaussian | 1; 2; 3; 4; 5; 7 | Prague | [http://www.atem.cz/en/atem.html] |

[2] http://acm.eionet.europa.eu/databases/MDS/index_html

| Name of the model | Type | Applications | City | Documentation |
|---|---|---|---|---|
| SYMOS | Gaussian | 5 | Prague | http://pandora.meng.auth.gr/mds/showshort.php?id=119 |
| REM_CALGRID_RCG | Eulerian | 1,3 | Berlin | http://pandora.meng.auth.gr/mds/showshort.php?id=173 |
| IMMISluft (IMMIScpb) | Gaussian | 1, 3, 4, 7,8 | Berlin | http://pandora.meng.auth.gr/mds/showshort.php?id=178 |
| CHIMERE | Eulerian | 1;2;3;4;6;7 | Paris | http://pandora.meng.auth.gr/mds/showshort.php?id=144 |
| ADMS urban | Gaussian, Lagrangian | 1<br>1,2,3,5,6,7,8 | Paris<br>Vilnius | http://pandora.meng.auth.gr/mds/showshort.php?id=18 |
| PMSS | Eulerian | | Paris | http://www.harmo.org/Conferences/Proceedings/_Kos/publishedSections/H14-176.pdf |
| STREET | Street canyon | 2; 4; 7 | Paris | NA |
| AUSTAL 2000 | Lagrangian | 1; 3; 4; 5; 7;8 | Plovdiv | http://pandora.meng.auth.gr/mds/showlong.php?id=132 |
| PROKAS_B | Gaussian | 1; 3; 4; 5; 7 | Plovdiv | http://pandora.meng.auth.gr/mds/showlong.php?id=115 |
| VinMISKAM | Eulerian | 1; 3; 4; 5; 7 | Plovdiv | http://pandora.meng.auth.gr/mds/showlong.php?id=123 |
| POLTRAN | Eulerian | 1; 3; 7; 8 | Plovdiv | NA |
| RIO | Interpolation model | 1;4;7;8 | Antwerp | http://rma.vito.be/demo/faces/documents/rio/RIO.pdf |
| AURORA | Eulerian | 1;4;7;8 | Antwerp | http://pandora.meng.auth.gr/mds/showlong.php?id=167 |
| IFDM | Gaussian | 1;4;7;8 | Antwerp | http://pandora.meng.auth.gr/mds/showlong.php?id=50 |

List of applications:
1) Assessment of air quality in general (including evaluating the environmental (AQ) impact of new infrastructure like highways, airport, etc.)
2) Reporting of air quality compliance assessment
3) Assessment of source contributions
4) Long-term planning and scenario calculations
5) Short-term action plans
6) Air quality forecasting
7) Assessment of population exposure
8) Supplement measurements

# 4 Overview of the models and applications

In this section an overview of the models used in each city and a brief summary of their experience as users of AQ models is presented. The city of Ploiesti has not completed the questionnaire provided to the cities but has sent a document with a brief description of the modelling activities performed in the city. The information from that document is presented in this section. However the document does not answer all the questions formulated in the questionnaire and therefore the information presented here for the city of Ploiesti is not as complete as for the other cities.

## 4.1 Berlin

The city of Berlin has applied two models, REM_CALGRID and IMMISluft, covering several spatial scales from regional and urban background to street canyons (see table 3). The models are run by a service contract consultant. Apart from these applications, there have been other modelling studies in the city of Berlin. For instance, the Eulerian grid model REM_CALGRID[3] has been used on different scales to simulate air quality in the city giving valuable indications on background and regional contribution to air quality; also trajectory studies have been performed[4].

The models are used on a frequent basis, and they have been found to be helpful for the purposes they were applied. For instance, in relation to air quality assessment activities they have been used for source apportionment and long range transport assessment. The model results have been taken into account in air quality management decisions. Moreover the models have been linked to other topics such as deposition and noise. The two main weak points encountered by the city of Berlin in the application of the models is the $PM_{10}$ underestimation in the Eulerian grid model and the background dependency in the street canyon model.

## 4.2 Madrid

The city of Madrid employs four different modelling systems for air quality purposes. In some of the cases they also employ a meteorological model (WRF) to drive an Eulerian Photochemical models (CMAQ and Chem). The models employed are Eulerian (WRF/Chem and CMAQ), combined plume and box model (OSPM) and statistical neural networks (SERENA). All the models are run by external institutions.

All the models have been helpful for the purpose used, and all of them with the exception of SERENA have been helpful for the AQ activities they have been applied for. SERENA model has only been applied for air quality forecasting and not for air quality assessment purposes. All the model results have been taken into account for air quality management decisions as long-term planning, short actions or public information. Some of the applications of the models include the estimation of GHG emissions.

The main weak points identified by the city of Madrid in their use of models are accounting for sub-grid scale processes at hotspots in complex urban geometries when using the Eulerian models; as well as the lack of spatial coverage in the statistical model, as the forecasting only covers the monitoring site. The city of Madrid also points out the necessity for a general framework and criteria for harmonization in modelling.

## 4.3 Malmö

The city of Malmö applies two different models for different air quality applications, a Gaussian model based on a modified version of AERMOD and the same street canyon model (plume and box model) used also by the city of Madrid (OSPM), and plans to develop a Land Use Regression model for ozone. The models are run by the institution itself. The city of Malmö collaborates with Lund University[5] on the development of the emission database and modelling software.

[3] http://pandora.meng.auth.gr/mds/showshort.php?id=173
[4] http://wekuw.met.fu-berlin.de/trumf/trajektorien/
[5] http://www.lunduniversity.lu.se

Both models employed by the city of Malmö have been helpful in relation to air quality assessments and also the results have been taken into account in air quality management decisions as well as other environmental management decisions, for instance noise management. The main use of air quality models is for planning and follow-up on measures implemented in the action plan.

The city of Malmö identifies as weak points in the modelling the inventory of heavy vehicles on each road as well as the estimation of boundary conditions (sources outside the geographical area). The further guidance required by the city is related to technical aspects on the applications of models, as for example, how to evaluate the outputs of the model, how to know if a model can be applied under certain conditions or how to estimate the concentrations of certain pollutants.

## 4.4 Milan

The city of Milan applies 4 different models, one Eulerian (FARM) and two Lagrangian models (SPRAY and CALPUFF) for different air quality purposes such as reporting of air quality or long term planning. Table 4 summarizes the applications of each of the models. In the case of Milan the models are run by the same institution. Additionally, there are other modelling studies conducted by other institutes in the Lombardy region.

The Eulerian and Lagrangian models have been helpful in relation to air quality assessment activities and their results have been taken into account in air quality management decisions. The city of Milan has not identified any weak points concerning the model applications.

## 4.5 Vienna

The city of Vienna has applied two different models, one Lagrangian model (GRAL) and the Eulerian photochemical model CAMx. The last for air quality forecasting and short action plans. Both models are run by other institutions.

The models have been helpful both for air quality assessment activities and for air quality management decisions. Other topics like noise and climate change have also been considered through a cross-functional cooperation with noise and climate change experts.

The main weaknesses encountered when applying the model are related to the interpretation of the results that requires air quality experts, the amount of resources required, and the limitations in the results (overestimation, limited knowledge about some processes and emissions, etc.).

## 4.6 Prague

The city of Prague has used two different models for air quality activities, the two models are Gaussian: ATEM and SYMOS (Table 4), and are run by another institute. The experience with ATEM has been mostly satisfactory, and the results have been taken into account in air quality management decisions. ATEM model has also been applied for generating concentration maps and estimating population exposure. However, the second model, SYMOS did not provide precise enough results due mainly to the poor quality of input data employed. Model SYMOS is used only for different limited areas of Prague. Despite this, the SYMOS model has been applied successfully for short term action plans. The ATEM model is more sophisticated and it is designed to cover all territory of Prague. Concentration maps produced by the ATEM model covering all territory of Prague are regularly updated. The update of ATEM 2012 is under preparation and will be published on the website http://www.premis.cz/AtlasZP/. The model ATEM has been employed for short term action plan evaluation, although it is a climatological Gaussian model producing annual statistics as results.

Both models employ annual averages of emission sources with their specifications and annual or climate wind roses as input. The output is a field of annual mean concentrations of pollutants $NO_2$, $NO_x$, $SO_2$, CO, $PM_{10}$, $PM_{2.5}$ and benzene.

## 4.7 Ploiesti

In Ploiesti city the models are used to assess air quality in general, for instance the impact of economic activities on air quality. Air quality management programs as well as the measures necessary to reduce the concentration of pollutants in the region are based on the modelling results.

The modelling analysis are not performed by Prahova EPA but by companies contracted by the Ministry of Environment and Forests. In the local agency yearly emission inventories are made according to a guideline in accordance with the requirements of the EMEP/EEA 2009 in the context of AQ Directive 2008/50/EC. The emission inventory (described in Annex B) is the input for the air quality models.

During the presentations at the project kick-off meeting, the city of Ploiesti highlighted that one of the difficulties they are facing is the elaboration of emission inventory due to fugitive emissions. It was commented that one of the key implementation successes was the inclusion of the refineries in the area of Ploiesti city. A dispersion study of pollutants was carried out to assess the individual contribution of each refinery.

## 4.8 Paris

The city of Paris use models for different purposes as for instance reporting of air quality, assessment of source contributions or air quality forecasting. The selection of the model depends on the type of application. A total of five models are employed in the city, including both Eulerian and Gaussian models. Only two of the models are documented in the MDS database, CHIMERE and ADMS urban. AirParif runs the models[6], but the city of Paris has also established cooperation with other institutes like INERIS and ESMERALDA in relation to modelling activities.

The models have been helpful in relation to AQ assessment activities and the results have been successfully taken into account in AQ management decisions as long-term planning. Moreover the models have also been employed to estimate the geographic areas and population exposure to regulatory pollutants.

The city of Paris also reports some of the difficulties that have been found in the application of the models as for instance biases at kerbside for near real time air quality assessment applications and the underestimation of $PM_{10}$ levels during high concentrations events when applying the CHIMERE model for air quality forecasting.

## 4.9 Plovdiv

Plovdiv uses models in the city for air quality activities such as assessment of air quality in general, long term planning and assessment of population exposure. The models employed depend on the application. Two models have been applied, AUSTAL 2000 and POLTRAN. Only the first one, AUSTAL

[6] http://www.airparif.asso.fr/en/index/index

2000 is documented in the MDS database. The models are run by independent experts at the National Institute of Meteorology and Hydrology[7] in Bulgaria, and no other collaborations are hold with other research institutes or administrations regarding air quality modelling.

Both models have been found helpful for the purposes they were applied, but only the results from AUSTAL 2000 have been taken into account in air quality decisions as long-term planning or short actions.

Some of the difficulties pointed out by the city of Plovdiv are the absence of data regarding the regional background concentration levels or that the meteorological conditions are estimated through interpolation and indirect methods.

## 4.10 Antwerp

The city of Antwerp employs air quality models for management activities such as long term planning or to supplement measurements. The chain of models RIO-AURORA-IFDM-OSPM is used for the different applications. The modelling activities are conducted by VITO[8]. The model has been documented and the results have been published in scientific papers describing the parameterisations and numerical methods employed.

AURORA is a three-dimensional Eulerian model and it is intended for regional applications with typical grid cell sizes ranging from 500 m to 30km, over domains 30 by 30 to 3000 by 3000 km. The AURORA model consists of several modules. The emission generator of AURORA calculates hourly pollutant emissions at the desired resolution, based on available emission data, and proxy data to allow for proper downscaling of coarse data.

The IFMD model (Immission Frequency Distribution Model) is a bi-Gaussian transport and dispersion model. It is used to assess the impact of emissions from point and area sources up to a distance of 30 km. Input to IFDM are the emissions of point and area sources in the region of interest, a receptor grid of arbitrary size and resolution, and a time series of hourly meteorological parameters over a period up to one year.

The RIO model it is not documented in the MDS database, but has been documented in scientific papers (see table 13).

The city of Antwerp has not made any comments about the user experience and if the model has been helpful for the purposes it has been applied.

## 4.11 Vilnius

The city of Vilnius employs the ADMS-Urban model for air quality management in the city. Some of the purposes addressed are reporting of air quality compliance assessment or short action plans evaluation (see Table 2). The model is run by a company and there are other modelling studies that have been realized in the city by the Environmental agency of Lithuania. In that case the models are used to create air pollution maps. The city of Vilnius cooperates with the Environmental protection agency for assessment of air quality in general, exchanging information and data, identifying possible

[7] http://www.meteo.bg
[8] http://www.vito.be

problems in the modelling, etc. As result of this cooperation annual air quality maps for the city for $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$ among other pollutants have been created.

The ADMS-Urban model has also been employed in the city of Paris for air quality management and assessment in general. The model has $NO_x$-$NO_2$ chemistry, sulphate chemistry and includes modules for street canyons (based on OSPM), complex terrain and buildings. Moreover a simple Lagrangian trajectory model is used to calculate background concentrations for the air approaching the main modelling area.

Some of the weak points identified by Vilnius concerning air quality modelling are the long computational time or the lack of knowledge in the model application.

# 5 Intercomparison of practices

The Air Quality Directive (2008/50/EC) lists three main applications of models:

1. Assessment of the existing air quality
    a. To supplement fixed data when a zone is in exceedance of the upper assessment threshold
    b. In combination with monitoring when a zone is in exceedance of the lower assessment threshold
    c. To replace monitoring when a zone is below the lower assessment threshold
2. Management: when limit or target values are exceeded an air quality plan is required
    a. Long term air quality plans
    b. Short term action plans in regard to exceedances of alert thresholds
    c. Co-operative air quality plans with other member states when transboundary air pollution in the cause of exceedances
3. Source apportionment: modelling in combination with monitoring to assess the causes of exceedances and the contribution from different sources.

As commented before, the city of Ploiesti has not completed the questionnaire sent to the cities but submitted a document describing the procedure to build up the emission inventory instead. A very brief description of the modelling activities in Ploiesti can be found in section 4, but the information has not been compiled in the tables and figures in this section for compatibility reasons. Therefore, all the information in this section is exclusively related to the 10 cities that have submitted the questionnaire.

In the questionnaire distributed to the cities it was asked if they have used models for the applications listed in Table 2. Figure 1 gives an overview of the purposes for which models have been applied. All of the cities except Vilnius have used models for long term planning, and most of them have employed models for air quality assessment in general, source contributions, and population exposure estimation. Only five of the cities have applied models for AQ forecasting (Milan, Vienna, Madrid, Paris and Vilnius). The cities of Milan, Vienna, Berlin, Plovdiv, Antwerp and Vilnius have employed modelling to supplement fixed data.  Finally, seven cities have applied modelling for reporting: Malmo, Milan, Vienna, Madrid, Prague, Paris and Vilnius. None of the cities have provided a description of alternative applications.

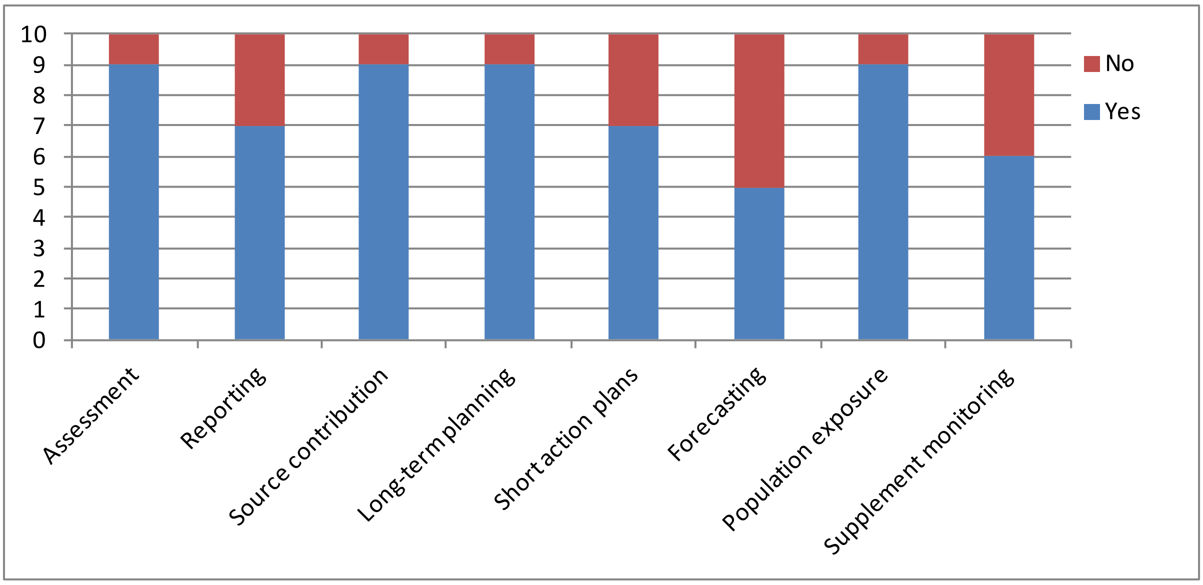


**Figure1. Number of cities that have used models for each particular air quality purpose.**

Regarding the user experience in the application of models for AQ purposes, all the cities have found that the model has been helpful for the purpose it was applied (the city of Antwerp has not answered this part of the questionnaire), although the city of Vilnius mention that the model results have not been taken in account in AQ management decisions. All the cities have used different models depending on the purpose of application with the exception of Vilnius that has employed one model for all the purposes. Only two cities run the models by themselves (Malmo and Milan), while in the other cities other institutions run the models. Moreover, the cities have identified needs for further guidance on the necessity of a general framework for modelling and more orientation on to how to use and validate a model.

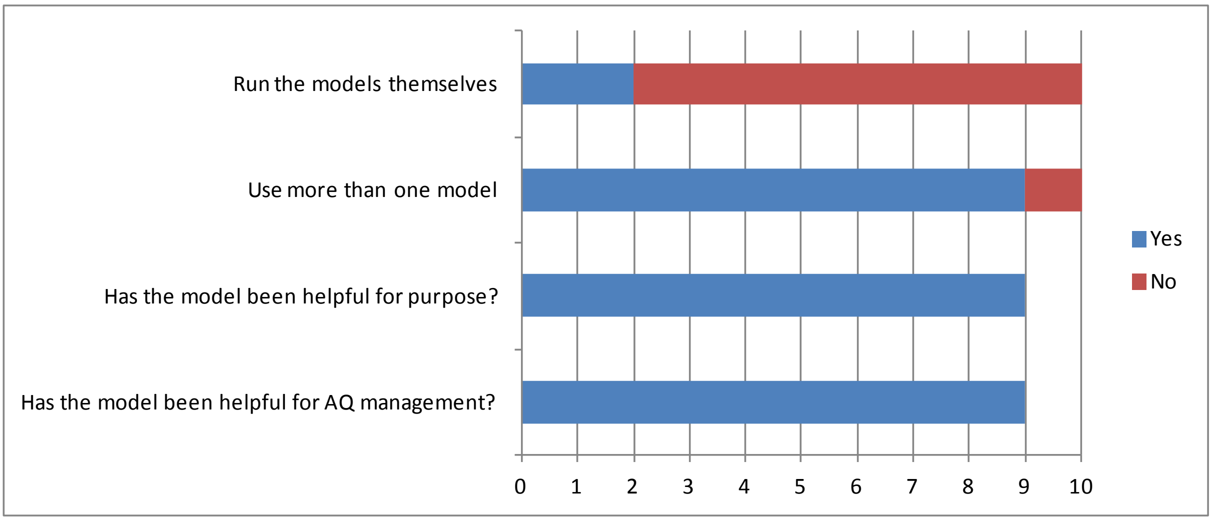


**Figure 2. Summary of user experience evaluation.**

In the next subsections we will compare how each city has applied the models for AQ purposes, comparing the different models they have used for each specific purpose and the configuration of the models (spatial and temporal resolution, pollutants modelled, etc.).

## 5.1 Assessment of air quality

Nine cities have applied models for assessment of air quality in general including evaluating the environmental impact of new infrastructures (highways, airports, etc.): Malmö, Milan, Vienna, Prague, Berlin, Paris, Plovdiv, Antwerp and Vilnius (Table 4). Each city has applied a different model for assessment of air quality.

The city of Malmö uses a Gaussian model (AERMOD) for assessment of air quality in general, the resolution employed depends on the purpose. This model is also employed for other purposes such as assessment of source contributions, long-term planning and source apportionment, just to mention some of them. The model outputs have hourly resolution and the components taken into account are nitrogen oxides. The model input includes all emission sources (traffic, domestic, industrial) although not all of them are updated on a yearly basis. For the meteorological fields the data from a measurement tower in Malmö are employed.

The city of Milan employs an Eulerian model for assessment of air quality (FARM). This model is also employed for other purposes as for instance reporting of air quality or long-term planning. The model outputs the concentrations for particulate matter and nitrogen oxides on an hourly basis. All the emission data for known sources have been included. The meteorological fields employed as input are ECMWF fields interpolated with the local monitoring network. The outputs of the dispersion model are validated against measurement data.

The city of Vienna employs the GRAL model, a Lagrangian model for assessment of air quality in general. Additionally this same model is employed for other applications such as reporting, assessment of source contributions or assessment of population exposure. The emissions introduced in the model consider all industrial, commercial, domestic and traffic sources. The meteorological fields are produced with the prognostic wind field model GRAMM (Grazer Mesoskaliges Modell).

The city of Prague uses the Gaussian model (ATEM) for air quality assessment. This model is employed for all the purposes addressed by the city of Prague (see table 3). The emissions included as input to the model cover all the known industrial, commercial, domestic and traffic sources. The model is validated against the data measured in the air quality monitoring network.

The city of Berlin employs two models for assessment of air quality in general, an Eulerian model (REM_CALGRID) and a Gaussian model (IMMISluft). The Eulerian model is also employed for source apportionment studies, and the Gaussian model is employed for the rest of the applications addressed by Berlin such as assessment of source contributions, long-term planning or short-action plans. The REM_CALGRID model considers both natural and anthropogenic emission sources; and the meteorological fields are obtained from an optimum interpolation of observations. The outputs of the model are validated against observations. The IMMISluft Gaussian model is employed to predict concentrations at street level, and the meteorology is obtained from one observation site. For the background concentrations the outputs from the REM_CALGRID model are employed. The background concentrations include the industrial and commercial sources, the emissions from traffic are included as line sources. The output of this model is also validated against measurements.

The city of Paris conducts near real time air quality assessment employing CHIMERE and then ADMS-urban and CALPUFF. ADMS-urban is employed over the Paris agglomeration, whereas the CALPUFF model is employed over specific areas as the western part of the Paris agglomeration for the motorway underground infrastructure and also for the air quality assessment around the airports of Orly and Roissy. For the modelling a specific local emission inventory has been developed with an spatial resolution of 1km that contains specific traffic emission for 40000 traffic lines. The emissions for traffic are based on traffic counts and the emission model COPERT IV is used. The emissions for industry and commercial and domestic sector take into account the vertical distribution of the emissions. Additionally the monitoring data has been used in combination with the model through sequential assimilation methods as for instance various kriging methods. The outputs of the models are validated against measurements using classical metrics as bias, root mean square error, etc.

The city of Plovdiv employs two models for general assessment of air quality; the models are AUSTAL 2000 and POLTRAN. The AUSTAL model is a Lagrangian particle model that models the transport of passive trace substances, and the result of the dispersion calculation is the substance-specific quantities according to EU directives. The estimation of emissions is conducted for traffic, industry and domestic sectors. For the estimation of transport emissions data about vehicle fleet has been employed (differentiation between light and heavy duty vehicles, speed, road obstacle density, type of fuel, etc.). For commercial and domestic sectors an average height is assumed according to the prevailing floor height. For the industrial emissions the characteristics of the stack is employed in the modelling. However, with the second model POLTRAN only industry and domestic sector emissions are considered and no PM speciation is conducted. When POLTRAN is employed for air quality assessment total dust is considered. The POLTRAN model is run with more simplistic assumptions, as for instance the background concentration are not taken into account. The quality of the results from both models AUSTAL and POLTRAN is assessed through error calculation using several statistics.

The city of Antwerp uses the same model for different applications with the same input data (emissions and meteorology). We will briefly discuss the setting of the model in this section and we will refer to this section in the next ones. The chain of models employed in Antwerp is RIO, AURORA, IFDM and OSPM. The pollutants modelled are: $PM_{10}$, $PM_{2.5}$, $NO_2$ and EC. Regarding the emissions, and specific local emission inventory for road traffic has been developed, but generic emissions inventories are employed for other purposes. Different sectors are employed depending on the model, for instance, all sources are included implicitly in RIO, all SNAP sectors in AURORA, industry and road emissions in IFDM and exclusively road emissions in OSPM. For traffic emissions the emissions have been updated in regard to fleet composition and emission factors. For instance the speciation for NO and $NO_x$ is conducted employing the COPERT model. Traffic is considered as line source emissions for the modelling, the commercial and domestic sector is considered as surface emissions and the industrial sources are considered as a combination of point sources and surface emissions. The meteorology employed depends on the model, for AURORA modelling input is employed, while for IFDM and OSPM meteorological measurements are used. The model results have been compared against observations and the uncertainty of the model has also been determined for RIO and AURORA models.

As mentioned before the city of Vilnius employs the same model for assessment of air quality in general as for the other purposes (see Table 3). A general overview of how the model is configured will be given in this section. The model ADMS urban was applied with a finer resolution of 130 x 130m over an area of 400 $km^2$. The time resolution is annual and seasonal and it is done for $NO_2$, $SO_2$, CO, $PM_{10}$ and since 2013 it also includes $PM_{2.5}$. The emission inventory does not cover all the sources, but it includes the main ones as for instance stationary, road, rail and residential sources. Emissions from domestic sector and small industries are identified as difficult to collect and include in the modelling system. The model outputs have been verified employing monitoring data.

If we compare how the models have been configured in the different cities we see that for instance the spatial scale ranges from street scale (tens of meters) to a more urban or regional scale. Six cities have used nesting in the models. The cities of Vienna, Prague, Plovdiv and Vilnius have employed annual time resolution, while Antwerp, Malmö, Milan and Paris have employed models with hourly resolution outputs. The city of Berlin has used two different models with different spatial and temporal resolution: hourly resolution for the regional scale (REM_CALGRID) and annual resolution for the street scale (IMMISluft).

All the cities use a dispersion AQ model, but only three models are able to resolve the local/hotspot spatial scales: AERMOD (Malmö), GRAMM/GRAL (Vienna), IMMISluft (Berlin), in the rest of cities this issue is not well solved. For instance in Paris emissions are based on traffic counts (flow and speed) that cannot reflect completely congestion effects. Regarding the photochemical activity in the atmosphere Milan, Berlin, Paris, Antwerp, Plovdiv and Vilnius included it. All the cities have validated the model against measurements with different types of stations (background, traffic, etc.). For the validation common statistical errors are employed (bias, RMSE, correlation factor, etc.). The city of Malmö only uses bias, but a more stringent quality process is being developed.

In table 13 references to more detailed information about the application of models in the cities can be consulted.

**Table 4: General description of model configuration for AQ general assessment.**

| | Malmö | Milan | Vienna | Prague | Berlin | Berlin |
|---|---|---|---|---|---|---|
| **Model** | AERMOD | FARM | GRAMM/GRAL | ATEM | REM_CALGRID | IMMISluft |
| **Spatial scale** | Depending on applic. | 4x4 $km^2$ | 10x10$m^2$ | 50m-100km | 4000$m^2$ | Street canyon |
| **Nesting** | Yes | No | No | No | Yes | No |
| **Time resolution** | Hourly, daily, annual | Hourly | Annual means | Annual | Hourly | Annual |
| **Pollutants** | $NO_x/NO_2$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$ | $PM_{10}$, $NO_x$, $NO_2$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$, $SO_2$, benzene, CO | $PM_{10}$ (components), $NO_2$, $O_3$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$ |
| | **Paris** | **Paris** | **Plovdiv** | **Plovdiv** | **Antwerp** | **Vilnius** |
| **Model** | CHIMERE + CALMET - ADMS-urban | CHIMERE + CALMET-CALPUFF | AUSTAL 2000 | POLTRAN | RIO-AURORA-IFDM-OSPM | ADMS urban |
| **Spatial scale** | ~ 2700 km 50m x 50m | 50m, refinement along roads | 54 $km^2$ 24mx24m | 250mx250m | 10mx10m irregular grid | 400 $km^2$ 130x130m |
| **Nesting** | Background from regional model | Background from regional model | Yes | Yes | Yes for road emissions | Yes |
| **Time resolution** | Daily | Hourly, daily | yearly | hourly | hourly | Yearly, Seasonal |
| **Pollutants** | $PM_{10}$, $PM_{2.5}$, $NO_2$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, benzene | 2002 – $SO_2$, $PM_{10}$, Cd<br>2007 and 2010 – $PM_{10}$, $NO_2$<br>2011 – $PM_{2.5}$, B(a)P | Dust, $SO_2$, $NO_x$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, EC | $PM_{10}$, $PM_{2.5}$ $NO_2$, $SO_2$, CO |

## 5.2 Reporting of air quality compliance assessment

A total of 7 cities have applied air quality models for reporting of air quality assessment: Malmö, Milan, Vienna, Madrid, Prague, Paris and Vilnius. The cities of Milan, Vienna, Vilnius and Prague have used the same model for reporting as for assessment of air quality in general. The city of Malmö has used a street canyon model for reporting of AQ assessment, the city of Madrid has used two models, one of them, the street canyon model, is the same as in Malmö. The city of Paris has employed the CHIMERE and STREET model for reporting of air quality compliance assessment (Table 5). In those cities that have also used the model for air quality assessment (Milan, Prague, Vilnius and Vienna) the model has been configured with the same settings (see Tables 4 and 5) and no further analysis is provided in this section.

The city of Madrid uses two models for reporting of air quality compliance assessment. The models are used for notification of time extension but not for annual compliance assessment. One of the models is the chain of grid models WRF-SMOKE-CMAQ for meteorology, emissions and air quality dispersion, respectively. The model uses 4 nested domains from 48 $km^2$ to 1 $km^2$ in the inner domain. The pollutants modelled include not only PM and NOx but also $O_3$, $NH_3$ and VOC with hourly time resolution. The second model employed is the plume and box model for street canyon applications OSPM, the spatial scale is not fixed and it has temporal hourly resolution.

The photochemical model CMAQ employed by the city of Madrid includes full chemistry and in order to solve the local spatial scales and hotspots the street canyon OSPM model has been applied. The validation of the model results has been performed using the Delta tool[9]. The uncertainty of the model results fulfils the requirement of the AQ Directive.

The city of Malmö has also applied the OSPM model (Table 5). Malmö use the dispersion model for reportning on concentrations at certain critical streets in the city. The model has been validated against local measurement for $NO_x$ and $NO_2$, but only bias has been used as a quality indicator. The uncertainty of the model has not been determined. The model is run in a base of 1 or 2 times per year, and the model has been found helpful for AQ compliance assessment. The results have been successfully taken into account in AQ management decisions, where applicable, and also have been linked to topics such as noise. The outputs of the model have been used for estimating spatial distribution and population exposure of national limit values and have also served for epidemiological research studies.

The city of Paris uses the chain of models CHIMERE and STREET for reporting of air quality compliance assessment. The model covers the Île-de-France region (12,012 $km^2$) with a high horizontal resolution (50 meters) and annual temporal resolution. A specific emission inventory has been developed, with 1 km for the local sources and around 40000 traffic lines. The outputs of the model have been validated against measurement employing metrics such as bias, mean error or correlation factor. The models CHIMERE-STREET have been found helpful for reporting AQ compliance, and the model results have been taken into account for AQ management decisions.

[9] http://aqm.jrc.it/DELTA/

**Table 5: General description of the model configuration for reporting of AQ compliance assessment.**

| | Malmö | Milan | Vienna | Madrid | Madrid | Prague |
|---|---|---|---|---|---|---|
| **Model** | OSPM | FARM | GRAMM/GRAL | WRF-CMAQ | OSPM | ATEM |
| **Spatial scale** | Street canyon (50-500m) | 4x4 $km^2$ | 10x10 $m^2$ | 1x1 $km^2$ | Depending on application | 50 m |
| **Nesting** | Dual grid | No | No | Yes | - | No |
| **Time resolution** | Hourly, daily, annual | Hourly | Annual | Hourly | Hourly | Annual |
| **Pollutants** | NOx/NO2 | PM10, PM2.5, NO2, NOx | PM10, NOx, NO2 | PM10, PM2.5, NO2, NOx, O3, NH3, VOC, SOx | PM10, PM2.5, NO2, NOx, O3, NH3, VOC, SOx, Benzene, HM | PM10, PM2.5, NO2, NOx, SO2, benzene, CO |
| | **Paris** | **Vilnius** | | | | |
| **Model** | CHIMERE+STREET | ADMS urban | | | | |
| **Spatial scale** | 50mx50m | 400 $km^2$ 130x130m | | | | |
| **Nesting** | | Yes | | | | |
| **Time resolution** | Annual | Yearly, Seasonal | | | | |
| **Pollutants** | Regulatory pollutants | PM10, PM2.5 NO2, SO2, CO | | | | |

## 5.3 Assessment of source contributions

All the cities except Antwerp have applied AQ modelling for assessment of source contributions. The type of model applied varies, for instance Malmö, Prague and Berlin apply a Gaussian model, Milan a combination of Eulerian and Puff model, Vienna a coupled Eulerian (meteorology) and Lagrangian (air quality) model, Madrid a Eulerian model, Paris a Eulerian model, Plovdiv a Lagrangian model and Vilnius the ADMS Gaussian and Lagrangian urban model.

The general description of the model configuration can be consulted in the Table 6. The table shows that the spatial resolution is very high ranging from 10x10 $m^2$ to 1x1 $km^2$. Malmö and Madrid applied nesting, but with very different scales. In the case of Madrid the model is configured with 4 nested domains with horizontal cells from 48 $km^2$ to 1 $km^2$, while in Malmö the outer domain is 500x500 $m^2$. All the cities model $PM_{10}$ and $NO_x$, and all of them but Vienna and Plovdiv also include $PM_{2.5}$. As shown in the table some of the cities include other pollutants such as $O_3$, $NH_3$, benzene or VOC. $NO_2$ and $PM_{10}$ are the two pollutants included in the time extension notifications (TEN) and plans and programs (P&P) for the European Commission.

The dispersion AQ models have been validated employing the AQ monitoring network. The number and type of station vary from each city. For instance Vienna uses all the stations to validate $PM_{10}$, $NO_x$ and $NO_2$, while in Madrid the validation is conducted only with urban background monitoring stations. In Berlin, that employs a street canyon model, the validation is conducted at hot spots for $PM_{10}$, $PM_{2.5}$ and $NO_2$. The links for further information about the modelling approach in each city can be found in the table 13.

Table 6: General description of model configuration for source contributions (SC).

| | Malmö | Milan | Vienna | Madrid | Prague | Berlin |
|---|---|---|---|---|---|---|
| **Model** | AERMOD | SPRAY & CALPUFF | GRAMM/GRAL | WRF-CMAQ | ATEM | IMMISluft |
| **Spatial scale** | 50 m | Variable, 1x1 $km^2$ | 10x10 $m^2$ | 1 $km^2$ | 50 m | Street canyon |
| **Nesting** | Local (one road), inner (50x50 m), and outer (500x500m) | No | No | 4 nested domains from 48 $km^2$ | No | No |
| **Time resolution** | Annual | Hourly | Annual | Hourly | Annual | Annual |
| **Pollutants** | $NO_x$, $PM_{10}$, $PM_{2.5}$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$ | $PM_{10}$, $NO_x$, $NO_2$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$, $O_3$, $NH_3$, VOC, $SO_x$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$, $SO_2$, benzene, CO | $PM_{10}$, $PM_{2.5}$, $NO_2$, NOx |
| | **Berlin** | **Paris** | **Plovdiv** | **Plovdiv** | **Vilnius** | |
| **Model** | REM_CALGRID | CHIMERE | AUSTAL | POLTRAN | ADMS urban | |
| **Spatial scale** | 4 x 4 $km^2$ | 3x3 km | 24x24m | 250x250m | 400 $km^2$ 130x130m | |
| **Nesting** | Yes | Yes | Yes | Yes | Yes | |
| **Time resolution** | Hourly | Hourly | Annual | Hourly | Yearly, Seasonal | |
| **Pollutants** | $PM_{10}$ (components), $NO_2$, $O_3$ | Aerosols | $SO_2$, $NO_2$, $PM_{10}$, $PM_{2.5}$, Cd, B(a)P | Dust, $SO_2$, NOx | $PM_{10}$, $PM_{2.5}$ $NO_2$, $SO_2$, CO | |
| | | | | | | |
| | | | | | | |

## 5.4 Long term planning and scenario calculations

All cities except Vilnius apply models for long term planning and scenario calculations, as shown in Table 2. Malmö and Prague apply a Gaussian model, Milan, Paris and Madrid apply an Eulerian model, Vienna and Plovdiv apply a Lagrangian model, Berlin applies, as in all the applications on street level, a street canyon model, and Antwerp applies the chain of models described in section 5.1, including Eulerian and Gaussian models. The configuration of the models is the same as in the previous applications (see section 5.1 to 5.3). Only Malmö commented that the spatial scales and nesting depends on the purpose (Table 7), as long term scenario modeling often involves choosing between a number of different traffic solutions that may affect the entire city or just a specific set of hot-spots. The rest of cities keep the same configuration of the model independent of the purpose.

**Table 7: General description of model configuration for long term planning and scenario calculations.**

| | Malmö | Milan | Vienna | Madrid | Prague | Berlin |
|---|---|---|---|---|---|---|
| **Model** | AERMOD/OSPM | FARM | GRAMM/GRAL | WRF-CMAQ | ATEM | IMMISluft |
| **Spatial scale** | Depending on purpose | 4x4 $km^2$ | 10x10 $m^2$ | 1x1 $km^2$ | 50 m | Street canyon |
| **Nesting** | Depending on purpose | No | No | 4 nested domains from 48 $km^2$ | No | No |
| **Time resolution** | Hourly, daily, annual | Hourly | Annual | Hourly | Annual | Annual |
| **Pollutants** | $NO_x/NO_2$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, NOx | $PM_{10}$, NOx, $NO_2$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, NOx, $O_3$, $NH_3$, VOC, SOx | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$, $SO_2$, benzene, CO | $PM_{10}$, $PM_{2.5}$, $NO_2$, NOx |
| | **Paris** | **Plovdiv** | **Antwerp** | | | |
| **Model** | CHIMERE-STREET | AUSTAL | RIO-AURORA-IFDM-OSPM | | | |
| **Spatial scale** | 50x50 m | 24x24m | 10m (irregular grid) | | | |
| **Nesting** | Yes | Yes | Yes | | | |
| **Time resolution** | daily | annual | hourly | | | |
| **Pollutants** | $PM_{10}$, $PM_{2.5}$, $NO_2$, $O_3$ | $SO_2$, $NO_2$, $PM_{10}$, $PM_{2.5}$, Cd, B(a)P | $PM_{10}$, $PM_{2.5}$, $NO_2$, EC | | | |

## 5.5 Short term action plans

Seven cities have applied models for short term action plans: Malmö, Milan, Vienna, Madrid, Prague, Plovdiv and Vilnius (Table 8). The city of Malmö has applied a Gaussian model AERMOD covering the entire city and a street canyon model OSPM. The city of Malmö evaluates the expected outcome of the actions as for instance rerouting of public transportation to avoid local hotspots but also more general traffic actions as street/lane configuration changes. The city of Milan has applied the Eulerian model FARM, configured in the same way as it was for the assessment of air quality and for the long term planning and scenario calculations. The city of Madrid applies, as in most of its applications, the chain of models WRF, SMOKE and CMAQ for meteorology, emissions and air pollutant dispersion, respectively. The city of Prague has applied two models for short term action plans, the Gaussian model ATEM with the same configuration as for the assessment of air quality, and the Gaussian model SYMOS, that has only been applied for short term action plans.

The city of Vienna has applied the Eulerian model CAMx driven by the meteorological model ALARO. This model has been applied for short term actions and forecasting. In Vienna, the air quality model is considered “fit for purpose” and the outputs have been validated for ozone at all the monitoring stations. Also the model has been validated in similar environments in the provinces Niederösterreich (Lower Austria) and Burgenland. It has been observed that the model tends to overestimate the concentrations.

The city of Plovdiv has employed the Lagrangian model AUSTAL for the development of short term action plans. The model uses the same input data and configuration as for air quality assessment in general and long term planning (see sections 5.1 and 5.4). The domain covers the city of Plovdiv with a final resolution of 24x24m. The model employs nested domains with coarse resolutions of 250x250m2 and 400x400m2. The results from modelling have been useful but some of the difficulty in applying the AUSTAL model is that there is not data about regional background concentration levels.

The city of Vilnius applies the ADMS urban model with the same configuration as in air quality assessment with also annual and seasonal time resolution (see 5.1 for further description).

**Table 8: General description of model configuration for short action plans.**

| | Malmö | Milan | Vienna | Madrid | Prague | Prague |
|---|---|---|---|---|---|---|
| **Model** | AERMOD/OSPM | FARM | CAMx | CMAQ | ATEM | SYMOS |
| **Spatial scale** | Depending on purpose | 4x4 $km^2$ | 9.6x9.6 $km^2$ | 1 $km^2$ | 50 m – 100 Km | Depending on purpose |
| **Nesting** | Depending on purpose | No | No | 4 nested domains from 48 $km^2$ | No | No |
| **Time resolution** | Hourly, daily, annual | Hourly | Hourly | Hourly | Annual | Annual |
| **Pollutants** | $NO_x/NO_2$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$ | $O_3$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$, $O_3$, $NH_3$, VOC, $SO_x$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$, $SO_2$, benzene, CO | $PM_{10}$, $NO_2$, $NO_x$ |
| | **Plovdiv** | **Vilnius** | | | | |
| **Model** | AUSTAL | ADMS urban | | | | |
| **Spatial scale** | 24mx24m | 400 $km^2$ 130x130m | | | | |
| **Nesting** | Yes | Yes | | | | |
| **Time resolution** | Annual | Annual, Seasonal | | | | |
| **Pollutants** | $SO_2$, $NO_2$, $PM_{10}$, $PM_{2.5}$, Cd, B(a)P | $PM_{10}$, $PM_{2.5}$ $NO_2$, $SO_2$, CO | | | | |

## 5.6 Air quality forecasting

Five cities have used models for air quality forecasting: Milan, Vienna, Madrid, Vilnius and Paris. However, Milan has not included a description of the modelling activities (model configuration, data input, user experience, etc.) and, therefore, no further information is provided. The city of Vienna has employed the CAMx model with the same configuration and data input as in the short term action plan application. The city of Madrid has employed a statistical model for air quality forecasting, SERENA (Statistical Neural Network Air-Quality Forecasting System). In table 9 the model configurations for air quality forecasting purposes are indicated.

The city of Madrid does not employ a dispersion model for air quality forecasting but a statistical model based on neural networks. This model does not employ emissions as data input and the meteorology is based on single point measurement. The background concentrations are considered. Monitoring data have been used as a historical database to produce prediction algorithms and also as numerical predictors. The model has been validated against observations. The main difficulties associated with the use of this statistical model are the need for historical data representative of each point to be modelled and also that hourly observations from the monitoring network are needed to run the model. The weaker point of the model is its spatial coverage, as actually the forecasting is only for the locations where the monitoring stations are placed and does not cover the entire city.

The city of Paris employs the CHIMERE model on a daily basis for air quality forecasting with a 3x3 km resolution that covers an area of 250000 $km^2$. A nested modelling with 4 nested domains from continental (45km), national (15km) and 2 interregional domains with a finer resolution of 3km. The temporal resolution is 1 hour and the pollutants forecasted are $NO_2$, $O_3$, $PM_{10}$ and $PM_{2.5}$. The main difficulty that has been found in the forecasting application is the underestimation of $PM_{10}$ concentration during high concentration events.

The city of Vilnius employs as in the rest of applications the ADMS urban model. The model is run in a daily operational basis and the pollutants include: $PM_{10}$, CO, $SO_2$ and $NO_2$. Currently NO and $PM_{2.5}$ are being tested.

**Table 9: General description of model configuration for air quality forecasting.**

| | Vienna | Madrid | Paris | Vilnius |
|---|---|---|---|---|
| **Model** | CAMx | SERENA | CHIMERE | ADMS urban |
| **Spatial scale** | 9.6x9.6 km | Monitoring station (receptor oriented statistical model) | 3kmx 3km | 400 $km^2$ 130x130m |
| **Nesting** | No | No | Yes | Yes |
| **Time resolution** | Hourly | Hourly | hourly | daily |
| **Pollutants** | $O_3$ | $PM_{10}$, $NO_2$, $O_3$ | $NO_2$, $O_3$, $PM_{10}$, $PM_{2.5}$ | $PM_{10}$, $PM_{2.5}$ $NO_2$, $SO_2$, CO |

## 5.7 Assessment of population exposure

The cities of Malmö, Milan, Vienna, Prague, Berlin, Paris, Plovdiv, Vilnius and Antwerp have used the model results for estimating spatial distribution of pollutant concentrations and population exposure to exceedances of the air quality limit values (Table 10). For that purpose they have used the models already employed in other applications such as air quality assessment or forecasting. In some of the cities, such as Malmö, Plovdiv and Vienna, the results of two different models have been applied to assess population exposure. The city of Malmö has employed the plume and box model OSPM and the Gaussian model AERMOD, while the city of Vienna has employed the GRAL Lagrangian model and the Eulerian photochemical model CAMx. The cities of Milan, Prague, Berlin and Vilnius have only used the outputs from one model to evaluate human exposure. The city of Milan has employed an Eulerian model (FARM), the city of Prague a Gaussian model (ATEM) and the city of Berlin a Gaussian semi-empirical chemical model (IMMISluft). The city of Vilnius has employed the ADMS urban model, but it is not usually run to estimate geographic areas and population exposure, however it is being employed in 2013 to identify educational institutions where air pollution exceed the limit values.

Paris has employed the chain of models CHIMERE+STREET to assess the population exposure in public-access buildings, for that purpose a resolution of 50m have been employed. This chain of models has also been employed for AQ compliance assessment (see section 5.2) for regulatory pollutants. The assessment of population exposure has been conducted for $PM_{10}$, $NO_2$ and Benzene (see table 10). The cities of Plovdiv and Antwerp have employed the same models and configurations as for assessment of air quality in general (see table 10 and section 5.1 for model set up details).

For all the cities the configuration, as can be seen in the table 10, does not change from the configuration used in previous applications, and the same model outputs have also been employed to estimate population exposure.

**Table 10: General description of model configuration for assessment of population exposure.**

| | Malmö | Malmö | Milan | Vienna | Vienna | Prague |
|---|---|---|---|---|---|---|
| **Model** | OSPM | AERMOD | FARM | GRAMM/GRAL | MM5-CAMx | ATEM |
| **Spatial scale** | Street canyon (50-500m) | 50x50 m | 4 x 4 km | 10 x 10 m | 9.6 x 9.6 km | 50 m |
| **Nesting** | Dual grid | Local (one road), inner (50x50 m), and outer (500x500m) | No | No | No | No |
| **Time resolution** | Hourly, daily, annual | Annual | Hourly | Annual | Hourly | Annual |
| **Pollutants** | $NO_x/NO_2$ | $NO_x$, $PM_{10}$, $PM_{2.5}$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$ | $PM_{10}$, $NO_x$, $NO_2$ | $O_3$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$, $SO_2$, benzene, CO |

| | Berlin | Paris | Plovdiv | Plovdiv | Antwerp | Vilnius |
|---|---|---|---|---|---|---|
| **Model** | IMMISluft | CHIMERE + STREET | AUSTAL | POLTRAN | RIO-AURORA-IFDM-OSPM | ADMS urban |
| **Spatial scale** | Street canyon | 50x50m | 24mx24m | 250x250m | 10m (irregular grid) | 400 $km^2$ 130x130 m |
| **Nesting** | No | Yes | Yes | Yes | Yes | Yes |
| **Time resolution** | Annual | Annual | Annual | Hourly | hourly | Yearly, Seasonal |
| **Pollutants** | $PM_{10}$, $PM_{2.5}$, $NO_2$, $NO_x$ | $PM_{10}$, $NO_2$, Benzene | $SO_2$, $NO_2$, $PM_{10}$, $PM_{2.5}$, Cd, B(a)P | Dust, $SO_2$, $NO_x$ | $PM_{10}$, $PM_{2.5}$, $NO_2$, EC | $PM_{10}$, $PM_{2.5}$ $NO_2$, $SO_2$, CO |

## 5.8 Supplement measurements

Six of the cities have employed models to supplement monitoring stations, Milan has employed the Eulerian model FARM; Vienna has applied GRAMM/GRAL; Berlin has employed the IMMISluft street canyon model, Vilnius has employed the ADMS urban model, Plovdiv has employed the models AUSTAL 2000 and POLTRAN, and Antwerp has employed the chain of models RIO-AURORA-IFDM-OSPM. The spatial scales employed ranged from 10x10 meters in Vienna to 4x4 $km^2$ in Milan, and the time resolution is both hourly and annual (Table 11). For further information about modelling activity links, Table 13 can be consulted.

**Table 11: General description of model configuration for supplement measurements.**

| | Milan | Vienna | Berlin | Vilnius |
|---|---|---|---|---|
| **Model** | FARM | GRAMM/GRAL | IMMISluft | ADMS urban |
| **Spatial scale** | 4x4 km | 10x10 m | Street canyon | 400 $km^2$ 130x130m |
| **Nesting** | No | No | No | Yes |
| **Time resolution** | Hourly | Annual | Annual | Yearly, Seasonal |
| **Pollutants** | $PM_{10}$, $PM_{2.5}$, $NO_2$, NOx | $PM_{10}$, $NO_x$, $NO_2$ | $PM_{10}$, $PM_{2.5}$, NO2, $NO_x$ | $PM_{10}$, $PM_{2.5}$ $NO_2$, $SO_2$, CO |
| | **Plovdiv** | **Plovdiv** | **Antwerp** | |
| **Model** | AUSTAL | POLTRAN | RIO-AURORA-IFDM-OSPM | |
| **Spatial scale** | 24mx24m | 250x250m | 10m (irregular grid) | |
| **Nesting** | Yes | Yes | Yes | |
| **Time resolution** | Annual | Hourly | hourly | |
| **Pollutants** | $SO_2$, $NO_2$, $PM_{10}$, $PM_{2.5}$, Cd, B(a)P | Dust, $SO_2$, NOx | $PM_{10}$, $PM_{2.5}$, $NO_2$, EC | |

# 6 Summary of models applied for each purpose

A range of different model types have been applied by the cities for the purposes described in the last section. Table 12 summarizes the models applied for each purpose and the list of cities that have addressed each of the applications.

- For assessment of air quality in general the type of models that have been applied are Gaussian (6), Eulerian (4) and Lagrangian (3), street canyon model (1) and also an statistical model based on interpolation (1).
- For reporting of air quality compliance the type of models applied are Street canyon model (1), Eulerian (2), Lagrangian (1) and Gaussian (1).
- For assessment of source contribution Gaussian (5), Lagrangian (4), Eulerian (4) and also a chemical mass balance model (1) have been applied.
- For long term planning and scenario calculations, Street canyon (2), Gaussian (4), Eulerian (3) and Lagrangian (2) models have been employed.
- For short term action plans Gaussian (4), Eulerian (3) and Lagrangian (2) models have been applied. For air quality forecasting the cities have employed Eulerian dispersion models (2), a statistical model based on neural networks (1), Lagrangian models (2) and Gaussian models (1).
- For assessing the exposure of the population the models used have been Gaussian (5), Eulerian (3), Lagrangian (3), street canyon (1) and interpolation model (1).
- Finally, to supplement measurements the type of models applied are Street canyon (1), Eulerian (3), Lagrangian (3) and Gaussian (3).

A more detailed description of the applications for each city can be found in the references supplied by the cities in the Table 13.

**Table 12: Summary of models applied for each purpose. G: Gaussian, E: Eulerian, L: Lagrangian, SC: Street Canyon, B: Box model, NN: Neural network model, Int: Interpolation model**

| | Purpose | Models | Cities |
|---|---|---|---|
| 1 | Assessment of air quality in general | AERMOD (G), FARM (E), GRAL (L), ATEM (G), REM_CALGRID_RCG (E), IMMISluft (G), ADMS-urban (G,L), CALPUFF (G), AUSTAL 2000 (L), POLTRAN (E), RIO(Int)-AURORA(E)-IFDM (G)-OSPM (SC) | Malmö, Milan, Vienna, Prague, Berlin, Paris, Plovdiv, Vilnius, Antwerp |
| 2 | Reporting of air quality compliance assessment | OSPM (SC), FARM (E), GRAL (L), CMAQ (E), ATEM (G), STREET (SC), ADMS-urban (G) | Malmö, Milan, Vienna, Madrid, Prague, Paris, Vilnius |
| 3 | Assessment of source contributions | AERMOD (G), SPRAY (L), CALPUFF (G), GRAL (L), CMAQ (E), IMMISluft (G), CHIMERE (E), AUSTAL (L), POLTRAN (E), ADMS-urban (G, L), ATEM (G), REM_CALGRID (E), CBM (B) | Malmö, Milan, Vienna, Madrid, Prague, Berlin, Paris, Plovdiv, Vilnius |
| 4 | Long term planning and scenario calculations | AERMOD (G), FARM (E), GRAL (L), CMAQ (E), IMMISluft (G), STREET (SC), AUSTAL (L), ATEM (G), RIO(Int)-AURORA (E)-IFDM (G)-OSPM (SC) | Malmö, Milan, Madrid, Prague, Berlin, Paris, Plovdiv, Antwerp |
| 5 | Short action plans | AERMOD (G), FARM (E), CAMx (E), CMAQ (E), ATEM (G), SYMOS (G), AUSTAL (L), ADMS-urban (G, L) | Malmö, Milan, Vienna, Madrid, Prague, Plovdiv, Vilnius |
| 6 | Air quality forecasting | CAMx (E), SERENA(NN), CHIMERE (E), AUSTAL (L), , ADMS-urban (G, L) | Vienna, Madrid, Paris, Plovdiv, Vilnius |
| 7 | Assessment of population exposure | AERMOD (G), FARM (E), GRAL (L), ATEM (G), IMMISluft (G), STREET (SC), AUSTAL (L), POLTRAN (E), ADMS-urban (G, L), RIO (Int)-AURORA (E)-IFDM (G)-OSPM (SC) | Malmö, Milan, Vienna, Prague, Berlin, Paris, Plovdiv, Vilnius, Antwerp |
| 8 | Supplement measurements | FARM (E), GRAL (L), IMMISluft (G), AUSTAL (L), POLTRAN (E), ADMS-urban (G, L), RIO(Int)-AURORA (E)-IFDM (G) -OSPM (SC) | Milan, Vienna, Berlin, Plovdiv, Vilnius, Antwerp |

**Table 13: Documentation related to the application of models in the cities for AQ modelling.**

| City/Model | System | References |
|---|---|---|
| Malmö<br>AERMOD<br>OSPM | Emissions | Susanna Gustafsson (2007), Building and validation of an air pollution emission database for Skåne (in Swedish), licenciate thesis, Lund University |
| | Meteorology | NA |
| | AQ Modelling | NA |
| Milan<br>FARM | Emissions | http://www.inemar.eu/xwiki/bin/view/Inemar/WebHome |
| | Meteorology | NA |
| | AQ Modelling | http://ita.arpalombardia.it/ITA/qaria/doc_valutazione_mod_annuale.asp |
| Vienna<br>GRAM/GRAL | Emissions | http://emikat.ait-projects.uenterprise.de/wp-content/uploads/2011/08/Bericht-emikat.at-ARC-sys-0049-April-2005.pdf |
| | Meteorology | ZAMG (2011): Immikat Wien - Meteorologische Analysen - final report from 20.05.2011; on GRAMM:<br>http://pandora.meng.auth.gr/mds/showlong.php?id=133;<br>Öttl, D. (2000): Weiterentwicklung, Validierung und Anwendung eines Mesoskaligen Modells, PhD-thesis at Graz University |
| | AQ Modelling | http://pandora.meng.auth.gr/mds/showlong.php?id=133&MTG_Session=2a1c690d43644288abbcc9f635632406 |
| Vienna<br>MM5-CAMx | Emissions | http://emikat.ait-projects.uenterprise.de/wp-content/uploads/2011/08/Bericht-emikat.at-ARC-sys-0049-April-2005.pdf |
| | Meteorology | http://wwwx.zamg.ac.at/cms/de/forschung/wetter/alaro |
| | AQ Modelling | http://www.zamg.ac.at/forschung/umweltmeteorologie/ozonprognose/ozonprognose/<br>http://www.zamg.ac.at/docs/forschung/umweltmeteorologie/11_Harmonisation.pdf |
| Prague<br>ATEM | Emissions | National database of emissions, CHMI |
| | Meteorology | NA |
| | AQ Modelling | Bednář J., Brechler J., Bubník J., Keder J., Macoun J., Píša V.: Kompendium ochrany kvality ovzduší. Část 6: Modelování přenosu a rozptylu znečišťujících příměsí v atmosféře. Gaussovské rozptylové modely. Ochrana ovzduší 1/2006. |
| Prague<br>SYMOS | Emissions | National database of emissions, CHMI |
| | Meteorology | NA |
| | AQ Modelling | User manual (Czech only):<br>http://www.idea-envi.cz/download/symos97v2006/Symos97.pdf<br>Model description (Czech only):<br>http://old.chmi.cz/uoco/prj/model/doc/symos_97.zip<br>http://old.chmi.cz/uoco/prj/model/doc/symos_doplnek1.zip |
| Berlin<br>REM_CALGRID | Emissions | http://www.umweltbundesamt.de/luft/infos/veranstaltungen/parest2010/index.htm |
| | Meteorology | Reimer, E. & Scherer, B., 1992. An operational meteorological diagnostic system for regional air pollution analysis and long term modelling. Air Pollution Modelling and its Application IX , eds. H. v. Dop und G. Kallos, NATO Challenges of Modern Society, Kluwer Academic/Plenum Publisher, New York. |

| City/Model | System | References |
|---|---|---|
| | AQ Modelling | http://www.geo.fu-berlin.de/met/ag/trumf/Veroeffentlichungen/index.html |
| Berlin IMMISluft | Emissions | http://www.ivu-umwelt.de/front_content.php?idcat=92 Lenschow et al., 2001, Some ideas about the source of PM10, Atmos. Enivorn., 35, suppl. 1, S23-S33. |
| | Meteorology | http://www.ivu-umwelt.de/front_content.php?idcat=92 Lenschow et al., 2001, Some ideas about the source of PM10, Atmos. Enivorn., 35, suppl. 1, S23-S33. |
| | AQ Modelling | http://www.ivu-umwelt.de/front_content.php?idcat=92 Lenschow et al., 2001, Some ideas about the source of PM10, Atmos. Enivorn., 35, suppl. 1, S23-S33. |
| Madrid WRF-CAMQ OSPM | Emissions | NA |
| | Meteorology | NA |
| | AQ Modelling | http://www.sciencedirect.com/science/article/pii/S1352231008002355; http://www.sciencedirect.com/science/article/pii/S1352231008007954; http://www.sciencedirect.com/science/article/pii/S1364815207002174; http://www.sciencedirect.com/science/article/pii/S1352231010003511; Air quality modelling at urban scale. Ongoing NO2 modelling activities for the Madrid city (Spain) in "Cet 2011 World Congress on Engineering and Technology, Oct.28 – Nov.2, 2011 Shanghai, China"; http://www.sciencedirect.com/science/article/pii/S1352231008009795; http://fairmode.ew.eea.europa.eu/fol404948/sg3_background_document_oct10_draft.pdf; http://www.epa.gov/ttnchie1/conference/ei16/session1/borge.pdf |
| Madrid SERENA | Emissions | NA |
| | Meteorology | NA |
| | AQ Modelling | Internal reports |
| | | |
| Paris CHIMERE+ STREET CALPUFF ADMS-urban | Emissions | Methodology is defined with regard to national guide on emission calculation |
| | Meteorology | http://www.airparif.asso.fr/_pdf/publications/Robservatoire_1004.pdf |
| | AQ Modelling | |
| Plovdiv | Emissions | Information is availavle in the database of RIEW |
| AUSTAL 2000 | Meteorology | |
| | AQ Modelling | http://www.plovdiv.bg/plovdiv/images/stories/10.2-Ekologiya/10.2.3.1-Upravlenie_na_KAV/id0002727-Plovdiv_Programa_KAV_2011-2013_Plan+za+deistvie.pdf |
| Plovdiv | Emissions | |
| POLTRAN | Meteorology | |
| | AQ Modelling | Atanassov, D., Validation of the Eulerian Pollution Transport Model PolTran on the Kincaid Data Set, Int. J. Environment & Pollution, vol. 20, No.1-6, 105-113, 2003 |
| Antwerp RIO-AURORA-IFDM-OSPM | Emissions | Lefebvre W., Janssen S., Degraeuwe B., Lodewijks P., Deutsch F., Veldeman N., Vankerkom J., Schrooten L., Cochez E., Meynaerts E., Maiheu B., Van Looy S., Peelaerts W., Schepens J., Nikolova I., de Vlieger I., Lefebre F., 2011c. Modellering van de concentrations aan en bronnentoewijzing van NO2, PM10 en PM2.5 in de Vlaamse |

| City/Model | System | References |
|---|---|---|
| | | luchtkwaliteitszones Gent, Antwerpen en Haven Antwerpen in het kader van de richtlijn luchtkwaliteit 2008/50/EG, Report for the administration 'Leefmilieu, Natuur en Energie' of the Flemish Government, 2011/RMA/R/45. |
| | Meteorology | Xue, M., Droegemeier K.K., and Wong V., 2000. The Advanced Regional Prediction System (ARPS) – A multiscale non-hydrostatic atmospheric simulation and prediction tool. Part I: Model dynamics and verification. Meteor. Atmos. Physics, 75, 161-193.<br>Xue, M., Droegemeier K.K., Wong V., Shapiro A., Brewster K., Carr F., Weber D., Liu Y., and Wang D.-H., 2001. The Advanced Regional Prediction System (ARPS) – A multiscale non-hydrostatic atmospheric simulation and prediction tool. Part II: Model physics and applications. Meteor. Atmos. Physics, 76, 134-165. |
| | AQ Modelling | Cosemans, G., Mensink, C., Veldeman, N., Deutsch, F., Van Looy, S., Peelaerts, W., Lefebre, F., 2011b. Validation of the MIMOSA-AURORA-IFDM model chain for policy support: modeling concentrations of elemental carbon in Flanders, Atm. Env., 45/37, 6705-6713., doi: 10.1016/j.atmosenv.2011.08.033<br>OSPM: Berkowicz, R., Hertel, O., Larsen, S.E., Sørensen, N.N., Nielsen, M., 1997. Modelling traffic pollution in streets (report in PDF format, 850 kB), link on http://www.dmu.dk/en/air/models/ospm/ospm_description/<br>Different aspects of model coupling: Lefebvre, W., Vercauteren, J., Schrooten, L., Janssen, S., Degraeuwe, B., Maenhaut, W., de Vlieger, I., Vankerkom, J., Cosemans, G., Mensink, C., Veldeman, N., Deutsch, F., Van Looy, S., Peelaerts, W., Lefebre, F., 2011b. Validation of the MIMOSA-AURORA-IFDM model chain for policy support: modeling concentrations of elemental carbon in Flanders, Atm. Env., 45/37, 6705-6713., doi: 10.1016/j.atmosenv.2011.08.033<br>Lefebvre W., Degraeuwe B., Beckx C., Vanhulsel M., Kochan B., Bellemans T., Janssens D., Wets G., Janssen S., de Vlieger I., Int Panis L., Dhondt S., 2013a. Presentation and evaluation of an integrated model chain to respond to traffic- and health-related policy questions, Env. Mod. & Soft., 40, 160-170, doi: 10.1016/j.envsoft.2012.09.003<br>Lefebvre W., Van Poppel M., Maiheu B., Janssen S., Dons E., 2013. The RIO-IFDM-street canyon model chain: a validation study in Antwerp, Belgium, Atm. Env., submitted.<br>Lefebvre W., Schillemans L., Op 't Eyndt T., Vandersickel M., Poncelet P., Neuteleers C., Dumez J., Janssen S., Vankerkom J., Maiheu B., Janssen L., Buekers J., Mayeres I., Voorstel van maatregelen om de luchtkwaliteit te verbeteren en de geluidshinder te beheersen in de stad Antwerpen, 2011/RMA/R/29, Studie uitgevoerd in opdracht van Stad Antwerpen - Stadsontwikkeling/Milieu<br>(*) Lefebvre W., Van Poppel M., Maiheu B., Janssen S., Dons E., 2013. The RIO-IFDM-street canyon model chain: a validation study in Antwerp, Belgium, Atm. Env., submitted |
| Vilnius | Emissions | NA |
| | Meteorology | NA |
| | AQ Modelling | http://www.cerc.co.uk/environmental-software/ADMS-Urban-model.html |

# 7 Summary of input data for AQ modelling

## 7.1 Emissions

All the cities have developed a specific local emission inventory to run the model, the spatial and temporal resolution of the emission inventories vary according to the model used and the resolution employed in the AQ modelling. For instance, spatial resolution goes from 24 m in the AUSTAL 2000 (Plovdiv) or 50m in the OSPM model (Malmö) to 4x4km$^2$ in the FARM model (Milan); the temporal resolution employed is hourly or annual.

The sources included in the emission inventory also vary from city to city and from model to model. For instance in street canyon models only the relevant sources are included, and that refers usually to road traffic sources, while in other models as AERMOD, GRAL, ATEM, REM_CALGRID or CMAQ the cities have indicated that all the known sources are included, which usually means that all sectors are taken into account in the emission inventory. However, there are sources such as non-exhaust traffic PM emissions that, although known to be a significant source, are not usually fully included in the emission inventory.

In relation to the traffic emissions, all the cities have answered that traffic congestion is a problem in their cities with the exception of Vilnius, however not all the models are capable of reflecting it. For instance, FARM (Milan) or REM_CALGRID (Berlin) are not reflecting traffic congestion, and the cities of Paris and Plovdiv also indicate the difficulties in modelling traffic congestions as traffic emissions are based on traffic count that cannot reflect completely congestion effects. The city of Berlin uses the IMMISluft model to reflect those traffic situations. Traffic emission estimation includes traffic counts and traffic speed per vehicle class in all the cities but Prague and Vilnius. The traffic emission inventories have been updated in regard to fleet composition and emission factors for NO and $NO_2$ in all the cities and in Vienna, Madrid, Prague, Berlin and Plovdiv the speciation for NO and $NO_2$ is done according to the fleet composition (Table 15). Traffic emissions are included in some modelling activities as line sources, as for instance in AERMOD and OSPM (Malmö and Antwerp), STREET (Paris) or ATEM (Prague) but in some models are included as gridded emissions as in FARM (Milan) or CAMx (Vienna).

The PM speciation ($PM_{10}$ and $PM_{2.5}$) for the commercial and domestic sector is not completely implemented in any of the cities. For instance the city of Madrid uses the US EPA speciate database and the city of Berlin has implemented dust resuspension and secondary particles are treated explicitly in the Eulerian model REM_CALGRID. However, secondary particles are not implemented in the IMMISluft street canyon model also used by the city of Berlin. In the emission inventory from Malmö no speciation is applied and all airborne particles are considered as $PM_{10}$, this is also similar to Vienna where PM speciation was analyzed in the Aquella[10] project, but is not considered in the modelling activities (Table 14). In the cities of Plovdiv and Antwerp PM speciation is considered in some models but not in others, for instance in Plovdiv only total dust is considered in POLTRAN model but emissions factors for PM are applied in AUSTAL; in Antwerp the PM speciation is contemplated in AURORA and implicitly in RIO but not in the other models (IFDM and OSPM).

The commercial and domestic sources are not in all the cases precisely distributed in height as allocated point sources, for instance in Malmö only large sources are located as height sources, in

[10] http://publik.tuwien.ac.at/files/PubDat_173988.pdf

Madrid only coal-fired boilers are treated as point sources and all the rest are allocated as surface emissions, in Prague and Vilnius commercial sources are considered as point sources while domestic are allocated as surface sources, in Paris the source height is taken into account when the information is available and in Plovdiv an average height is assumed according to type of construction. In the chain of models employed in Antwerp all the emissions from commercial and domestic sector are allocated in the lowest layer of the model.

The PM speciation for the industrial sector is also not well resolved in the cities. The city of Milan uses speciation profiles to disaggregate $PM_{10}$ and $PM_{2.5}$, the city of Madrid uses the US EPA speciate database and the city of Paris employs a PM speciation based on literature. But, for instance, Malmö considers the sources individually but often considers only that $PM_{2.5}$ = $PM_{10}$, Vienna does not consider any speciation, and Berlin considers that EC and OC are percentages of $PM_{10}$ dependent on source in REMCALGRIC, but IMMISluft considers EC directly as it is calculated with the emission model IMMISem (based on HBEFA 3.1). In all the cities the source height is precisely described when the information is available and usually industries are considered as point sources in the modelling or they are included as a combination of gridded surface emissions and point sources.

The city of Ploiesti, as commented before, didn't fill in the information regarding the use of air quality models in the questionnaire but sent a separate document relating how emissions are estimated. Therefore, the city of Ploiesti is not included in the Tables 14, 15 and 16 and its information regarding the inputs to air quality models can be found in Annex B.

**Table 14: Summary of the emissions used as input to the AQ models**

| | **Malmö** | **Malmö** | **Milan** | **Milan** |
|---|---|---|---|---|
| | **AERMOD** | **OSPM** | **FARM** | **SPRAY** |
| Did you develop a specific local emission inventory to run the model? | Specific local traffic flow (vehicle count) is usually updated. | Yes | yes | point source data used |
| What is the spatial and temporal resolution you have chosen? | | dual grid: 50 m and 500 m<br>Hourly | municipality/annual level (proxy used to disaggregate on cell and hourly base) | point source, hourly data used |
| Have emission data for all known sources been included? | Yes but not all sources are updated every year. | Yes but not all sources are updated every year. | yes | No |
| What sources have been included? | Road traffic, Point sources (industries and power plants) Sea traffic, Railway traffic, Airway traffic, non-road machinery, small-scale heating. | traffic, point, line (ship, rail) and area sources | NA | NA |
| *Traffic:* | | | | |
| Is traffic congestion a problem and is it reflected in the modelling? | yes, sometimes and yes it is reflected | yes, sometimes and yes it is reflected | yes, no | NA |
| Do the emission | yes | yes | yes (as output from | |

| | Malmö | Malmö | Milan | Milan |
|---|---|---|---|---|
| | **AERMOD** | **OSPM** | **FARM** | **SPRAY** |
| inventories for traffic include traffic counts and traffic speed per vehicle class? | | | traffic assignment model) | |
| Have the emission inventories been updated in regard to fleet composition, and emission factors (both for NO and $NO_2$)? | HBEFA_31_program to get the emission factor. But only for NOx. | HBEFA_31_program to get the emission factor. But only for NOx. | yes | |
| Which speciation for NO and NO2 is used in the emission data according to the fleet composition? References? | No speciation is used. All calculation is based on NOx. | No speciation is used. All calculation is based on NOx. | emission inventory provides total NOx emissions | |
| Are line source emissions included or only gridded emissions? | Included | Included | gridded emissions | |
| *Commercial/domestic sector:* | | | | |
| How do you deal with PM speciation? | No speciation. All airborne particles as PM10 | No speciation. All airborne particles as PM10 | | |
| Is the source height precisely described? | All large sources are precisely described. Small sources may be estimated depending on the situation. | All large sources are precisely described. Small sources may be estimated depending on the situation. | emission inventory provides total PM 2.5 and PM 10 emissions, to disaggregate speciation profiles are used | |
| How are those sources described (surface emissions or point sources?) | Mostly as surface emissions | Mostly as surface emissions | no | |
| *Industry:* | | | | |
| How do you deal with PM speciation? | individually, often PM2.5=PM10 | individually, often PM2.5=PM10 | emission inventory provides total PM 2.5 and PM 10 emissions, to disaggregate speciation profiles are used | |
| Is the source height precisely described? | yes | yes | yes | |
| How are those sources described (surface emissions or point sources?) | point, national environmental report portal: www.smp.se | point | both, as areal and point sources | |

| | Vienna | Vienna | Madrid | Madrid |
|---|---|---|---|---|
| | **GRAL** | **CAMx** | **CAMQ** | **OSPM** |
| Did you develop a specific local emission inventory to run the model? | the model is based on the emission inventory "emikat wien" | the model is based on the emission inventory "emikat wien" | Yes | Yes |
| What is the spatial and temporal resolution you have chosen? | 100x100 m; emission data are disaggregated hourly via analysis of diurnal variations | 100x100 m; emission data are disaggregated hourly via analysis of diurnal variations | Accordingly to domain resolution (down to $1km^2$) | Street length, 1 hour |
| Have emission data for all known sources been included? | yes | yes | Yes | No |
| What sources have been included? | all SNAP categories | all SNAP categories | | Only traffic |
| *Traffic:* | | | | |
| Is traffic congestion a problem and is it reflected in the modelling? | yes | yes | Yes | Yes |
| Do the emission inventories for traffic include traffic counts and traffic speed per vehicle class? | yes | yes | Yes, average speed data is vehicle type independent | Yes, average speed data is vehicle type independent |
| Have the emission inventories been updated in regard to fleet composition, and emission factors (both for NO and $NO_2$)? | yes | yes | Yes (modelling inventory) | Yes (modelling inventory) |
| Which speciation for NO and NO2 is used in the emission data according to the fleet composition? References? | NO/NO2 conversion model Romberg (VDI-Richtlinie 3782, adapted for Vienna); Handbook Emission Factors for Road Transport - HBEFA (http://www.hbefa.net/e/index.html) | Handbook Emission Factors for Road Transport - HBEFA (http://www.hbefa.net/e/index.html) | COPERT IV and HBFA 3.1 | COPERT IV and HBFA 3.1 |
| Are line source emissions included or only gridded emissions? | line sources | gridded emissions | Line | Line |
| *Commercial/domestic sector:* | | | | |
| How do you deal with PM speciation? | not in case of the modelling results, PM speciation was | not at all | Basically using US EPA speciate database | Implicitly through background concentration |

| | | | | |
|---|---|---|---|---|
| | analysed elsewhere (project "Aquella" publik.tuwien.ac.at/ files/PubDat_173988.pdf) | | | |
| Is the source height precisely described? | yes | no | Yes | nr |
| How are those sources described (surface emissions or point sources?) | surface and point sources | surface and point sources | Surface emissions, except for coal-fired boilers treated as point sources | nr |
| *Industry:* | | | | |
| How do you deal with PM speciation? | not in case the modelling results, PM speciation was analysed elsewhere (Aquella: publik.tuwien.ac.at/ files/PubDat_173988.pdf) | not at all | Basically using US EPA speciate database | Implicitly through background concentration |
| Is the source height precisely described? | yes | yes | Yes | nr |
| How are those sources described (surface emissions or point sources?) | point sources | point sources | Point sources including stack parameters | nr |
| | **Prague** | **Prague** | **Berlin** | **Berlin** |
| | **ATEM** | **SYMOS** | **REM_CALGRID** | **IMMISluft** |
| Did you develop a specific local emission inventory to run the model? | yes | yes | yes | yes |
| What is the spatial and temporal resolution you have chosen? | 300x250 m | 300 m | 2 x 2 km², annual | annual car fleet, traffic situation, street description |
| Have emission data for all known sources been included? | yes | only relevant | yes | yes |
| What sources have been included? | industrial, commercial, domestic, traffic | industrial, commercial, traffic | anthropogenic, natural, biogenic | |
| *Traffic:* | | | | |
| Is traffic congestion a problem and is it reflected in the modelling? | yes | no | no | yes |
| Do the emission inventories for traffic include traffic counts and traffic speed per vehicle class? | yes | no | no | yes |
| Have the emission inventories been | Yes | yes | Yes | yes |

| | | | | |
|---|---|---|---|---|
| updated in regard to fleet composition, and emission factors (both for NO and $NO_2$)? | | | | |
| Which speciation for NO and NO2 is used in the emission data according to the fleet composition? References? | references and measurements MEFA6 (http://www.atem.cz/mefa.html) | references and measurements MEFA6 (http://www.atem.cz/mefa.html) | [http://www.umweltbundesamt-daten-zur-umwelt.de/umweltdaten/public/theme.do?nodeIdent=3573](http://www.umweltbundesamt-daten-zur-umwelt.de/umweltdaten/public/theme.do?nodeIdent=3573) | HBEFA 3.1 (www.hbefa.net) |
| Are line source emissions included or only gridded emissions? | Yes | yes | only gridded emissions and point sources | only line sources |
| *Commercial/domestic sector:* | | | | |
| How do you deal with PM speciation? | dust resuspension implemented, secondary particles not implemented | NA | EC and OC are percentages of PM10 dependent on source | EC directly as it is calculated with the emission model IMMISem (based on HBEFA3.1). |
| Is the source height precisely described? | yes | yes | gridded emissions are input on corresponded vertical level | urban background added to street canyon model |
| How are those sources described (surface emissions or point sources?) | commercial-point/domestic-surface sources | commercial - point sources | surface sources, vertical level sources, if appropriate | urban background added to street canyon model |
| *Industry:* | | | | |
| How do you deal with PM speciation? | dust re-suspension implemented, secondary particles not implemented | | EC and OC are percentages of PM10 dependent on source | EC directly as it is calculated with the emission model IMMISem (based on HBEFA3.1). |
| Is the source height precisely described? | yes | yes | yes | urban background added to street canyon model |
| How are those sources described (surface emissions or point sources?) | point sources | point sources | point sources | urban background added to street canyon model |
| | **Paris** | **Plovdiv** | **Plovdiv** | **Antwerp** |
| | **CHIMERE/STREET/ ADMS-urban/ CALPUFF** | **AUSTAL 2000** | **POLTRAN** | **RIO-AURORA-IFDM-OSPM** |
| Did you develop a specific local emission inventory to run the | yes | Yes | yes | yes for road emissions, no for other sectors |

| | | | | |
|---|---|---|---|---|
| model? | | | | |
| What is the spatial and temporal resolution you have chosen? | 1 km resolution for the local emission inventory and traffic emission on ~ 40 000 traffic lines | 250 x 250 $m^2$ and 400 x 400 $m^2$; 48m x 48m and 24m x 24m<br>IE for the industrial and transport sector is based on hourly emission rates, whereas in the household sector – modelling is done on a seasonal basis (1 November - 1 April) | 250m ; 1 hour | Emissions: road network: 1m; other sectors: 3x3 km²; grid resolution of models: irregular grid up to 10m; hourly concentrations |
| Have emission data for all known sources been included? | yes | In the modelling actifities for the year:<br>- 2002 - not all (excluding transport)<br>- 2007, 2010 and 2011 - all | no | not explicitely (implicit via measurement interpolation tool RIO) in IFDM en OSPM; explicitely in AURORA |
| What sources have been included? | level 3 SNAP classification | In the modelling actifities for the year 2002 are included emission data about sources in industrial and household sector, and in 2007, 2010 и 2011 - emission data about sources in industrial and household sector and transport | industry, domestic sector | All (implicitely) in RIO; all SNAP-sectors in AURORA; industry and road emissions in IFDM; road emissions in OSPM |
| *Traffic:* | | | | |
| Is traffic congestion a problem and is it reflected in the modelling? | Difficult to model as traffic emissions are based on traffic counts (flow and speed) that cannot reflect completely congestion effects. COPERT IV is used. | Traffic congestion of up to 2-3 minutes stay occur mostly in rush hours in several intersections of the city. Those are not included and kept in a register and are not taken into consideration in the modelling activities. | | it is a problem, not explicitly taken into account |
| Do the emission inventories for traffic include traffic counts and traffic speed per vehicle class? | yes | One-hour traffic counting is performed twice a year during the performance of noise monitoring – done by the Regional health | | Yes |

| | | | | |
|---|---|---|---|---|
| | | inspectorate. It was further updated in 2008, 2009 and 2011 for the purpose of elaborating strategic noise maps, and in 2012 in the development of a General plan for traffic organization on the territory of the city of Plovdiv. Distribution in 24-hour and weekly periods is done by applying standard characteristics. For the emission inventory, the traffic structure (light duty and heavy duty vehicles) is taken into consideration as well as speed and road obstacle density relating to emissions. | | |
| Have the emission inventories been updated in regard to fleet composition, and emission factors (both for NO and $NO_2$)? | NOX emission factors are used with NO/NO2 speciation | For the estimation of transport emissions is used data about registered vehicle fleet: vehicle class, type of fuel, year of manufacture | | Yes |
| Which speciation for NO and NO2 is used in the emission data according to the fleet composition? References? | COPERT IV | $NO_x$; HBEFA - Handbook Emission Factors for Road Transport, Version HBEFA 3.1 (Jan. 2010) | | COPERT |
| Are line source emissions included or only gridded emissions? | line sources | Streets with 24-hour traffic intensity above 2000 vehicles are modelled as linear sources | | Line sources included |
| *Commercial/domestic sector:* | | | | |
| How do you deal with PM speciation? | PM speciation based on bliography | Emission factors for different forms of PM are attributed to the relevant solid or liquid fuel type | total dust is considered at the present | in AURORA: complete; in RIO: implicitly; otherwise: no |

| | | | | |
|---|---|---|---|---|
| | | according to CR-CORINAIR | | |
| Is the source height precisely described? | Source height is taken into account when available | Residential areas are classified according to the type of construction (prevailing floorage). According to this floorage, for each type is assumed average stack height. | yes | no (lowest layer of model) |
| How are those sources described (surface emissions or point sources?) | gridded surface emissions, point sources and line sources are used | Emissions from residential heating are estimated for specific type of housing construction. Emission from the thus determined surface source is calculated as the product of the number of households with individual combustion installations multiplied by the fuel quantity by its emission factor. | surface | surface emissions |
| *Industry:* | | | | |
| How do you deal with PM speciation? | PM speciation based on bibliography | Data about industrial sources is used from the annually updated database of RIEW Plovdiv. The database contains information about source parameters (height and diameter), flow parameters and concentration of pollutants in released gas flow. | total dust is considered at the present | in AURORA: complete; in RIO: implicitly; otherwise: no |
| Is the source height precisely described? | Source height is taken into account when available | Yes, as described above. | yes | in IFDM yes; in AURORA: not precise |
| How are those sources described (surface emissions or point sources?) | gridded surface emissions and point sources are used | Point sources only. | point | combination |

| | **Vilnius** | | | |
|---|---|---|---|---|
| | **ADMS urban** | | | |
| Did you develop a specific local emission inventory to run the model? | Yes, by EMIT toolkit | | | |
| What is the spatial and temporal resolution you have chosen? | *130 x130 m* | | | |
| Have emission data for all known sources been included? | No | | | |
| What sources have been included? | Stationary, road, rail, residential | | | |
| *Traffic:* | | | | |
| Is traffic congestion a problem and is it reflected in the modelling? | Not at all | | | |
| Do the emission inventories for traffic include traffic counts and traffic speed per vehicle class? | No | | | |
| Have the emission inventories been updated in regard to fleet composition, and emission factors (both for NO and $NO_2$)? | No | | | |
| Which speciation for NO and NO2 is used in the emission data according to the fleet composition? References? | NOx (using generic reaction set) and supthate chemistry | | | |
| Are line source emissions included or only gridded emissions? | Both | | | |
| *Commercial/domestic sector:* | | | | |
| How do you deal with PM speciation? | Difficulties with domestic sector | | | |
| Is the source height precisely described? | Commercial yes, domestic - no | | | |
| How are those sources described (surface emissions or point sources?) | Commercial both, domestic - grid | | | |
| *Industry:* | | | | |
| How do you deal with | No data available of | | | |

| | | | | |
|---|---|---|---|---|
| PM speciation? | small industry points | | | |
| Is the source height precisely described? | Yes | | | |
| How are those sources described (surface emissions or point sources?) | Both | | | |

## 7.2 Meteorology

As described in the Table 15, the meteorological fields for AQ modelling are obtained from 1) measurement towers (Malmö, Prague, Berlin, Plovdiv, Antwerp) but depending of the city and model on some occasions only one observation site is employed (IMMISluft, Berlin) or an optimum interpolation of observations is conducted (REM_CALGRID, Berlin); 2) high resolution meteorological models including GRAMM, ALADIN/ALARO (Vienna) or WRF (Madrid, Paris) and 3) ECMWF fields interpolated with local monitoring network (Milan). The meteorological fields in the case of Vienna, Madrid, Paris and Antwerp have been validated against local measurements.

**Table 15: Summary of the meteorological fields used as input to the AQ models**

| | **Malmö** | **Malmö** | **Milan** | **Milan** |
|---|---|---|---|---|
| | **AERMOD** | **OSPM** | **FARM** | **SPRAY** |
| How are the meteorological fields obtained? | Data from measurement tower in Malmö | Data from measurement tower in Malmö | ECMWF fields interpolated with local network measurements | ECMWF fields interpolated with local network measurements |
| If a meteorological model is used, has it been validated against local measurements? | | | | |
| | **Vienna** | **Vienna** | **Madrid** | **Madrid** |
| | **GRAL** | **CAMx** | **CAMQ** | **OSPM** |
| How are the meteorological fields obtained? | with the prognostic wind field model GRAMM (Grazer Mesoskaliges Modell) | with the high resolution models ALADIN/ALARO | With WRF model | With WRF model |
| If a meteorological model is used, has it been validated against local measurements? | yes | yes | Yes including urban parameterizations | Yes including urban parameterizations |
| | **Prague** | **Prague** | **Berlin** | **Berlin** |
| | **ATEM** | **SYMOS** | **REM_CALGRID** | **IMMISluft** |
| How are the meteorological fields obtained? | annual windroses for different stability classes | annual windroses for different stability classes | optimum interpolation of observations | one observation site |
| If a meteorological model is used, has it | nr | nr | nr | |

| | | | | |
|---|---|---|---|---|
| been validated against local measurements? | | | | |
| | **Paris** | **Plovdiv** | **Plovdiv** | **Antwerp** |
| | **CHIMERE/STREET/ ADMS-urban/ CALPUFF** | **AUSTAL 2000** | **POLTRAN** | **RIO-AURORA-IFDM-OSPM** |
| How are the meteorological fields obtained? | MM5/WRF/CALMET/monitoring stations | Modelling system SELMA$^{GIS}$ requires statistical data about wind direction, wind speed and dispersion class in TA Luft format. Transformation of data of Plovdiv weather station into said data format is done by NIMH with BAS. | Bulgarian weather forecast model and surface in-situ measurements | Measurements for IFDM and OSPM; Modelling for AURORA |
| If a meteorological model is used, has it been validated against local measurements? | yes | The preparation of the file containing statistical data about wind dispersion classes is done on the basis of meteorological data from Trakia AWS. | yes | total validation on concentration levels; validation of meteorology to local meteorology only on more regional scale |
| | **Vilnius** | | | |
| | **ADMS urban** | | | |
| How are the meteorological fields obtained? | Supplied by the hydrometeorological institute and the meteorology institute of Finland | | | |
| If a meteorological model is used, has it been validated against local measurements? | No | | | |

## 7.3 Background concentration

The background concentration of pollutants is considered in all the cities but using different sources (Table 16) as for instance 1) estimation from modelling of regional sources together with several measurement stations (Malmö); 2) estimation from monitoring data from background stations and emission inventories of neighbouring provinces when needed (Vienna, Paris, Plovdiv, Vilnius and Antwerp); 3) provided as boundary conditions under nesting models (Madrid), other regional models (Berlin, Vilnius) and models run at national level for forecasting (Vilnius); and 4) European simulations (Berlin).

## 7.4 Model combination with monitoring data

Four of the cities have used monitoring data in combination with a dispersion model. The city of Malmö has used it for adjusting the regional background concentrations of $NO_2$ and PM, the city of Milan has employed it for data fusion, the city of Paris has used monitoring data with sequential assimilation methods and the city of Antwerp has also employed models and observations to characterize spatial representativeness of air quality monitoring stations and its relevance for model validation. Madrid has only employed monitoring data with the statistical model as a historical database to produce prediction algorithms, but has not employed it for other purposes with dispersion models (Table 16). The rest of the cities have employed monitoring data only for validation purposes.

**Table 16: Summary of other data (background and monitoring) used as input to the AQ models**

| | **Malmö** | **Malmö** | **Milan** | **Milan** |
|---|---|---|---|---|
| | **AERMOD** | **OSPM** | **FARM** | **SPRAY** |
| How are background concentrations of the various pollutants taken into account? | Estimation from modelling of regional sources and several measurement stations | Estimation from modelling of regional sources and several measurement stations | yes | NA |
| Has monitoring data been used in combination with the model? | Yes | yes | yes | NA |
| If monitoring data has been used, describe how it has been used. | For adjusting the regional background concentrations of NO2 and PM | For adjusting the regional background concentrations of NO2 and PM | Data fusion | NA |
| From a more general point of view: How do you evaluate boundary conditions provided to your model or the chain of nested models? | | | data from Prev'Air system based on CHIMERE model | NA |
| | **Vienna** | **Vienna** | **Madrid** | **Madrid** |
| | **GRAL** | **CAMx** | **CAMQ** | **OSPM** |
| How are background concentrations of the various pollutants taken into account? | by considering the monitoring data of background stations and the emission data of inventories of neighbouring provinces | by considering the monitoring data of background stations and the emission data of inventories of neighbouring provinces | Provided by the boundary conditions under a nesting approach | In this model corresponds to the concentration at roof level which is provided by the eulerian model (avoiding double counting) |
| Has monitoring data been used in combination with the model? | No | No | No | No |

| | | | | |
|---|---|---|---|---|
| If monitoring data has been used, describe how it has been used. | Only for validation | Only for validation | | |
| From a more general point of view: How do you evaluate boundary conditions provided to your model or the chain of nested models? | | | By comparison with observations for the different domains | By comparison with specific measurements and experiments based on alternative strategies to provide background concentrations (station nearby, urban background stations, downscaling from mesoscale models, etc.) |
| | **Prague** | **Prague** | **Berlin** | **Berlin** |
| | **ATEM** | **SYMOS** | **REM_CALGRID** | **IMMISluft** |
| How are background concentrations of the various pollutants taken into account? | For each pollutant background concentration (distant sources and natural background) is included | maps of background concentrations produced by CHMI are used | European simulations with 30x30 km² grid resolution | calculated by REM-Calgrid |
| Has monitoring data been used in combination with the model? | no | no | No | no |
| If monitoring data has been used, describe how it has been used. | | | | |
| From a more general point of view: How do you evaluate boundary conditions provided to your model or the chain of nested models? | Comparison with data measured in AQ monitoring | | very important. | very important. optimum interpolation needed |
| | **Paris** | **Plovdiv** | **Plovdiv** | **Antwerp** |
| | **CHIMERE/STREET/ ADMS-urban/ CALPUFF** | **AUSTAL 2000** | **POLTRAN** | **RIO-AURORA-IFDM-OSPM** |
| How are background concentrations of the various pollutants taken into account? | Air quality monitoring stations and background concentration calculation | Background concentration levels are estimated on the basis of data from the national background station Rozhen. The general background level of pollutants is adjusted by the regional background factor, expertly determined for each pollutant individually. | background is not taken into account; emission sectors contribution is modelled | via use of measurement interpolation (RIO) |

| | | | | |
|---|---|---|---|---|
| Has monitoring data been used in combination with the model? | yes | In the process of gathering modelling input data collection is not used monitoring data. Emission concentration values reported by the automated measuring ssytem are compared to the results from the modelling for verification of uncertainty according to data quality goals contained in the national legislation and described in Annex I, item A of DAQ 2008/50/EC on modelling quality. | no | yes , via RIO |
| If monitoring data has been used, describe how it has been used. | Sequential assimilation methods (Optimal interpolation and various kriging methods) | As described above | | intelligent interpolation: Janssen, S., Dumont, G., Fierens, F., Deutsch, F., Maiheu, B., Celis, D., Trimpeneers, E., Mensink, C., 2012. Land use to characterize spatial representativeness of air quality monitoring stations and its relevance for model validation. Atmospheric Environment, 59, 492–500. doi:10.1016/j.atmosenv.2012.05.028 |
| From a more general point of view: How do you evaluate boundary conditions provided to your model or the chain of nested models? | For background modelling, the national air quality modelling system is used (PREVAIR) For local models, modelled background concentrations can be used as data from monitoring stations | Provision of boundary conditions for the process of modelling is insufficient - background concentration levels are expertly estimated on the basis of data from the national background station Rozhen. | | RIO has been validated extensively |

| | Vilnius | | | |
|---|---|---|---|---|
| | | | | |
| How are background concentrations of the various pollutants taken into account? | Background concentrations is provided by the regional environmental protection department, meteorology institute of Finland | | | |
| Has monitoring data been used in combination with the model? | Only for model verification | | | |
| If monitoring data has been used, describe how it has been used. | For model verification | | | |
| From a more general point of view: How do you evaluate boundary conditions provided to your model or the chain of nested models? | - | | | |

# 8 Validation of the model

All the cities have validated the model against local measurements, and in some cases the model has also been validated in a similar environment (Table 17). Most of the cities use the same air quality indicators to assess the quality of the model outputs (bias, rmse, me, etc). The city of Madrid has also validated the statistical model that they employ for air quality forecasting (not included in table 19). The statistical model has been validated against $PM_{10}$, $O_3$ and $NO_2$ employing twelve monitoring stations, including 4 traffic stations, 5 urban background and 3 suburban station. The indicators employed have been: bias, root mean square error and mean error. The uncertainty has also been estimated and the values obtained show that the model accomplishes the requirements of the AQ Directive. The city of Prague has only validated one of the models they have employed (ATEM), the other model (SYMOS) has not been validated, however this model is only employed for short action plans together with ATEM.

The cities of Milan, Vienna, Madrid, Berlin, Paris, Plovdiv, Antwerp and Vilnius have also estimated the uncertainty of the air quality model as required by the EU legislation (Table 17).

**Table 17: Summary of model validation for each of the city.**

| | **Malmö** | **Milan** | **Milan** | **Vienna** | **Vienna** |
|---|---|---|---|---|---|
| **Model** | **AERMOD & OSPM** | **FARM** | **SPRAY** | **GRAMM/GRAL** | **CAMx** |
| Pollutants | NOx, NO2 | NO2, O3, PM10 | | NO2, NOx, PM10 | O3 |
| Stations | 3 fixed 1 mobile | Different types | NA | All stations | All stations |
| Indicators | Bias | bias, root mean square error, mean error, correlation factor | NA | bias, root mean square error, mean error, correlation factor | NA |
| Uncertainty | NO | YES | NA | YES | NA |
| AQ requirements | - | YES | NA | YES | NA |
| | **Madrid** | **Prague** | **Berlin** | **Berlin** | **Paris** |
| **Model** | **CMAQ** | **ATEM** | **REM_CALGRID** | **IMMISluft** | |
| Pollutants | NOx, PM, | NO2, NOx, PM10, PM2.5, SO2 | PM10, NO2, O3 | PM10, PM2.5, NO2 | |
| Stations | 10 urban background monitoring stations | 13 stations | urban and regional background | Hot spots | monitoring network or specific monitoring campaigns. |
| Indicators | Delta tool | NA | bias, rmse, me, correlation coefficient | bias, correlation coefficient | Classical metrics : bias, root mean square error, mean error, correlation factor, factor of excess, standard deviation. |
| Uncertainty | YES | NO | YES | YES | YES |
| AQ requirements | YES | - | NA | NA | NA |
| | **Plovdiv** | **Antwerp** | **Vilnius** | | |
| **Model** | | | **ADMS urban** | | |
| Pollutants | | | PM10, PM2.5, NO2, SO2, CO | | |
| Stations | Monitoring network (transport oriented and background) | 50 independent NO2 stations in Antwerp (*) | 4 monitoring stations | | |
| Indicators | error calculation, relative error calculation | bias, RMSE, slope, R | Mean error, correlation factor | | |
| Uncertainty | YES (AUSTAL) / NO (POLTRAN) | YES (RIO) | Yes | | |
| AQ requirements | YES | YES | - | | |

# 9 Usefulness of the model

In the questionnaire sent to the cities it was asked if, in their opinion, the model is ‘fit for purpose’ and if the results have been helpful in relation to the AQ activities. The city of Antwerp has not filled out this part of the questionnaire, but the rest of the cities have in general found the models are fit for purpose and helpful in assessment activities and management decisions.

The city of Malmö has found that the models employed (AERMOD and OSPM) are fit for the purpose they were applied to and the results have been helpful in relation to AQ assessment activities. The results have successfully been taken into account in AQ management decisions. The model results have also been applied in other management decisions.

The city of Milan has also found that the models applied (FARM and SPRAY) are fit for purpose, the Eulerian model FARM has also been helpful in relation to AQ assessment activities, but there is no comment concerning the helpfulness of SPRAY. The results from FARM have been successfully taken into account in AQ management decisions.

The city of Vienna finds the applied models, GRAMM/GRAL and MM5-CAMx, to be fit for purpose. Both of them have been helpful in relation to AQ assessment activities and the model results have been successfully taken into account in AQ management.

The city of Madrid has applied three models, OSPM, WRF-CMAQ and a statistical model named SERENA. All of the models have been found to be fit for purpose. All the models have been helpful in relation to AQ assessment activities.

The city of Prague has found the ATEM model to be mostly fit for purpose, but the other model applied, SYMOS, is less fit for purpose. The results from ATEM have been applied for AQ assessment activities and the results have been taken into account in AQ management decisions.

The city of Berlin also finds that the models applied in Berlin, REM_CALGRID and IMMISluft, are fit for purpose. The results from the model have been satisfactory applied in AQ assessment activities. The outputs from REM_CALGRID have been used for source apportionment and long-range transport assessment. The results have been considered in AQ management decisions.

The city of Paris has found that the model is fit for purpose and the model results are taken into account for AQ assessment activities and management decisions. The model results have also been employed for estimating geographic areas and population exposure.

In the city of Plovdiv the model AUSTAL 2000 is found to be fit for purpose but the model POLTRAN is less fit for purpose. While the results from AUSTAL have been employed for air quality assessment activities and helpful in management decisions, the results from POLTRAN have not been taken into account in any management decisions. Both models have been employed for estimating geographic areas and population exposure to air quality limit values.

The city of Vilnius has employed the model ADMS urban and the results have been useful for the purpose they were applied. The model has been helpful in relation with AQ assessment and the results have been used in planning processes.

# 10 Difficulty in model application and need for further guidance

The list below shows the opinion of the cities in relation to the difficulties that they have found in the model application as well as where further guidance in the application of models for AQ purposes is needed based on their experience.

Some of the difficulties or weak points in the application of models identified by the cities are: (i) input data, especially the estimation of emissions and background concentrations; (ii) dealing with the uncertainties in the model and the interpretation of model results; and the (iii) high computational cost.

Regarding the point (i) for instance the city of Malmo comment the difficulties in estimating the correct amount of heavy vehicles on each road, as well as the emissions from sea traffic. Moreover, the emission factors are subjected to high uncertainty. The cities of Berlin, Madrid and Plovdiv also comment the difficulties associated with the background concentration estimation when using street canyon models.

In relation to point (ii), the city of Paris comment the problems associated with biases in the estimation of PM concentration and the difficulties to do prospective planning based on actual biases. In the case of Vienna, overestimation of the concentrations is a difficulty they need to deal with especially when the models are employed for AQ forecasting or when employed for short action plans.

Other of the difficulties mentioned by several cities is the high computational time and the need of experts to run the models and interpret the results. As pointed by the city of Vienna, the required human, temporal and financial resources are considerable.

The cities have identified the need for further guidance in three main areas: (i) estimation of the emissions; (ii) validation of the model results, (iii) framework for modelling approach and criteria harmonization, and (iv) general guidance in the use of models for AQ management.

# 11 Cooperative activities

The cities of Malmö, Prague, Paris, Antwerp and Vilnius have reported other modelling activities that have been undertaken in cooperation with other institutes. In Malmö the cooperation has been conducted at regional level with the Scania Air Quality Management Association and the University of Lund. In Prague the cooperation has been undertaken in the framework of two European projects (TRANSPHORM and PASODOBLE) with two research institutes NILU-Norwegian institute for air research and VITO-Flemish institute for technological research. The cooperation with both institutes is at national level. In Paris the cooperation has been conducted at national level with INERIS and at interregional level with ESMERALDA. In the city of Antwerp the cooperation is at regional level with LNE. In the city of Vilnius the cooperation is also at regional level with the Environmental protection agency.

## 11.1 Malmo

In the city of Malmö the aim of the cooperation was: 1) To develop and emission database (with Scania Air Quality Management Association) and 2) To share data and information regarding health effects of air pollution in the city (with Lund University). The objective of 1) is related to the purposes of assessment of air quality in general; assessment of source contributions and source apportionment. The cooperation with Lund University was related to assessment of population exposure. The models employed and the configuration of the models is the same as described in the chapter 5 for those purposes and no further description is included here.

## 11.2 Prague

In the city of Prague the aims of the cooperation were: 1) Dispersion modelling for the city of Prague in the framework of the TRANSPHORM[11] project (with NILU[12]) and 2) Set up an AQ forecast modelling system for Prague, conducted in the framework of PASODOBLE[13] project (with VITO[14]). The

[11] http://www.transphorm.eu
[12] http://www.nilu.no
[13] http://www.myair.eu
[14] http://www.vito.be

aim of the collaboration with NILU was to contribute to the AQ applications of assessment of air quality in general, long term planning and scenario calculations and assessment of population exposure. The collaboration with VITO was related with the purpose of Air quality forecasting.

In the collaboration with NILU the air quality model employed is EPISODE. The model is currently being run by CHMI in cooperation with the city of Prague. The spatial scale covered is 20x30 km with hourly temporal resolution for particulate matter ($PM_{10}$ and $PM_{2.5}$). A specific local emission inventory was not developed for this application but previous inventories were updated. The spatial and temporal resolution was 500m and 1 hour, respectively. The emission inventory included all the known source emissions from industrial, commercial, domestic and traffic sectors.

Regarding the estimation of traffic emissions, the NO and $NO_2$ speciation is based on MEFA06, and are not Czech fleet-specific. Traffic is included as a line source, but traffic congestion is not reflected in the model simulations.

For the commercial and domestic sectors the sources are included as point sources for commercial sector and area sources for the domestic sector. In both of them the height is precisely described. The PM speciation is the one from the National inventory that includes the speciation between $PM_{10}$ and $PM_{2.5}$.

For the industrial emissions a similar approach to the commercial and domestic sectors is employed, using the speciation from the National Inventory for PM. The industrial emissions are allocated as point sources and the source height is precisely described.

The meteorology used as input for the model comes from observations. The background concentrations are provided by a background measurement station. Although the background station was considered to be representative, that has not been strictly evaluate.

The air quality model employed is EPISODE[15] with a grid resolution of 500m. The outputs of the model have been validated against 20 stations in Prague, including urban, suburban and roadside stations. The model is still being tested and no real air quality applications have been carried out so far.

The second collaboration conducted by the city of Prague is in relation to AQ forecasting with VITO research institute. For that purpose the Eulerian air quality model AURORA[16] is employed. The spatial scale is 50x60 km and it uses nested domains, one covering most of Europe at 6km resolution with the Lotos-EUROS and the inner domain with 1 km resolution covering Prague with AURORA. The time resolution is hourly and the pollutants modelled include O3, NO2, PM10 and PM2.5.

No specific emission inventory has been developed to run the model, and the emissions are downscaled from national totals employing the National Inventory[17]. The final spatial and temporal resolution is 1km and 1 hour, respectively. Traffic and commercial and domestic emissions are included as gridded emissions whereas some of the industrial sources are included as point sources.

[15] The Urban Air Dispersion Model EPISODE applied in AirQUIS2003 Technical Description, Leiv Håvard Slørdal, Sam-Erik Walker and Sverre Solberg, NILU (2003), ISBN: 82-425-1522-0

[16] http://pandora.meng.auth.gr/mds/showlong.php?id=167&MTG_Session=8643a484284ea4a2b2e692cd3ce4bfdb

[17] http://portal.chmi.cz/files/portal/docs/uoco/oez/emisnibilance_CZ.html

The meteorological inputs are interpolated from the ECMWF forecasts. The evaluation of the outputs from AURORA is still being conducted. More information about the AURORA model can be found here: http://aurora.vito.be/manual.html.

As both collaborations are still ongoing and none of the models have yet been completely validated, Prague has not reported any weak points concerning the model applications. However it is highlighted that the main difficulty was in using Prague's emission inventory for 'bottom up emission' calculation, due to the fact that emissions were not known outside Prague's boundary. That is the main reason for VITO's downscaled emissions. In the case of the EPISODE model, the main difficulties for the application of the model are that the model is still being tested and bugs are still being found.

The collaboration with VITO has been found helpful, and it is expected to use AURORA for air quality forecasting in the city of Prague.

## 11.3 Paris

In Paris the collaboration with INERIS[18] and ESMERALDA[19] is addressing two different topics. The collaboration at national level with INERIS has as main goal the use of the national air quality forecasting system as boundary conditions of the regional forecasting system. In this case the national modelling system runs with a resolution of 50km and this is employed as boundary conditions as the 15km domain in the nested modelling system used in Paris for forecasting purposes. The collaboration with ESMERALDA requires the creation of an interregional high resolution emission inventory (3km or higher) for forecasting and scenario modelling purposes. The emissions are employed as input to the nested modelling system with one mother domain with 15km resolution covering a large part of France and two high resolution domains with 3km resolution. The ESMERALDA emission inventory does not consider line emissions, but can be used up to 1km resolution.

## 11.4 Antwerp

In Antwerp the collaboration is conducted with the Environment, Nature and Energy Department of the Flemish Government (LNE[20]). The department is responsible for planning and evaluating the environmental policy and the implementation and enforcement of the environmental legislation in Flanders. The collaboration covers the activities of air quality assessment, long term planning and scenario calculations, population exposure and source apportionment. The modelling system employed is the one described in section 5.

## 11.5 Vilnius

The city of Vilnius is also collaborating at regional level with the Environmental Protection Agency[21] for assessment of air quality in general. Result of this collaboration is the elaboration of annual averaged maps for $PM_{10}$, $NO_2$, CO and $SO_2$.

[18] http://www.ineris.fr
[19] http://www.esmeralda-web.fr
[20] http://www.lne.be
[21] http://oras.gamta.lt/cms/index?rubricId=4cff26a3-ece5-46be-ad58-c8d14b94bea6

# 12 Available resources for guidance on modelling

There are a range of web sites and documents available concerning air quality modelling. Several countries in Europe, e.g. The United Kingdom (DEFRA[22]), The Netherlands (INFOMIL[23]) and Norway (MODluft[24]), provide information on air quality modelling on a national level. In addition there is extensive guidance and documentation available concerning US EPA models[25].

On a European level a set of recommendations concerning air quality assessment and modelling was developed as part of the EU FP6 project Air4EU[26]. Since then a set of guidance documents, aimed principally at applications of models for the European air quality Directive, have been developed as part of FAIRMODE (Forum for Air Quality Modelling in Europe), which is a joint response action of the European Environment Agency (EEA) and the European Commission Joint Research Centre (JRC). These documents include:

- 'The application of models under the European Union's Air Quality Directive: A technical reference guide'
- 'Guide on modelling Nitrogen Dioxide ($NO_2$) for air quality assessment and planning relevant to the European Air Quality Directive'
- and the currently in progress guide on PM modelling 'Modelling of Particulate Matter (PM) for air quality assessment and planning relevant to the European Air Quality Directive'.

All of these documents can be accessed through the FAIRMODE web site (FAIRMODE[27]).

Another source of information that includes descriptions and applications of air quality models can be found in the Model Documentation System[28] (MDS), a database containing most air quality models currently applied in Europe.

During the course of the coming years new guidance will be developed within FAIRMODE specifically aimed at cities employing air quality modelling and the MDS will be updated to improve relevance and accessibility. These developments will be partially based on feedback obtained from this Air Pilot study.

# 13 Conclusions

The questionnaire was sent to 12 European cities: Berlin, Dublin, Madrid, Malmö, Milan, Ploiesti, Prague and Vienna in the year 2012 and Paris, Plovdiv, Vilnius and Antwerp in the year 2013. All the cities applied models for air quality management except the city of Dublin. All the cities expect to learn from the city pilot about how the other cities have applied models and share the difficulties inherent to the application of dispersion models: data input, interpretation of the results, etc.

As mentioned before, Dublin is the only city that had not applied air quality models at the time the questionnaire was sent, however they stated that their involvement in the city air pilot has been

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[22] http://uk-air.defra.gov.uk/research/air-quality-modelling
[23] http://www.infomil.nl/onderwerpen/klimaat-lucht/luchtkwaliteit/rekenen-meten/
[24] http://www.luftkvalitet.info/ModLUFT/ModLUFT.aspx
[25] http://www.epa.gov/scram001/
[26] http://www.air4eu.nl/reports_products.html
[27] http://fairmode.ew.eea.europa.eu/guidance-use-models-wg1
[28] http://acm.eionet.europa.eu/databases/MDS/index_html

highly beneficial as they worked closely with EPA-Ireland in the past months in commencing a process to develop an emissions inventory and an air quality model.

The models have been used for different purposes, as for instance, reporting of air quality compliance, long term planning, population exposure estimation or source apportionment. Not all the cities have applied models for all the purposes. All the cities have found models helpful for the applications they were used for, and the outputs have been used in air quality management in the cities.

All the cities have developed a specific local emission inventory to run the model, with the spatial and temporal resolution according to the horizontal grid cell, for instance for street models such as OSPM the resolution is 50m and for local models as REM_CALGRID the horizontal resolution is 2km. The sources included vary from city to city and from model to model, while in street canyon models only the relevant sources are included (usually road traffic emissions), in the local and regional models all known sources are included.

Regarding traffic emissions, all cities identified the representation of traffic emissions due to congestion to be a problem, with the exception of Vilnius. Also, traffic emissions are not included as line sources in all the models, for instance in FARM and CAMx they are treated as grid sources.

In the commercial and domestic emissions the PM speciation in $PM_{10}$ and $PM_{2.5}$ is not always completely implemented or generic speciations are employed. For example, Madrid employs the US EPA speciation developed for United States whereas in Vienna the PM speciation is not considered. Moreover, the consideration of height and the allocation of emissions as point sources is not always done for commercial and domestic emissions. For instance, Malmö only considers this for large sources.

Similar to the commercial emissions, the PM speciation from industrial sources is not well resolved in all the cities. For example, the city of Milan employs local speciation profiles for $PM_{10}$ and $PM_{2.5}$ but the city of Madrid employs speciation profiles from United States. In all the cities the industrial emissions are considered as point sources and the stack height is considered, however some of the cities such as Paris and Antwerp use a combination of surface emissions and point sources due to the fact that the chimney characteristics are not always available.

The meteorological fields employed as input to the air quality dispersion model are obtained from:

i. measurement towers;
ii. high resolution meteorological models and
iii. ECMWF fields interpolated with the local monitoring network.

The background concentrations are considered in all the cities, but different sources have been employed, ranging from the use of background stations to the use of nested models.

Only four of the cities have employed monitoring data in combination with the dispersion model, in the city of Malmö to adjust the regional background concentrations of $NO_2$ and PM, in the city of Milan for data fusion purposes, in Paris with assimilation methods as kriging to create spatial maps of pollution and in Antwerp to characterize the spatial representativeness of air quality monitoring stations.

The main difficulties that have been found in the use of air quality models are:

i. difficult to estimate the uncertainties of each source sector in source contribution and source apportionment studies;
ii. the computation time is very high;
iii. the model results can overestimate or underestimate the pollutant levels;
iv. the compilation of the emission inventory and
v. the estimation of the background concentration.

The weak points identified are:

i. the emission estimation (correct amount of vehicles in each road, sea traffic, spatial and temporal variation, emission factors, etc.);
ii. the interpretation of the model results (uncertainties, over and under-estimation, etc.);
iii. the high cost of the required resources (human, temporal and financial);
iv. the consideration of sub-grid processes and hotspots and
v. the background dependency in street canyon models.

The main point where further guidance is required are:

i. validation of the models (meteorology and air quality);
ii. estimation of the emissions (how to find a balance between the required emissions for modelling and the work effort);
iii. the necessity of a general framework for modelling approach and criteria harmonization.

# 14 Annex A. Questionnaire sent to the cities

## 14.1 Section 1: Overview

The aim of the task is to examine the model practices (if models have been applied at all) in 8 European cities, to assess the strengths and weaknesses of such applications and further to identify needs for guidance in the use of air quality models.

Table 1. Pilot Cities and EEA or DG ENV responsible person to contact them in the Pilot team

| City | Lead (institution) |
|---|---|
| Berlin | Anke Lükewille (EEA) |
| Dublin | Daniela Buzica (DG ENV) |
| Madrid | Alberto González Ortiz (EEA) |
| Malmö | Valentin Foltescu (EEA) |
| Milan | Giorgio Arduino (DG ENV) |
| Ploiesti | Daniela Buzica (DG ENV) |
| Prague | Alberto González Ortiz + Peder Gabrielsen (EEA) |
| Vienna | Daniela Buzica (DG ENV) |

Table 2. Pilot Cities and general and modelling responsible persons to contact them in the Pilot team

| City | General contact | Modelling activities contact |
|---|---|---|
| Berlin | Martin Lutz<br>martin.lutz@senstadt.berlin.de | Andreas Kerschbaumer<br>Andreas.kerschbaumer@senstadt.berlin.de |
| Dublin | Martin Fitzpatrick<br>martin.fitzpatrick@dublincity.ie | Martin Fitzpatrick<br>martin.fitzpatrick@dublincity.ie |
| Madrid | Paz Valiente<br>valientecp@madrid.es | Ángeles Cristóbal<br>cristoballma@madrid.es |
| Malmö | Mårten Spanne<br>marten.spanne@malmo.se | Mårten Spanne<br>marten.spanne@malmo.se<br>Lotten J. Johansson<br>lotten.jonsson-johansson@malmo.se |
| Milan | Guido Lanzani | Guido Lanzani |
| | g.lanzani@arpalombardia.it | g.lanzani@arpalombardia.it |
| Ploiesti | Cornelia Mateescu<br>cornelia.mateescu@apmph.anpm.ro | Cornelia Mateescu<br>cornelia.mateescu@apmph.anpm.ro |
| Prague | Mária Kazmuková<br>kazmukova@urm.mepnet.cz | Ondrej Vlcek<br>vlcek@chmi.cz |
| Vienna | Heinz Tizek<br>heinz.tizek@wien.gv.at | Heinz Tizek<br>heinz.tizek@wien.gv.at |

Table 3. Contact persons in EEA and ETC/ACM for the task on modelling activities

| Institution | Name | Role |
|---|---|---|
| EEA | Alberto González Ortiz | General project coordinator |
| EEA | Anke Lükewille | EEA task coordinator |
| NILU (ETC/ACM) | Nuria Castell-Balaguer ncb@nilu.no | Contact person if further guidance is needed to fill in the Questionnaire |
| INERIS (ETC/ACM) | Laurence Rouïl | |
| RIVM (ETC/ACM) | Frank de Leeuw | |

## 14.2 Section 2: Use of models

| | | |
|---|---|---|
| 2.1 | a | Are models used in your city for air quality activities? |
| 2.2 | | *If the previous answer was "No",* |
| | a | Could you explain why they are not used? |
| | b | Do you feel you would need guidance in case you decide to use them? |
| | c | What kind of guidance/help would you like to receive and from whom? |
| 2.3 | | *If the previous answer was "Yes",* |
| | a | For what purposes do you use them? |

| | | |
|---|---|---|
| | | Assessment of air quality in general (including evaluating the environmental (AQ) impact of new infrastructure like highways, airport, etc.) |
| | | Reporting of air quality compliance assessment |
| | | Assessment of source contributions |
| | | Long term planning and scenario calculations |
| | | Short action plans |
| | | Air quality forecasting |
| | | Assessment of population exposure |
| | | Supplement measurements |
| | | Source apportionment studies |
| | | If other, please include a description: |
| | b | In case of different applications, is the same model used for all purposes or are different models used? |
| | c | What is the name and version of the model(s) employed? If different models have been applied, please indicate which model has been used for each of the applications. |
| | d | Is(Are) the model(s) documented in the Model Documentation System (MDS, http://acm.eionet.europa.eu/databases/MDS/index_html)? If yes, give the link/reference. |
| | e | Is(Are) the model(s) run by your institution or is it (are they) run by another one (independent institute, service contract consultants, etc.)? If yes, could you give the coordinates of the institution and some references? |

| | | |
|---|---|---|
| 2.4 | a | Are you aware of other specific and independent modelling studies that had been realized for your city by research teams or other administrations? If yes, what do you think about them? (see also form 4 Cooperation activities) |

## 14.3 Section 3: Modelling activities

| | | | |
|---|---|---|---|
| 3.1 | a | General desciption | Indicate the type of application according to question 2.3a [2] |
| | b | | Spatial scale ($m^2$) |
| | c | | Describe the spatial resolution of nested models implemented if needed. |
| | d | | Time resolution (annual, seasonal mean, daily, hourly) |
| | e | | List the pollutants modelled (PM10, PM2.5, NO2, NOx, etc.) |
| 3.2 | | Input data | |
| | a | Emissions | Did you develop a specific local emission inventory to run the model? |
| | | | What is the spatial and temporal resolution you have chosen? |
| | | | Have emission data for all known sources been included? |
| | | | What sources have been included? |
| | | | *In relation to traffic:* |
| | | | Is traffic congestion a problem and is it reflected in the modelling? |

| | | | |
|---|---|---|---|
| | | | Do the emission inventories for traffic include traffic counts and traffic speed per vehicle class? |
| | | | Have the emission inventories been updated in regard to fleet composition, and emission factors (both for NO and $NO_2$)? |
| | | | Which speciation for NO and NO2 is used in the emission data according to the fleet composition? References? |
| | | | Are line source emissions included or only gridded emissions? |
| | | | *In relation to commercial/domestic sector:* |
| | | | How do you deal with PM speciation? |
| | | | Is the source height precisely described? |
| | | | How are those sources described (surface emissions or point sources?) |
| | | | *In relation to industry:* |
| | | | How do you deal with PM speciation? |
| | | | Is the source height precisely described? |
| | | | How are those sources described (surface emissions or point sources?) |
| | | | If available, please include the references to reports or publications where the estimation of emissions is described. |

| | | | |
|---|---|---|---|
| | b | Meteorology | How are the meteorological fields obtained? |
| | | | If a meteorological model is used, has it been validated against local measurements? |
| | | | If available, please include the references to reports or publications where the meteorological modelling is described. |
| | c | Other input data | How are background concentrations of the various pollutants taken into account? |
| | | | Has monitoring data been used in combination with the model? |
| | | | If monitoring data has been used, describe how it has been used. |
| | | | From a more general point of view: How do you evaluate boundary conditions provided to your model or the chain of nested models? |
| 3.3 | a | Air Quality Model | Has a dispersion model been employed? |
| | b | | If the previous answer was 'No', What kind of air quality model has been used? |
| | c | | Is the model type 'fit for purpose' for the spatial and temporal scales assessed? |

| | | | |
|---|---|---|---|
| | d | | Does the model resolve the local/hotspot spatial scales? How do you deal with that issue? |
| | e | | Does the model include photochemical reactions? |
| | f | | Has the model been validated against local measurements? What pollutants? Against how many and which type of stations? |
| | g | | Has the model been validated in a similar environment? |
| | h | | Which kind of quality indicators has been assessed: bias, root mean square error, mean error, correlation factor... ? |
| | i | | Has the uncertainty of the model been determined? If yes, does it fulfil requirements in the AQ Directives? |
| | j | | Has the model been documented including a complete description of parameterisations and numerical methods? If yes, please include the references. |
| | k | | If available, please include the references to reports or publications where the modelling activities are described. |
| 3.4 | a | User experience | Who runs the model? (see also 2.3.e) |
| | b | | How frequent are run and used models for the different applications? |

| | | | |
|---|---|---|---|
| | c | | What difficulties have been found in the model application? |
| | d | | Has the model been helpful for the purpose it was used for? |
| | e | | Have the model results been helpful in relation to AQ assessment activities (exceedances of limit/target values; exchange of information; reporting)? |
| | f | | Have the model results successfully been taken into account in AQ management decisions (long-term planning, short actions, public information, etc.)? |
| | g | | Have the model results been taken into account in any other management decisions (evaluating the environmental impact of new infrastructure, etc.)? |
| | h | | Have the model results being used for estimating geographic areas and population exposure to exceedances of the AQ limit values? Have these maps been reported according to the AQD? |
| | i | | Are other topics linked to AQ (noise, climate change, etc.) considered? If yes, in which way? |
| | j | | What are, for your situation, weak points concerning the model applications? |

| | | | |
|---|---|---|---|
| | k | | Is any further guidance on modelling needed? If yes, please specify. |
| | | | |
| | | | |
| | **[1] The table needs to be completed for each one of the applications where you have used models** | | |
| | **[2] Describe the applications according to question 2.3a** | | |
| | | Assessment of air quality in general | |
| | | Reporting of air quality compliance assessment | |
| | | Assessment of source contributions | |
| | | Long term planning and scenario calculations | |
| | | Short action plans | |
| | | Air quality forecasting | |
| | | Assessment of population exposure | |
| | | Supplement measurements | |
| | | Source apportionment studies | |
| | | If other please include the same descriptions as in question 2.3a | |

## 14.4 Section 4: Cooperation activities

For the cooperation activities the same questions as in Modelling activities were supplied (see section 3 of the questionnaire).

# 15 Annex B: Description of emission inventory in Ploiesti

In Ploiesti, Prahova EPA conducts the elaboration of the emission inventory. The emission inventory is structured in accordance with the Reporting Nomenclature (NFR) as defined in reporting guidelines LRTAP Convention. The previous Nomenclature version-SNAP97 sources are still considered to ensure the continuity in emission inventory drafting. The local emissions inventories include anthropogenic and natural sources located within the district of Prahova, as for instance: industrial units, residential areas, transport infrastructure, farms, farmland and forests.

In order to estimate the local emission inventories Prahova EPA draws data collection questionnaires containing information on:

- Location in space, coordinates;
- Type of activities as NFR;
- Source type: punctual, linear, surface;
- Type of process: combustion, industrial process, etc.
- Type of fuel used;
- Techniques and technologies used, including the emission control;
- Physical characteristics: height level above ground, chimney diameter (for point sources), speed and temperature of exhaust gas, volumetric flow of the gas (for point sources);
- Temporal variation during the year: daily, weekly and monthly operating mode;

To meet the purposes for which the local emission inventories are used, they must, for the territorial unit (industrial site, neighbourhood, city, county) include point, linear and surface sources in Prahova district. After receiving the completed questionnaires, the assurance and quality control data procedure is used for:

- Verification of the source data and their references;
- Checking for errors in transmission and transcription;
- Checking completeness of information;
- Identify confidential data and checking their credibility and quality;
- Verify proper registration of measurement units and the use of appropriate conversion factors.

The pollutants that are part of the annual emission inventory are: NOx, CO, NMVOC, SOx, TSP, $PM_{10}$, $PM_{2.5}$, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, benzo-a-pyrene, benzo-b-fluoranthene, benzo-k-fluoranthene, indo(1 2 3) pyrene, PCB, PAH and HCB. The method of developing the local emission inventories is the based on emission factors.

Finally, the emissions inventory of the district of Prahova is submitted to the Environment National Authority. This emission inventory is the starting point of other dispersion studies that are later conducted by companies contracted by the Ministry of Environment and Forests.