Appraisal

Integrated assessment for regional and local air quality policies

Layman's report

FP7 308395

Contents

0 Introduction

This e-book contains all the main results of APPRAISAL EU-FP7 project (FP7/CA 308395 http://www.appraisal-fp7.eu) aiming at assessing the strengths and weaknesses of the various methodologies used within the EU Member States for the assessment and monitoring of air quality.
For each of the main project Deliverable, this e-book contains its abstract and the link to the Deliverable complete text to examine in depth the treated topic.

1 The Challenge

Air quality in Europe is still facing continued and widespread exceedances, particularly regarding PM, NOx and O3. In case of non-compliance, the 2008 Air Quality Directive requests Member States (MS) to design local and regional plans and assess their impacts on air quality and human health. MS have therefore developed and applied a wide range of modelling methods to cope with these obligations. During the revision of the EU air quality policy, there was the need to consolidate and assess the research results in the field of Air Quality and Health Impact Integrated Assessment and make them accessible to policy makers.
So, the Appraisal project objectives are related to:
1. Perform an overall review of the air quality and health assessment methodologies.
2. Analyze the limitations of the currently available assessment methods.
3. Evaluate the possibility of implementing integrated assessment modelling tools.
4. Inform key stake-holders, and in particular policy-makers on current research/application achievements.
5. Identify key areas to be addressed by research and innovation.

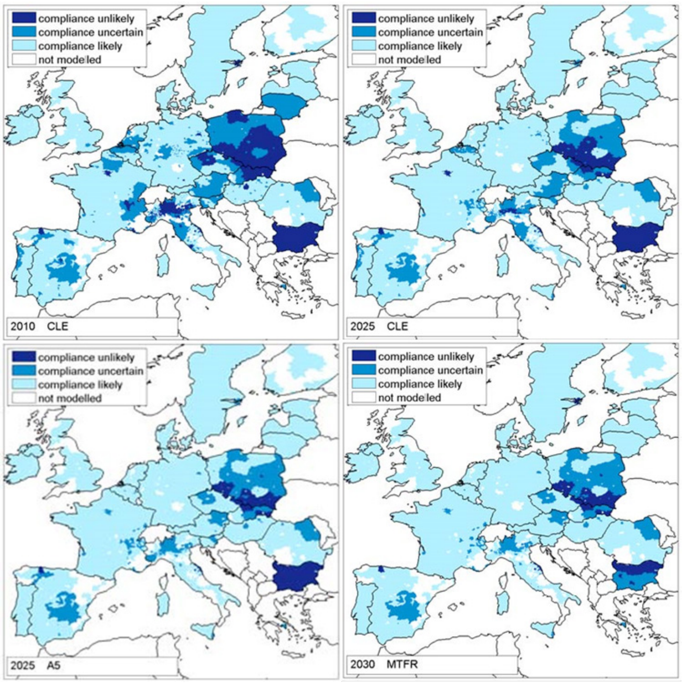


Fig. 1: Different scenarios of probability on compliance with air quality limit values (PM10 concentrations). Scenarios: 2010 (top-left), 2025 (top-right), policy scenario in intermediate case (lower-left) and policy scenario with all possible measures applied (lower-right) (source: IIASA TSAP reports, 2013).

In terms of the context in which air quality plans have to be implemented, it is important to analyze some of the results of the recent air quality policy review.
Figure 1, above, shows the probability of compliance with air quality limit values according to the Legislation, in terms of PM10 concentrations, for different scenarios. “Light blue” means that a specific area probably will meet the limit values, while “dark blue” means that this is unlikely to happen. The two top panels represent the situation in 2010 (left) and 2025 (right). The bottom panels represent two policy scenarios, obtained applying further emission reduction measures. Some important observations can be derived from these figures:
1.Considering the two top maps, in 2010 and 2025, it is clear the move away from a general picture of non-compliance (2010) to few limited remaining areas of non-compliance (2025). European wide measures (already mandated) will determine a significant improvement in compliance with limit values in the future, especially in the western Member States
2.Looking at the bottom maps (left for an intermediate policy scenario in 2025, and right for the improvement that could be obtained by maximum technical feasible measures, in 2030), the potential of further EU-wide measures to avoid exceedances of the limit values is clearly not sufficient. Even in the case of application of all the possible technical measures, still compliance will remain unlikely in some hot- spots. This means that, introducing tougher European-wide measures to address residual non-compliance could be more costly than directly addressing non-compliance areas with specific locally designed measures. This issue also underlines the importance of APPRAISAL, as a project able to “fill this gap” of knowledge, to help addressing non-compliance areas with a local/bottom-up perspective.

2 The APPRAISAL Questionnaire and Database

To meet the project objectives in identifying the strengths and weaknesses in current practices, it was necessary to collect information on the different methodologies used by the European MS to assess the effects of emission abatement policy options and measures. To collect this information in a common format:
 The analysis of the current practices was broken down into five TOPICS which determined the database structure: (i) synergies among national, regional and local approaches, including emission abatement policies; (ii) air quality assessment, including modelling and measurements; (iii) health impact assessment approaches; (iv) source apportionment; and (v) uncertainty and robustness, including Quality Assurance/Quality Control
 A suitable on-line questionnaire has been designed and the APPRAISAL database has been populated http://servizi.appraisal-fp7.eu/appraisal/

The general structure of the database is shown in the Figure 2 below.

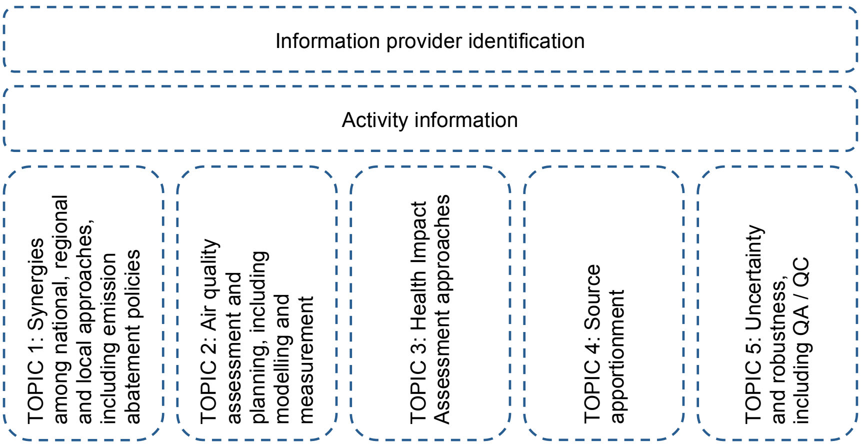


Fig. 2: General structure of APPRAISAL database.

This database concept both simplifies data entry and facilitates the analysis of the results. Data entry of the database is guaranteed by an online questionnaire described in the following including mainly multiple choice questions and some open questions for each topic.
To learn more about the database structure please refer to D 2.1 First version of database structure.

To fill in and maintain the database, a collaborative multiple users tool was implemented: the questionnaire is completely published online through a specific Web App included in the APPRAISAL website. The aim of this Web App is to manage all the life cycle of the questionnaire:

- opening a new questionnaire and filling in
- submitting to Appraisal Steering Committee's reviewers
- approving and feeding the questionnaires' database
- querying the questionnaires' database.

Once a filled questionnaire is approved by one of the Reviewers, its data move automatically to the final database that can be queried to obtain relevant information in statistical terms. These query statistics are publicly available.
An example of a typical statistics that allows to know the number of questionnaires filled in for each country is provided by Figure 3, below.

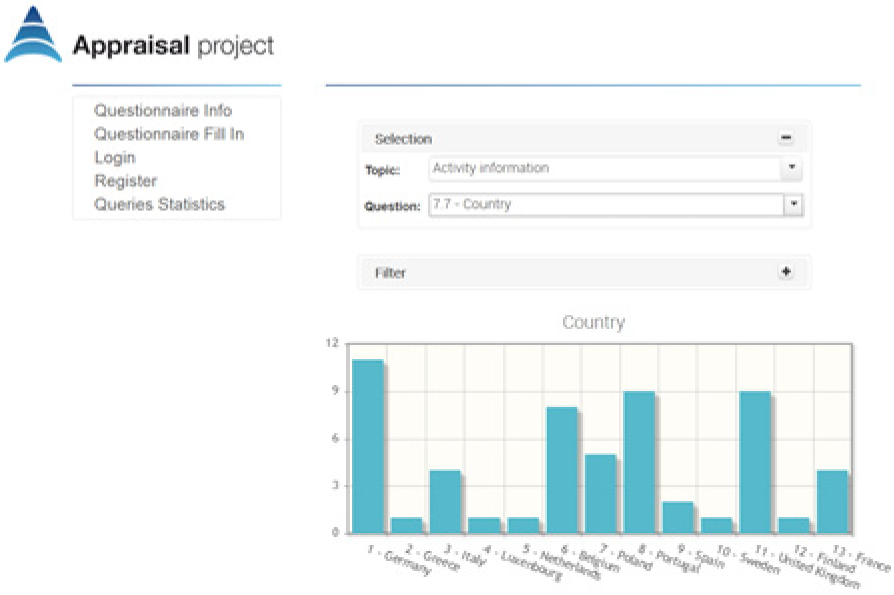


Fig. 3: Example of query statistics on the Web App included in the APPRAISAL website.

Access to the section dedicated to the questionnaire can be gained from the left menu of the official website of the project or using the direct link.

Also a specific radar chart has been designed to graphically represent the level of completeness of the answers in the selected questionnaire according to the DPSIR model (explained later).

To better know the main functionalities of the online questionnaire and related database please refer to D 2.8 Database entry finalized.

2.1 The Database Topics

Five topics have been addressed in the database. Each topic matches one deliverable and is described below.
Air quality experts and regional/local environmental agencies were invited to fill the questionnaire, detailing the methodologies they use to build their Air Quality Plan (AQP) or research project. More than 60 air questionnaires were finally completed. In particular, almost 60% were AQPs and 30% were research projects (10% other). Almost 70% concern AQ Planning, more than 20% concern AQ assessment and only 1% deal with health assessment. About the number of questionnaire completed in each Country: only Germany exceeds 10, 9 questionnaires are from Portugal and UK, 8 for Belgium and all the other Countries are below this threshold.

2.1.1 TOPIC I - Synergies among national, regional and local approaches, including emission abatement technologies

This topic is suitable to identify how emission abatement strategies at the national level are considered and integrated in the definition of regional and local air quality plans and programs.
In this respect, the main stakeholders were interviewed and more than half indicated that these synergies are taken into account.
The first two questions in Topic I appear to have a contrasting response. In fact, the majority of respondents appears to use input from regional and local synergies in their approaches. However, when asked which strategies were included in their decision making process, the major European Directives predominated.
The analysis on the type of measure shows that a greater number of non-technical measures are considered; looking at the response to the question on National Strategies, the focus appears to be on transport.
Examining the responses to the questions in Topic I, a common difficulty appears to be how balancing and reconciling emission inventories, especially between EU, national, regional and local scales. In addition, there is a recognition that policy needs properly consider the responsibility hierarchy required in the implementation phase; the policy written without taking into account the risks connected to these factors should become “undeliverable”, both in terms of attainability of targets and in terms of an appropriate executive function or body.

To learn more about the Topic I, please refer to D2.2 Synergies among national, regional, and local approaches, including emission abatement technologies.

2.1.2 TOPIC II - Air quality assessment and planning, including modelling and measurement

This topic investigates the air quality assessment and planning processes, with special attention to how results are obtained at different scales and how these are combined.

The information in the APPRAISAL database are analyzed and compared with the state of the art for assessment and planning tools, to determine the limitations of the current methodologies and the key areas for further research. Currently, air quality integrated assessment and planning are mainly done through scenario analysis, while optimization methods are still more used in research field. Furthermore, at present, many different models are applied for air quality assessment without any standard modelling tools. Moreover, assessing the air quality, the resolution of the emission inventory and other inputs are adapted to the geographical zone under study: this indicates that, in the most of cases, scale represents an issue for using the measurement data in model evaluation.

Another crucial point concerns the challenge posed by modelling air quality at a local scale and especially the integration of these local scale results with results at larger scales. At the end of this deliverable, some recommendations about tools for air quality integrated assessment are given, with respect to the Air Quality Directive.

To learn more about the Topic II, please refer to D2.3 Air quality assessment and planning, including modelling and measurement.

2.1.3 TOPIC III - Health Impact Assessment (HIA)

"HIA is a mean of assessing the health impacts of policies, plans and projects using quantitative, qualitative and participatory techniques" (http://www.who.int/hia/en/). HIA addresses different methodological issues, which must be clarified for proper interpretation of results by policymakers. Different methodologies exist for developing a HIA. The aims and objectives of the assessment, data availability, resources and time-frames have an influence for the HIA methodologies used in particular assessment. With HIA, policymakers will be able to make a more balanced or scientifically weighted decision for the different policy options or scenarios. HIA is usually performed in a relative way by which different options, and interventions can be weighted against each other.

The questionnaire results pointed out that the most common approach used is the predictive approach, with time-series focused on both short-time and long-term exposure. The most frequent air pollutants included in the health impact assessments are the "traditional" pollutants, such as particles (PM10 and PM2.5), nitrogen oxides (NOx) and ozone (O3).

For accurately assessing health effects of air pollution, detailed exposure estimates need to be available. Aggregating monitored data collected by different monitoring stations, or concentrations measured at central monitoring stations do not seem to reflect the personal exposure in many cases. Analyzing epidemiological studies, it is also evident that, to fully assess the health impacts, we must take a multiple pollutant exposure approach and consider also that air pollution exposure has both physical and psychological effects. This latter dimension is less documented and is more difficult to measure. Subjective indicators constitute an appropriate alternative.

To learn more about the Topic III, please refer to D 2.4 Health Impact Assessment (HIA).

2.1.4 TOPIC IV - Uncertainty and robustness

The topic analyzes model validation and uncertainty estimation describing their limitations. In particular, the key point concerns the use of model for regulatory purposes, and the different uncertainty approaches in Air Quality (AQ) Assessment, Health Impact Assessment (HIA) and Integrated Assessment Modelling (IAM), also with respect to the EU legislation requirements.

The main outcome from the analysis of the questionnaires indicates that model evaluation and uncertainty estimation is more regularly performed in air quality modelling, while it is not often applied in other components, like in HIA applications. The needs that emerged from the questionnaires relate to the quality and quantity of input and validation data, to the improvement of modelling tools and the use of better modelling practices. Many respondents reported the need for the establishment of an evaluation protocol to standardize and harmonize validation and uncertainty estimation methods in EU countries.

To learn more about model quality assessment and evaluation methods, examined separately for model used in relation to Air Quality Planning and for model used in relation to other purposes, refer to D 2.5 Uncertainty and robustness.

2.1.5 TOPIC V - Source Apportionment Methodologies

This topic analyzes the studies on source apportionment in Europe and their increasing number in recent years, closely related to the development of improved tools with better functionalities and performance. However, the lack of a European network of aerosol pollutants monitoring sites is becoming a limiting factor for a further growth and consolidation of source apportionment techniques. The partial information on European sources emission factors and fingerprints is limiting sources identification.

Moreover, the definition of European methodological protocols to guarantee a minimum level of quality and to make results from different studies comparable is required.
From the methodological point of view, both Receptor models and Eulerian models appear as the most dynamic areas in the source apportionment field.
The most important source categories to target in order to abate exceedances of air quality limits are secondary inorganic aerosol (e.g. nitrogen oxides due to traffic), agriculture (e.g. ammonia) and biomass burning during the cold season.
According to these results, future studies on source apportionment in Europe should focus on the relevance of gas-to-particle conversion and photochemical processes as the main contributors to recalcitrant pollutants like PM and ozone.

To learn more about the Topic V please refer to D2.6 Source apportionment methodologies.

To conclude the review and gaps identification in air quality and health assessment methodologies at regional and local scale, a summary has been produced and the results are showed in the D2.7 Summary review of air quality and health assessment methods.
This document focuses on the current practice limitations and identifies areas where further research is needed. A recurring theme is the challenge that is being posed by the integration of local scale results within larger scales.
The main weakness reported in 70% of the studies is related to the emission inventories. Finally, the question was raised as how model results can best be combined with observed measurements in scenario calculations.
In the overall IAM framework, the optimization approach fully responds to the AQ Directives: the emission reduction measures are selected by an optimization algorithm that assesses their impact on air quality, health exposure, and implementation costs. Such optimization algorithms requires thousands of air quality evaluations; in these cases, standard AQ models cannot directly be used because of the computing time demand, so a limited number of simulations must be performed and then processed to identify 'simple' emissions-AQ links (source-receptor relationships) able to capture the specific features of a region.
The final chapter of D2.7 deliverable is dedicated to the Air Quality Directive and addresses how the different tools that are available for integrated air quality assessment can and/or should best be applied to support the Directive as well as some issues which are currently not covered by the Directive. It is also important and well-timed to disseminate, promote and advice the use of IA models at the urban scale in order to facilitate decision-making regarding the most cost-effective air pollution mitigation measures.

3 From the database to the Guidance

Starting from the plans collected in the database and from the background expertise of the partners, a guidance to the development of an Integrated Assessment System has been proposed. The First version of IAS design is explained widely below, but more details can be found in D3.1 First version of IAS design.

3.1 The Integrated Assessment Framework

To address the challenge of improving air quality at the regional/local scale in a cost-effective way, a new methodological approach is needed and has been proposed in the project. First, the EEA (European Environmental Agency) DPSIR (Drivers, Pressures, State, Impacts, Responses) scheme has been adopted as a methodological framework. Then, this has been interpreted to explain all the steps needed to improve air quality at the regional/local level by the use of an air quality plan (Fig.4).

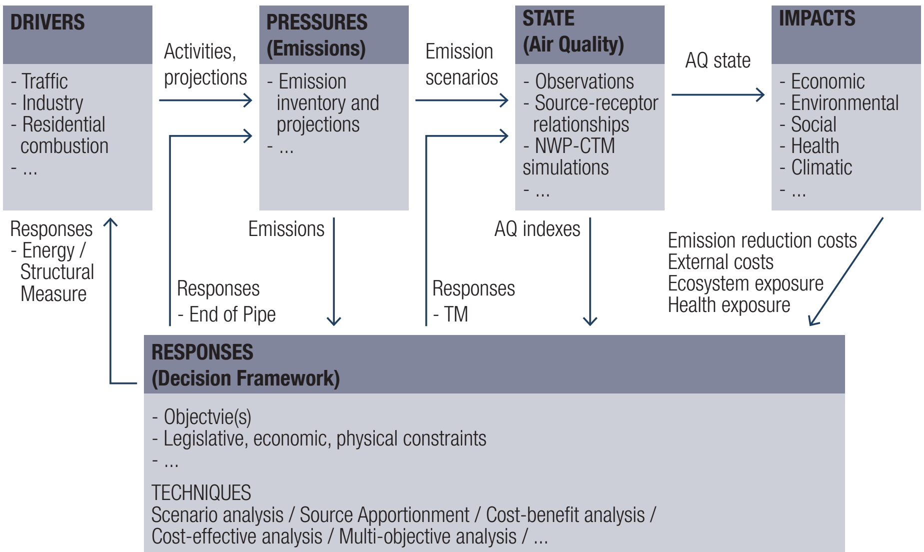


Fig.4: EEA (European Environmental Agency) DPSIR (Drivers, Pressures, State, Impacts, Responses) scheme adapted for the air quality plans preparation.

In particular, in the DPSIR scheme the meaning of each block, as adapted for the air quality plans preparation, is as follows:
- DRIVERS (Activities): it describes the "action resulting from or influenced by human/natural activity or intervention, in particular referring to variables describing traffic, industries, residential heating, etc."
- PRESSURES (Emissions): it describes the "discharge of pollutants into the atmosphere from stationary sources, surface areas, etc." PRESSURES depend on DRIVERS, and are computed as functions of the activities and the quantity of pollution emitted per activity.
- STATE (Air Quality): it describes the concentrations of air pollutants resulting from the PRESSURES defined in the previous block (additional input to the system are meteorology, topography, etc. not considered here, because they cannot be modified by the decision maker).
- IMPACT: it deals with human health, vegetation, ecosystem and economy due to exposure to harmful concentration of pollutants and with the direct costs of emission abatement implementation.
- RESPONSES (Policies): it describes all the measures that could be applied, at a regional/local scale, to influence DRIVERS, PRESSURES, STATE and IMPACTS

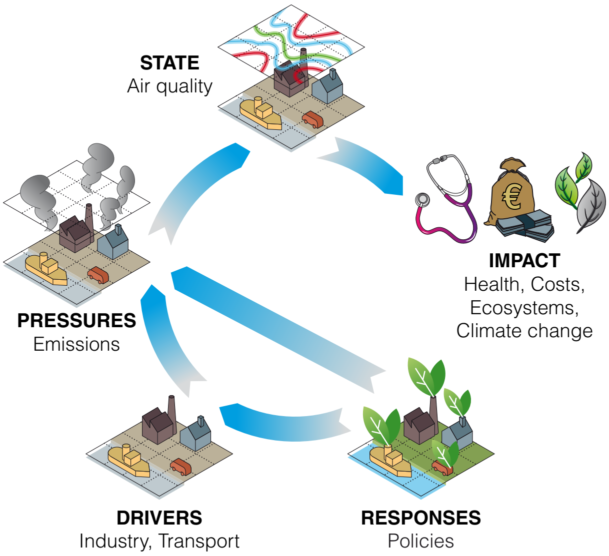


Fig.5: Scenario analysis approach.

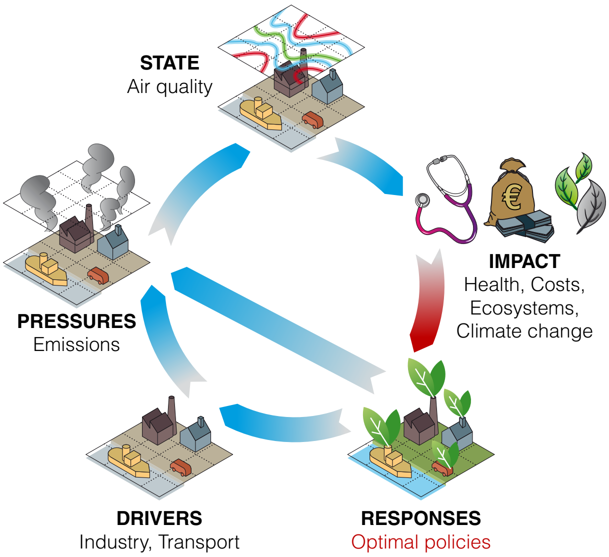
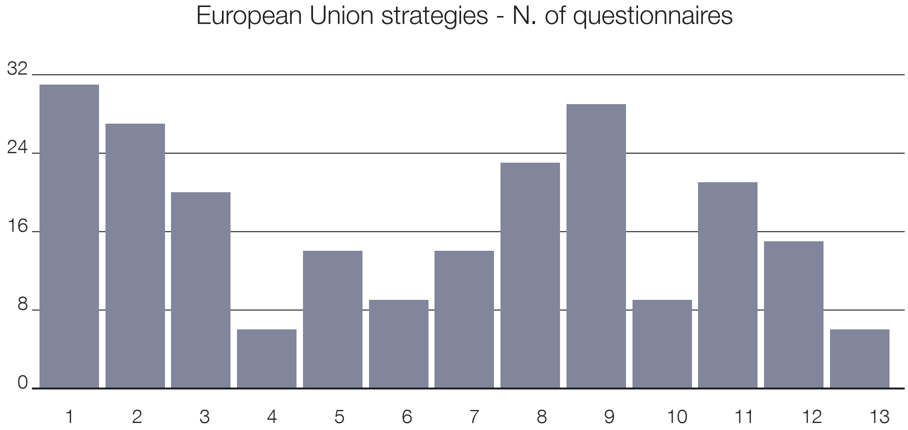


Fig.6: Optimization approach.

Through the DPSIR scheme, it is also possible to define two alternative approaches to improve air quality:
1. Scenario approach: this is the approach mainly used at the moment to build air quality plans at regional/local scale, and is based on simulations through chemical transport models. These simulations are usually configured to test policy scenarios defined by experts, e.g. applying source apportionment techniques (Fig. 5).
2. Optimization approach : in this case (Fig. 6) a more complex procedure is applied, selecting emission reduction measures for air quality improvement through the solution of an optimization problem, and taking into account at the same time different impacts (exposure, costs...).
From here onward a detailed explanation is provided to show how the DPSIR scheme can be used to classify air quality plans, and to support regional/local authorities in the effort of reducing pollution in their regions/domains. For each block, a figure is reported representing the characteristics of the air quality plans (AQPs) and research activities analyzed by the project and stored in its database.

3.1.1 Drivers



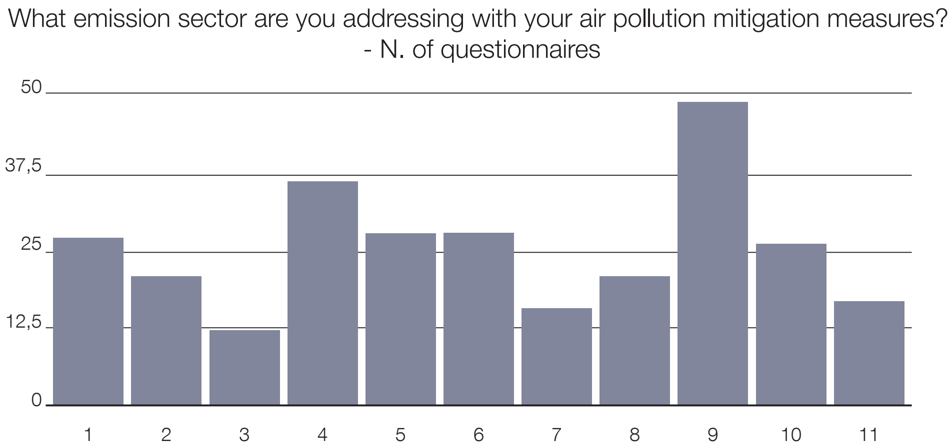
1 - Emission regulation for on-road (so-called EURO standards, e.g. Directive 98/69/EC)
2 - National Emission Ceilings (NEC) Directive
3 - Promotion of low emission vehicles (e.g. EC 443/2009)
4 - Received from another entity
5 - Other
6 - Emission regulation for new non-road vehicles and machinery (so-called STAGE I…IV standards, e.g. Directive 2010/26/EU)
7 - MARPOL pollutants emissions from ships
8 - Energy Efficiency Directive
9 - Industrial Emissions (IE) Directive
10 - Ecodesign Directive for local space heaters
11 - Climate Change programmes (EECP)
12 - Renewable Energy (REN) Directive
13 - Emissions Tradind System (ETS)

Fig.7: Air pollution and climate strategies and legislation at EU level: emission strategies (EURO standards for on-road vehicles, NEC Directive and IE Directive on industry) are the most considered in AQPs, followed by Energy Efficiency Directive and Climate Change Programmes.

The basic function of the DRIVERS block is to model the development of key activities (i.e. road traffic, residential combustion, centralized energy production/industry, agriculture) over time. For instance, for traffic, it means to analyze and/or project the fuel consumption due to traffic, the driven km by cars, the current and future fuel, etc. This information is then used as an input to compute emissions (PRESSURES).
More in general, the input parameters for drivers are factors that represent causes of emission-wise essential activities. Important input parameters include population, general economic activities (e.g. in the form of GDP), more specific activity factors (e.g. sector specific production intensities, transport demand, energy demand, etc.) and technology change factors (e.g. vehicle stock structure, energy efficiency of buildings, etc.) that may be driven by international, national or local requirements or goals (RESPONSES block) or "natural", non-forced development.

For the DRIVERS block, the following three-level classification is proposed to describe air quality plans:
LEVEL 1: when an aggregated approach is applied, using coarse spatial and temporal allocation schemes;
LEVEL 2: when a detailed approach with generic (i.e. national/aggregated) assumptions is applied, using more realistic spatial and temporal allocation schemes;
LEVEL 3: when a detailed approach with specific (i.e. local/detailed) assumptions is applied, using local spatial and temporal allocation schemes.

3.1.2 Pressure



1 - SNAP1 combustion in energy and transformation industries
2 - SNAP10 agriculture
3 - SNAP11 other sources and sinks
4 - SNAP2 non-industrial combustion plants
5 - SNAP3 combustion in manufacturing industry
6 - SNAP4 production processes
7 - SNAP5 extraction and distribution of fossil fuels and geothermal energy
8 - SNAP6 solvent and other product use
9 - SNAP7 road transport
10 - SNAP8 other mobile sources and machinery
11 - SNAP9 waste treatment and disposal

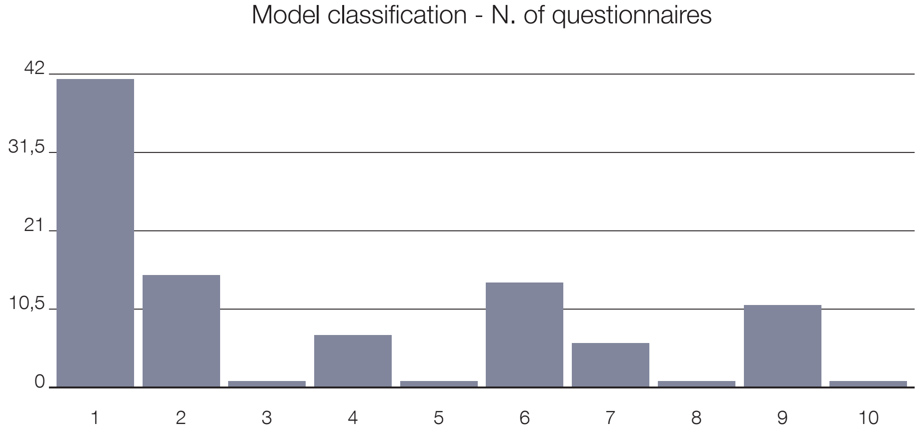
Fig.7: Most of the AQPs include air pollution mitigation measures on SNAP7 – road transport, followed by residential and industrial emission sectors.

Air pollutant emissions act as pressures on the environment. Thus, the PRESSURES block corresponds to the computation of the quantity of pollutants emitted into the atmosphere from stationary sources (such as stacks of large industrial facilities, e.g. power plants), surface areas (residential, commercial or industrial facilities), and mobile sources (for example locomotives, aircrafts, ships, cars, etc.).

The emission of a pollutant at a source (emitter) can be measured (as in large point sources) or estimated. In the last case, it is generally calculated as the product of the activity of this emitter (DRIVERS) and an emission factor, which is the quantity of pollutant emitted per unit of activity.

From a general point of view, the PRESSURES can be estimated through three different approaches, depending on their further uses and the available data:
LEVEL 1: emissions are estimated for rough sectors on a coarse grid (spatialization), using an aggregated methodology. Uncertainties are not necessarily estimated.
LEVEL 2: a combination of detailed and aggregated methodologies is used to calculate the emissions. Emissions factors and activity data representative of the area of study are used when available. Uncertainties are not necessarily estimated.
LEVEL 3: emissions are calculated with the finest space and time resolution available, with a detailed method. Emission factors and activity data correspond to the specific activities of the studied area, and uncertainties are properly taken into account.

3.1.3 State



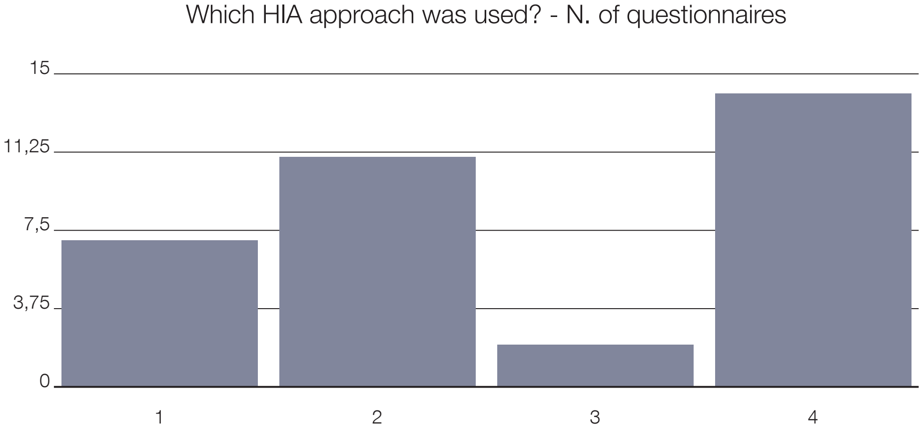
1 - Eulerian Chemical Transport Model
2 - Other
3 - Lagrangian Chemical Model
4 - Lagrangian Particle Model
5 - Obstacle Resolving Fluid Dynamical Model
6 - Gaussian Plume
7 - Gaussian Pluff
8 - Hybrid Methods
9 - Street Canyon Models
10 - Semi-empirical Models

Fig.9: Almost half of the plans examined are based on the use of a Chemical Transport Model (CTM), while only 20% uses Gaussian approach.

In the case of air quality, the STATE describes the ambient concentrations of targeted pollutants. In the case of traffic, it means to consider the air concentrations due to the emissions from cars. The air quality state can be described as gridded concentrations over the studied area, or as local concentrations on receptor sites, depending on the objectives and on the available tools. Also, in addition to the spatial dimension, the air quality state has a temporal dimension, considering that a pollutant can be monitored/ modelled with a temporal resolution of hours/days, etc. Once concentrations are estimated in space and time with different available approaches, one can calculate various air quality indicators, such as aggregation of the initial air quality data e.g. to provide the number of daily exceedances of particulate matter concentration on a cell, the annual mean of nitrogen oxides aggregated over a domain, etc. In this document we will focus on concentrations as a state indicator, even if the content would be basically the same for deposition of atmospheric pollutants.

More in detail, the STATE proposed three-level classification is as follows:
LEVEL 1: the simplest way to characterize air quality state is to use measurements taken routinely, or during a measurement campaign (together with an interpolation method if the aim is to obtain a map of concentrations).
LEVEL 2: it is based on a characterization of air quality using one model, adapted to the studied spatial scale. This model should be validated over the studied area and should use emissions input data also adapted to this scale.
LEVEL 3: it is based on a characterization of the air quality state using a downscaling models chain, both in term of air quality and meteorological models, from large scale (Europe, for example) to regional (country or regions) and local scale (city or street level). Such a model chain allows to take into consideration interactions between the various scales.

3.1.4 Impact



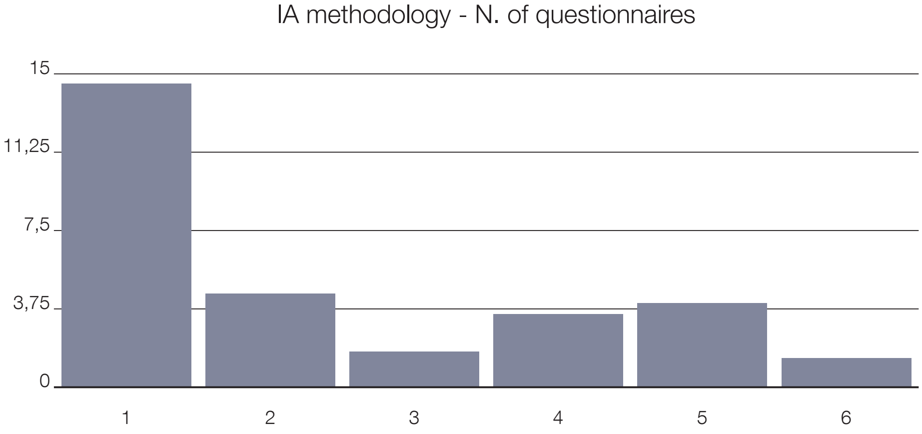
1 - Retrospective
2 - Predictive
3 - Counterfactual
4 - Other

Fig.10: A Health Impact Assessment approach is followed by two thirds of the analyzed AQPs and predictive approach is the most used.

IMPACT describes the consequences of any alterations or modifications of environmental conditions related to the STATE of air quality, being either beneficial or adverse. Among the various impacts, we could distinguish between impacts on human health, on environment (vegetation and ecosystems), on social and economic aspects, on climate or on visibility. Moreover some impact could be derived from another, such as economic valuation of human health or of ecosystems. This means, for instance, to evaluate a monetary equivalent of the increased morbidity/mortality related to traffic emissions. In this context, we specifically focus on impacts on human health. In general, the following input is needed to compute IMPACTS:
- air pollution concentrations;
- population data;
- dose/concentration-response functions.

How to implement the IMPACT block depends on the approaches used for input (STATE and PRESSURES) but also the level of details gathered on the population exposure:
LEVEL 1: a coarse description of exposure provided either by measurement or modelling of air quality (e.g. average mean annual exposure for a city) is used, in addition to a concentration-response function and a simple population description. For example, in this way it is possible to model the number of hospital emergency visits related to increased ozone levels for a city or region.
LEVEL 2: similar to level 1, but with spatial detail in the STATE description. Population data could be derived from national data or registers.
LEVEL 3: a detailed temporal and spatial resolution for exposure and population data will allow a detailed health information integrating, for instance, distance to roads, spatial distribution and vulnerable groups, which allows to model the number of hospital admissions of people living in greener or more traffic areas of a city.

3.1.5 Responses



1 - Scenario analysis
2 - Cost assessment
3 - Cost-benefit
4 - Cost-effectiveness
5 - Multi-objective approach
6 - Other

Fig.11: Half of the considered plans uses scenario analysis while the other more complex IA methodologies are less diffuse.

The RESPONSES block represents the decision framework, that is to say the set of techniques/approaches that can be used to take decisions on actions (mostly, emission reduction measures) to be implemented.
The main components of a decision framework are defined considering: control variables (these represent, for instance, the emission reduction measures that can be applied by the regional/local authority, as car-sharing, congestion charge, etc.); objectives (these represent what a Decision Maker would like to improve); constraints (these can be of different types, as legislative, economic, physical, etc. They can be mathematically formalized, if using a formal approach to take decisions, or they can be taken into account when making decisions, but without explicitly modelling them).

The RESPONSES block can be described considering the following tier:
LEVEL 1: using expert judgment and scenario analysis. In this case the selection of improvement actions is based on expert opinion, with/without modelling support to test the consequences of a predefined scenario on air quality. In this context, the costs of the reduction actions can be evaluated as an output of the procedure (even if in many cases they are not considered).
LEVEL 2: using source apportionment and scenario analysis. In this case, the sources of emissions that are mainly influencing air quality are derived through a formal approach; this then allows selecting the measures that should be applied to improve air quality and human health. Again, emission reduction costs, if any, are usually evaluated as a model output.
LEVEL 3: using an optimization approach. In this case the whole decision framework is described through a mathematical approach (Cost-benefit analysis, Cost-effectiveness analysis, Multi-objective analysis), and costs are explicitly taken into account in the procedure.

3.2 Guidance document

Based on the above general IAM framework design , a first version of the official Guidance Document of the APPRAISAL project has been structured, around the building blocks of the EEA DPSIR scheme. In the Guidance document, for each of these blocks a number of recommendations is provided, taking into account that each of these blocks can be elaborated to a different level of complexity according to the available data or the purpose of the IAM. Some of the questions relate to important cross cutting topics that reappear for each of the blocks (such as how to take into account the different scales and their interactions and how to deal with uncertainties) while other questions are specific to a single block.
This first version of the Guidance document is mostly based on the review and design work reports and aims by no means to provide detailed technical instructions on how to set up an IAM, but rather wants to present a comprehensive set of topics that should be addressed in a plan preparation. The emphasis is therefore rather on keeping the overview and less on providing all the details, as these can often already be found in other reports and peer reviewed literature sources.

To explore the first version of the guidance, please refer to D4.1 First draft version of the guidance document.

To write the final Guidance document on integrated air quality and health assessment systems, the draft version has been assessed using practical examples: in a first evaluation of the guidance document, existing AQPs were used as test cases with the aim to identify which guidance was currently lacking and should be further extended (see Guidance document evaluation paragraph). In the second step, this testing has been extended by applying an IAM tool (RIAT+, see below) to two test cases: one for the Brussels Capital Region in Belgium and the other to the region of Porto in the North of Portugal (see Guidance document test cases paragraph).

4 Guidance evaluation against existing AQPs

As said, in the first step of the evaluation of the guidance document, the focus has been on existing AQPs, with the aim to both reveal the differences between various 'practical applications' and test the congruence of what discussed in the document with real cases. Eight case studies have been analyzed and they are listed below:

- AQP for Antwerp (VITO)
- AQP for Athens (AUTH)
- AQP for the Northern Region of Portugal (UAVR)
- Preliminary AQP for Emilia Romagna (Terraria)
- Research project for the Alsace Region (CNRS/UdS/ASPA)
- AQP for the Warsaw Agglomeration (WUT)
- Research project for the Warsaw Agglomeration (SRI/WUT)
- AQP for Helsinki (SYKE)

The scheme to explore these 'practical application' has been always the same: the AQP was interpreted in terms of the DPSIR blocks, and a level of detail was assigned to the Drivers, Pressures, State, Impact, Response, according to the way they have been analyzed. Then possible improvements to the DPSIR blocks used were derived together with (possibly) missing or underestimated topics in the guidance document.

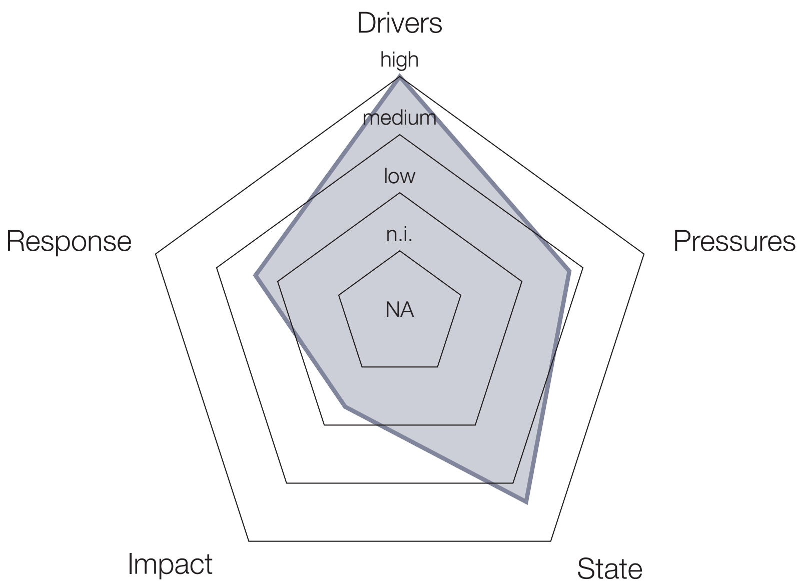


Fig.12: "Average graph" computed considering all air quality plans available in the Appraisal Database.

The analysis of individual AQPs has been summarized using the radar chart. This chart graphically represents the level of complexity for each of the DPSIR blocks based on the answers to the questionnaire. For each of the five blocks, five levels of complexity have been defined: N/A – not possible to assign level based on input from questionnaire ('no level'), Level 0 - the block is not considered in the AQP, Level 1 - low level of complexity in the implementation, Level 2 – medium level of complexity, and Level 3 – high level of complexity.
The radar chart (figure 12) represents the "average graph" computed considering all plans available in the database.
Based on the analysis of the eight practical AQP studies, some main observations were derived:

- The guidance document would benefit from the inclusion of (or at least the references to) practical examples
- Much effort was put into quantifying the drivers and pressures (emissions) in all the studies that were considered.
- The guidance document needs to be extended with guidance on using data assimilation and a better reference should be made to FAIRMODE initiative (http://fairmode.jrc.ec.europa.eu/) for the evaluation of model results.

To learn more about the practical AQP studies results and how they contributed to the guidance definition please refer to D4.2 Guidance document evaluation tier 1.

5 Test cases

The final step of the APPRAISAL project was the application of the IAM tool RIAT+ in two test cases: one in the Brussels Capital Region in Belgium and in the region of Porto in the North of Portugal. The experience obtained through these two test cases was used to further improve the Guidance Document.
The RIAT+ system, developed during the OPERA project (www.operatool.eu, LIFE09 ENV/IT/000092, awarded as 'Best LIFE Environment project' in 2014), is an IAM tool designed to help regional decision makers to select optimal air pollution reduction policies that will improve the air quality at minimum costs. To achieve this, the system incorporates explicitly the specific features of the area of interest with regional input data-set for the:
• precursor emissions of local and surrounding sources;
• abatement measures (technical and non-technical) described per activity sector and technology with information on application rates, emission removal efficiency factor and cost;
• the effect of meteorology and prevailing chemical regimes through the use of site specific source-receptor functions.
The system runs as a stand-alone desktop application and can be downloaded (free license) from the project web-site (http://www.operatool.eu/download/). RIAT+ has been already applied in Emilia-Romagna Region (IT) and in Alsace (FR) during the OPERA project and in Lombardy Region to evaluate AQP measures.

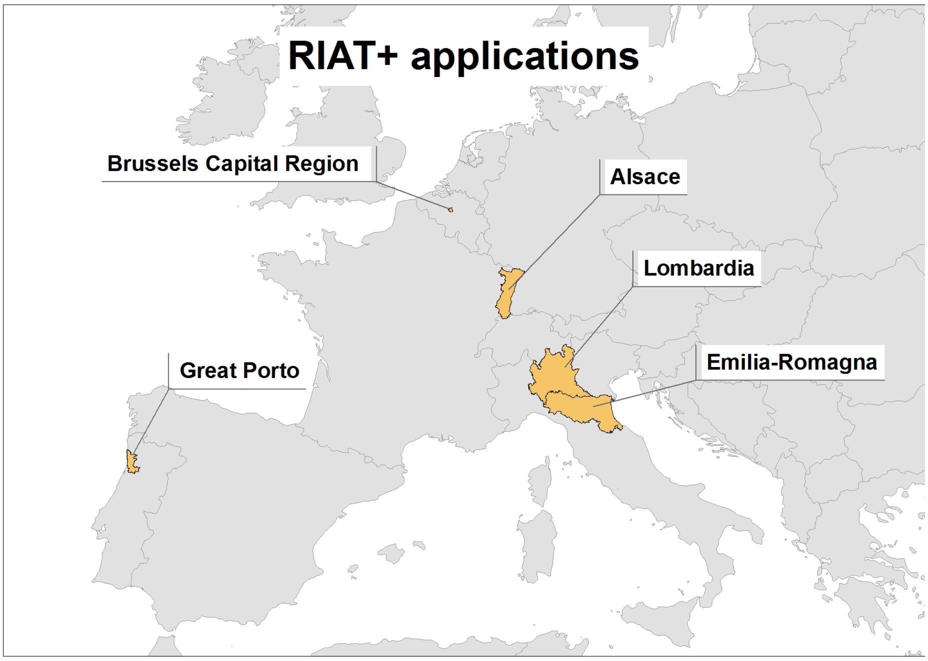


Fig.13: Countries involved in RIAT+ application.

The tool allows two possible decision pathways in the DPSIR scheme: scenario analysis and optimization. The main outputs from RIAT+ are a summary of emission reductions on the domain, a table of the application rates for the different measures, maps of a set of relevant air quality indexes (AQIs) and, for the optimization pathway, the Pareto Curve providing the efficient solutions of a specific AQI ranked by costs.
A source receptor (S/R) model is used, internally, to link emissions (pressure) to an air quality indicator, that represent the state. A S/R model can be as simple as a linear relationship, or as complex as a chemical transport model. To limit the computational time, RIAT+ normally uses a nonlinear relations identified by means of Artificial Neural Networks (ANNs), tuned to replicate the results of a limited set of simulations performed by the users with deterministic air quality model calibrated of the specific site.
The selection of which simulations to use is an important aspect in setting up the ANN. They must be representative of the range of emissions/concentrations that can be encountered during the optimization procedure. The definition of this training data set is typically referred to as the 'Design of Experiment': this establishes the configurations for the CTM simulations.

Both the test cases are presented below with the same scheme: a quick introduction on the area and the proposed abatement measures followed by the application of RIAT+, with a focus on the technology database used, the chemical transport modelling run, the Design of Experiment and the identification of the source-receptor models and, in the end, the results obtained.

5.1 Brussels case study

The Brussels Capital Region (BCR) has an area of 161 km2 and is home to more than 1.1 million people. The region consists of 19 municipalities, one of which is the Brussels Municipality, the capital of Belgium (see Figure 14).

Fig.14: Location of the BCR (red zone) in Belgium.

The proposed abatement measures are provided by BIM[1]: they are a list of 13 measures consisting of 9 traffic measures and 4 domestic heating measures, that have been approved by Brussels authorities. For these abatement measures, BIM provided order-of-magnitude estimations of the costs and emission reductions.
The RIAT+ database with abatement technologies that are available for the macro-sectors of interest - non-industrial combustion (2) and transport (7) – was derived from GAINS Europe (http://gains.iiasa.ac.at/gains/EUN/index.login?logout=1) in the frame of the OPERA LIFE+ project.
For air quality modelling of the BCR, the AURORA chemical transport model (see: http://pandora.meng.auth.gr/mds/showlong.php?id=167) was used with a domain of 49 x 49 grid cells at 1 km resolution (Figure 15) with base emissions for the year 2009. For the vertical discretization, 20 layers were used for a domain extending up to 5 km.

1 Brussels Environment, BIM (http://www.ibgebim.be) is responsible for the study, monitoring and management of air, water, soil, waste, noise and nature (green space and biodiversity).

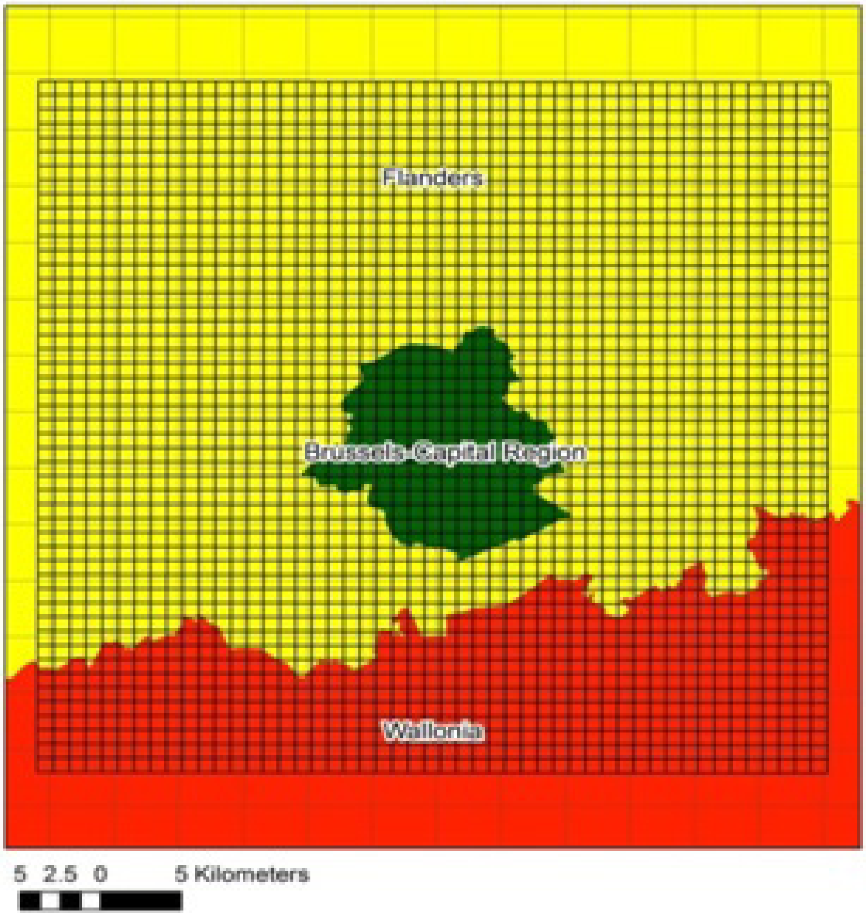


Fig.15: Model grid used for the CTM calculations. Both the 1 km resolution grid and the lower (5 km) resolution grid are shown. The different colors correspond to the different regions (green: BCR, yellow: Flanders, red: Walloon).

The results of the 1 km resolution model setup were validated by comparison to the observed values at the measurement stations inside the model domain. For the model validation, the FAIRMODE methodology (http://fairmode.jrc.ec.europa.eu/) was adopted.

For the Design of Experiment phase, three levels of emission reduction were distinguished: base case (B), high emission reductions (H) and low emission reductions (L). In order to determine the emission reduction scenarios for the ANN training, the three levels B, H, L were combined to produce 14 emission scenarios. These scenarios were applied to the emissions both in and outside the policy application domain (PAD), which, in this case, is the BCR.

In this study, the AQIs considered are:

• PM10: yearly average of PM10 concentrations
• NO2: yearly average of NO2 concentrations.

Once the ANNs have been trained, RIAT+ was run to look for optimal policies beyond the 2020 Current LEgislation. As the emission changes, that can be obtained with the selected set of measures, are limited, unsurprisingly, the concentration changes are also limited. Figure 16 shows an example of NO2 concentration changes due to the emission abatement measures.

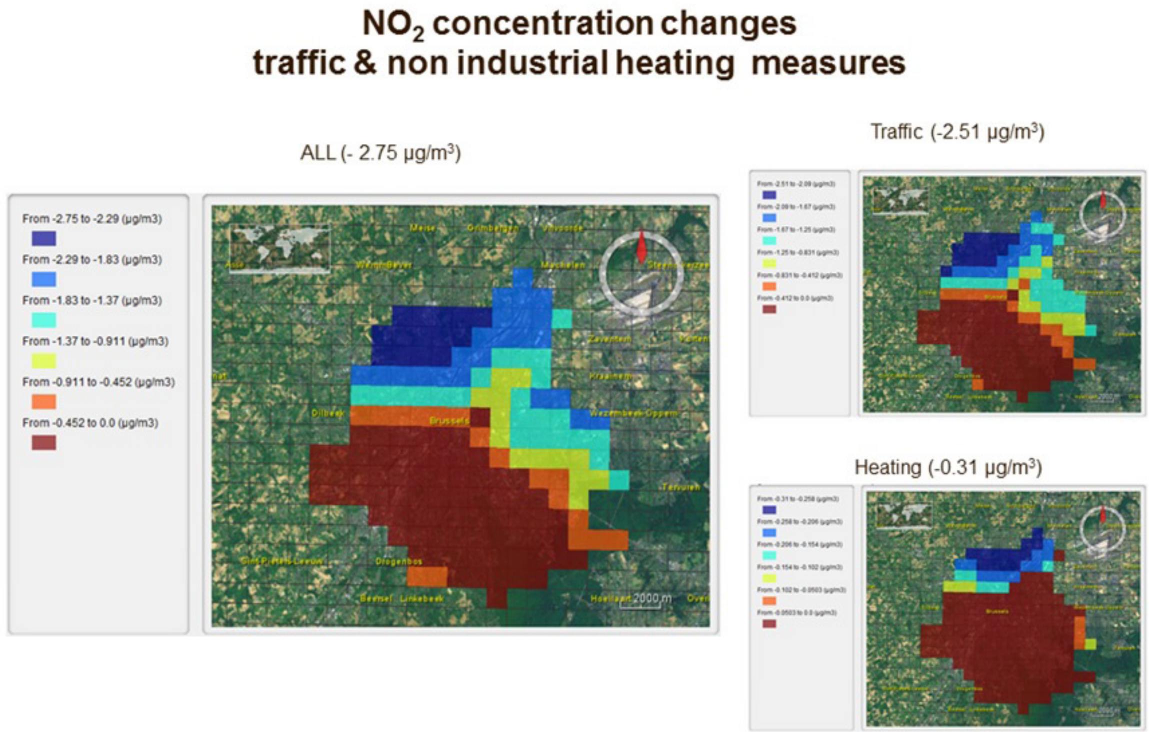


Fig.16: Yearly average NO2 concentration changes (µg/m3) for all traffic and all non-industrial heating measures as well as for the combination of these two in 2020 compared to the reference (CLE 2020). The number in parentheses is the maximum concentration change.

5.2 Porto case study

The Great Porto Area is a Portuguese NUTS3 subregion involving 11 municipalities. It covers a total area of 1024 km2 with a total population of more than 1.2 million inhabitants.

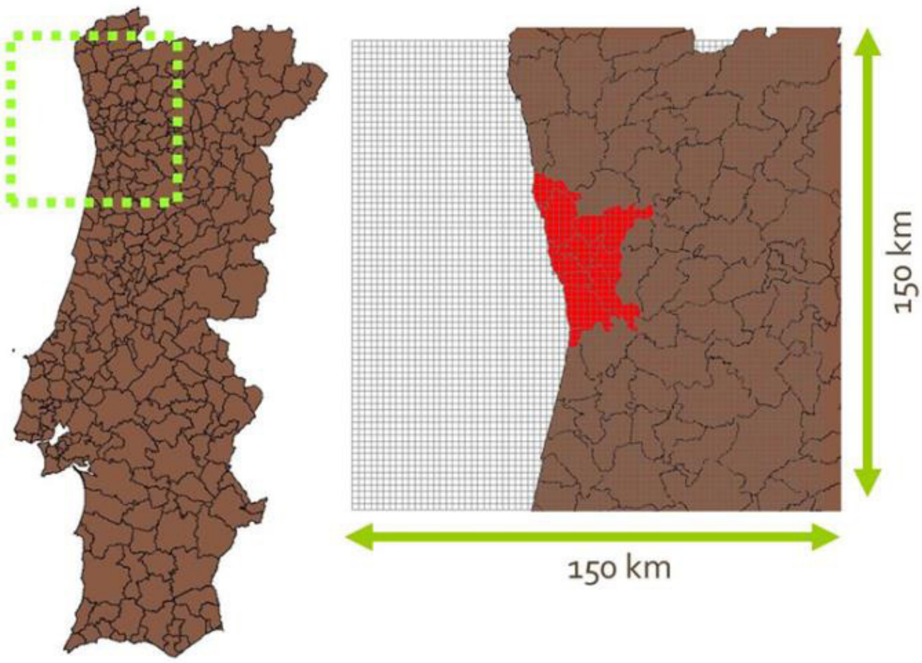


Fig.17: Location of the Great Porto Area in Portugal and in the Northern Region of Portugal.

The GAINS database of reduction technologies, which contains a large data set collected for Portugal by IIASA (http://www.iiasa.ac.at), was used. It contains values for the years 2010, 2015, 2020 and 2025, including costs and emissions effects. The reference scenario «TSAP» of March 2013 was considered in the study.
The TAPM[2] model was applied to the Great Porto Area (150x150 km) for one entire reference year (2012) with a 2x2 km2 spatial resolution using disaggregated emissions from the Portuguese 2009 emission inventory, which is the most recent available. Extending previous evaluations of the same model for the Great Porto Area, the results of the TAPM simulations were compared to the measured values at the monitoring stations inside the model domain. As in the Brussels case, the FAIRMODE methodology was used for the validation (http://fairmode.jrc.ec.europa.eu/).
The Design of the Experiment was influenced by the computational time constraints, so just 10 emission reduction scenarios were simulated. Processing the TAPM simulation results, low and high reduction levels were obtained. Each TAPM simulation is a full year simulation. The target considered in this application was the PM10 annual mean.
RIAT+ was applied in the optimization mode and Figure 18 shows the efficient solutions obtained for the Great Porto domain. On the horizontal axis of the figure, there are industrial costs (i.e. those related to the implementation of end-of-pipe measures), considered over CLE (i.e. those mandatory under the current legislation) and expressed in M€. On the vertical axis, there is the spatial average of PM10 annual mean (the AQI value for this particular case) estimated over the entire study area.

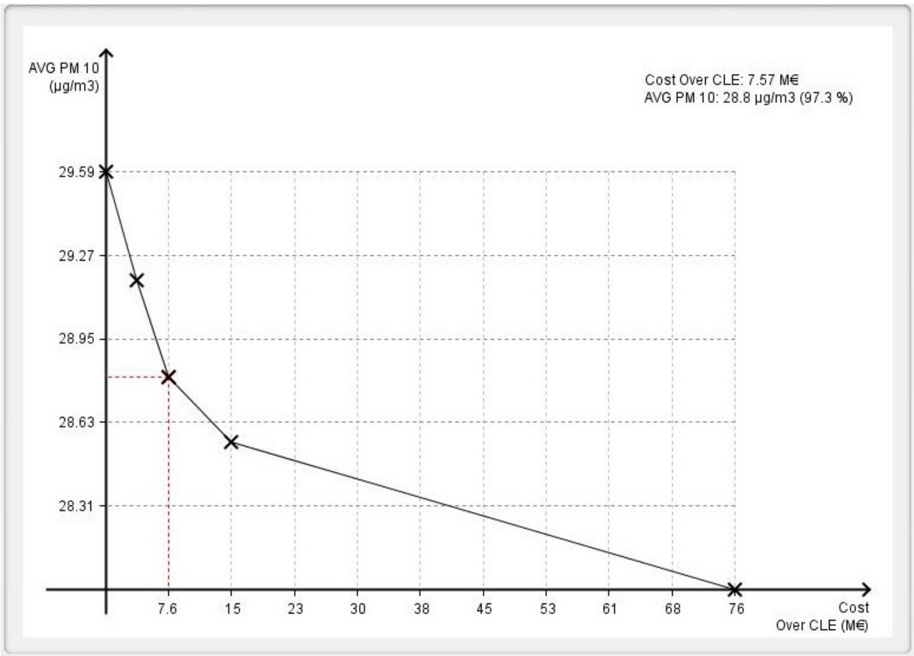


Fig.18: Pareto curve for the optimization of PM10 yearly mean concentrations.

The Pareto Curve shows that a PM10 mean concentration of 28.8 µg/m3 can be reached by adopting emission reduction technologies costing around 7.6 Million € per year.
For that point of the Pareto curve, Figure 19 shows the spatial distribution of PM10 annual concentration values. The largest reduction of PM10 emissions and concentration levels are expected over the Porto municipality where the population has the highest density.

2 The Air Pollution Model (TAPM) (see: http://pandora.meng.auth.gr/mds/showlong.php?id=120)

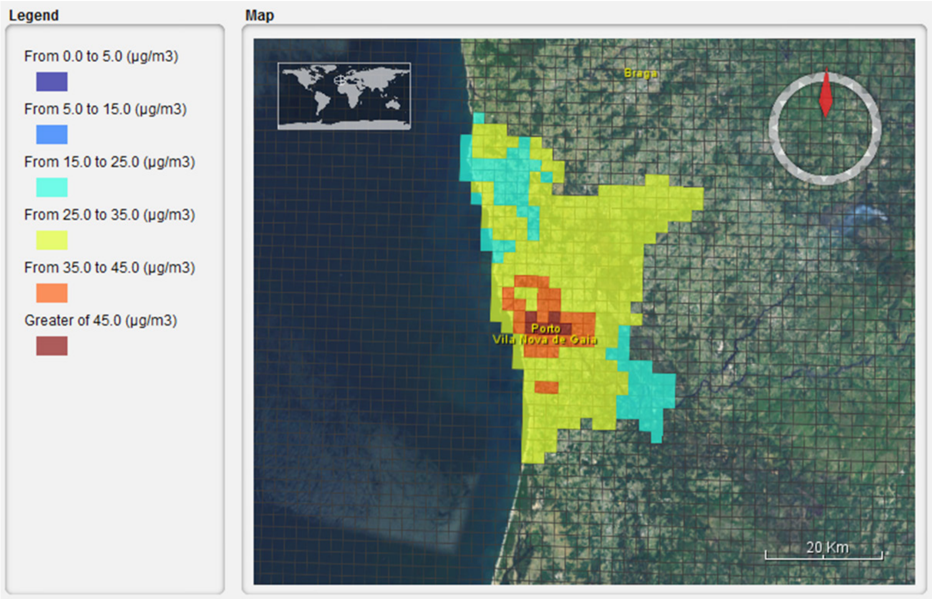


Fig.19: Mean PM10 concentrations resulting in RIAT+ (point C of the Pareto curve).

To learn more about the Brussels Capital Region and Great Porto Area applications, please refer to D4.3 Guidance document evaluation tier 2.

6 Guidance on integrated air quality and health assessment systems

The final guidance document was based on the first draft version further refined in a number of iterations and discussed during the technical meetings. This final document is also based on the numerous insights obtained through the evaluation of existing (AQPs) and the two real world applications that were performed during the project, using a comprehensive IAM approach. It can be used by all stakeholders and presents how different elements of an IAM methodology or system should be addressed and how an IAM can be set up.

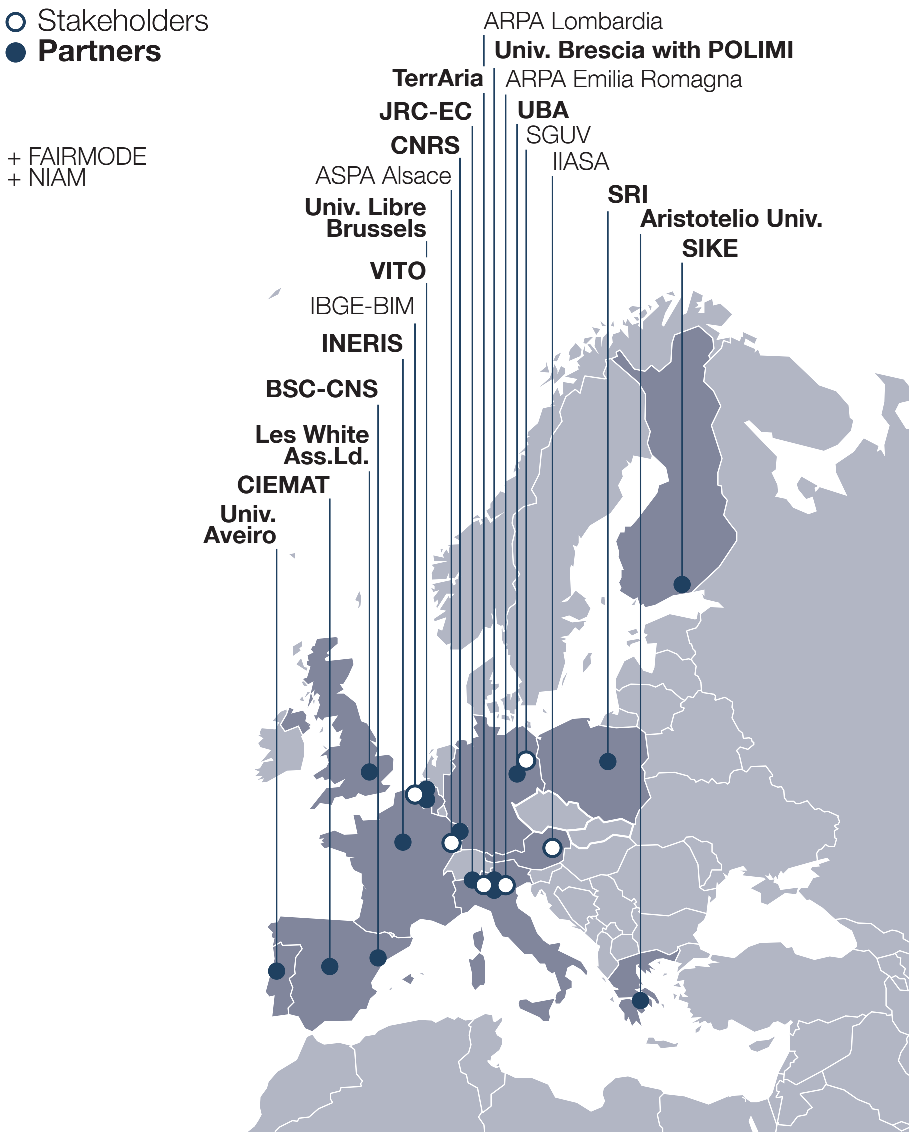
An important outcome of the project is the confirmation that there is no single, 'one size fits all' solution, as an IAM has to take into account the available data, regional/local specificity, financial means and the actual purpose of the assessment. The project's guide to IAM development indeed allows for different levels of complexity with which the blocks in the DPSIR definition can be elaborated. These levels can relate to the spatial and temporal resolution, to the extent to which uncertainty is accounted for and to whether different scales ranging from the European to the local scale are considered and integrated. For the choice of the abatement measures in the response block, levels were identified based on the procedure which is used to identify these measures. An overview of these different levels and their main characteristics for the different blocks is given directly in the document.

It is pointed out that the following aspects should be carefully addressed when setting up an IAM:

- The biggest issue to care when implementing a comprehensive IAM is, as in the case of standard air quality modelling applications – the quality of input data on local emissions and the cost and effectiveness of possible abatement measures. Emissions are still seen as the critical and most uncertain element in the IAM. When local data are lacking, one can still rely on existing European inventories and databases with data on abatement measures such as EMEP and GAINS, keeping in mind the uncertainty of such data for the region of interest and the implications for the results obtained using the IAM. The availability of detailed data is also one of the major constraints for the selection of the level of complexity used for each block of the IAM.
- The most uncertain activity, and so also emission source, relevant to local air quality with respect to PM was found to be the residential combustion of wood or, in the case of Central/Eastern European countries, of coal and coal substitutes.
- As meteorological conditions - which vary in time - significantly influence air quality, an important topic is the choice of a representative meteorology for the assessment of the efficiency of the abatement measures planned.
- In current air quality planning, performance evaluation is still very limited. Adoption of the general methodology developed within FAIRMODE would certainly be beneficial.
- HIA is clearly still a subject unfamiliar to most technicians involved in developing air quality plans. An IAM that evaluates an abatement strategy only based on the compliance to limit concentration values fixed by legislation, cannot be considered as to compute the impact on health. APPRAISAL guidance document recommends, as necessary step of a IAM study, the evaluation of the impact on health.
- For health impact assessment, there is currently not enough scientific evidence to warrant the use of threshold values below which health effects are negligible.
- Many of the local abatement measures are non-technical (not end-of-pipe) or efficiency measures for which it is difficult to estimate the costs, particularly, because they impact many other sectors besides air quality. Further research to address this would be necessary.
- In practice, the list of options for abatement measures is restricted not only by what is technically and economically feasible, but possibly even more by political and social acceptance. IAM tools should therefore be extended to allow their users to take into account the implications of political and social acceptance at an early stage of the decision process.
- If an IAM system uses source-receptor relationships (e.g., artificial neural networks, linear regression…) to relate emission changes to concentration changes, such relationships should be carefully tested to ensure that they not only correctly replicate the current concentration values obtained by more complex modelling tools, but also capture all the possible concentration changes calculated by the model for which they are a surrogate.
- One should always keep in mind that more complexity is not always better. In this sense, it is more advisable to adopt a simple but transparent IAM where limitations and assumptions are clear than to implement a comprehensive IAM using highly uncertain and maybe even flawed input data.

To learn more about the Final Guidance document, please refer to D4.4 Final version of the Guidance document.

7 Partners & Stakeholders



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