

Chapter 3

Current European AQ Planning at Regional and Local Scale

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3.1 Introduction

This chapter provides a review, derived from the extended survey conducted within the APPRAISAL project, of the integrated assessment methodologies used in different countries to design air quality plans and to estimate the effects of emission abatement policy options on human health.

The final purpose of this review is to foster the dissemination of knowledge on integrated assessment for air quality planning at regional and local scales, and to

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provide policy makers and regulatory bodies across EU member states with a broader understanding of the underlying scientific concepts.

The survey allowed to populate a structured database (<http://www.appraisal-fp7.eu>), designed in collaboration with experts involved in the design of Air Quality Plans (AQP), aimed at identifying methodologies adopted in Europe to define AQ plans. The following topics were considered: (1) synergies among national, regional and local approaches, including emission abatement policies; (2) air quality assessment, including modelling and measurements; (3) health impact assessment approaches; (4) source apportionment; and (5) uncertainty and robustness, including Quality Assurance/Quality Control (QA/QC).

The APPRAISAL database currently totals 59 contributions from 13 MS, fully checked for consistency and completeness. Though probably not being completely representative from the statistical viewpoint, they provide a good prospect on the current EU situation and clearly indicates some of the actual trends. Two groups of respondents were distinguished to refine the analysis: the stakeholders involved in the design of “air quality plans” (AQP) and groups involved in “research projects” (RP). While AQP, which represent 58 % of the database information coming from 10 MS, is representative of current practices in the decision process, RP (31 % of

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the database contributions, coming from 7 MS) are usually assumed to be based on the most updated methods. Seven studies stored in the database are classified as ‘Other’. Countries represent the study area in 20 % of cases, regions in 25 % and agglomeration or urban level in 30 % of the cases (the remaining percentage refers to other types of focus which could not be classified in these categories). The current status (September 2015) of the databases is presented in Fig. 3.1 where the contributions are shown per country. Local planning authorities (e.g. municipality) represent 25 % of the respondents whereas universities, research institutions, environmental agencies represent each, about 20 %.

In order to characterize the operational use of AQ assessment and planning modelling tools, the APPRAISAL questionnaire includes the following information for each air quality plan: the overall purpose of the activity (air quality assessment, mitigation and planning, source apportionment), the strategy followed (scenario analysis, cost-benefit, cost-effectiveness, multi-objective approach), the source/receptors (methodology, spatial and temporal resolutions, indicators), the modelling approaches (models, processes, spatial and temporal resolutions, nesting), the input data including emissions (inventory approach, split into activity sectors, resolution, etc.), meteorology (models, processes, time and spatial resolution), initial and boundary conditions. Also the use of measurements was investigated (measurements method, type and location of the monitoring stations, temporal resolution, transformation of the data if any).

In the following section, the DPSIR blocks used to describe the plans are analyzed. AQ plan scales and uncertainty, two common and transversal topics, are discussed in the second section, while a methodology to classify the Air Quality Plans in Europe is proposed in the last part of the chapter.

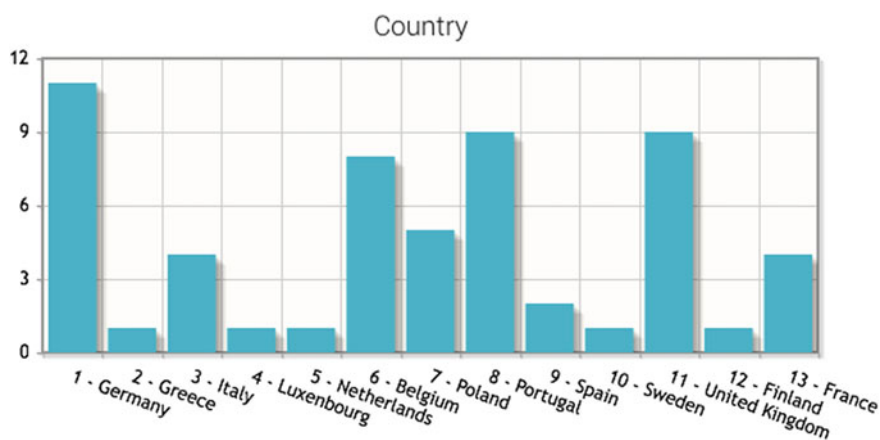


Fig. 3.1 Screenshot of the query to the online APPRAISAL database relative to the contributions in terms of countries

3.2 Actual Use of IA Components

This section focuses on the methodologies developed in recent years and implemented in the AQP and RP reported in the APPRAISAL database for each DPSIR component.

The database collects both AQPs and RPs. The rationale for this is that whilst AQPs are a consequence of air quality assessment and limit value exceedances actually detected, RPs might have a broader scope since there are no such formal constraints that have to be obeyed and so they may go beyond what is current practice.

3.2.1 Drivers and Pressures

The function of the DRIVERS block is to model the development of the driving activities (i.e. road traffic, off-road traffic and machinery, residential combustion, centralized energy production/industry, agriculture) over time. It is the direct and basic input to the PRESSURES block in the form of, e.g., road traffic kilometres driven, residential heating fuel consumption etc. The PRESSURE block holds the information on the quantity of pollutants emitted into the atmosphere from all the different sources. The emission of a pollutant can be measured or estimated. These are generally calculated as the product of the activity of this emitter and an emission factor, that is the quantity of pollutant emitted per unit of activity. There are also pressures affecting air pollution concentrations that are related to changes in urban structures (new buildings, roads, trees etc.) that can modify the dispersion of the pollutants.

At the moment, it is very complex to incorporate structural changes in a IAM scheme; so they have not been included in the current study.

Even though it is well known that emission inventories do not represent the actual contribution of sources to atmospheric pollution, many local governments use them directly as source identification tools for the design of abatement measures.

From the APPRAISAL database, it emerges that, in general, the scale and resolution of the emission inventory is in good agreement with the scale and purpose of the study (and model). Studies at the national level generally use emissions from national official inventories while studies that focus on the regional or urban (1–5 km), to local (up to 1 km) and street level scale use project specific emission data. In principle, the resolution of the modelling system should be in line with the resolution of the emission inventory but among the 59 questionnaires, 5 applications seemed to use an emission resolution not adapted to the geographical zone for which the study was intended.

Emissions are classified according to their sources. In the APPRAISAL questionnaire, the Selected Nomenclature for reporting of Air Pollutants (CORINAIR SNAP code) is used. This nomenclature was originally developed by the EEA's

European Topic Centre on Air Emissions (ETC/AE) and is common for emission inventories used as model inputs. In this nomenclature, sources are classified in three levels of details:

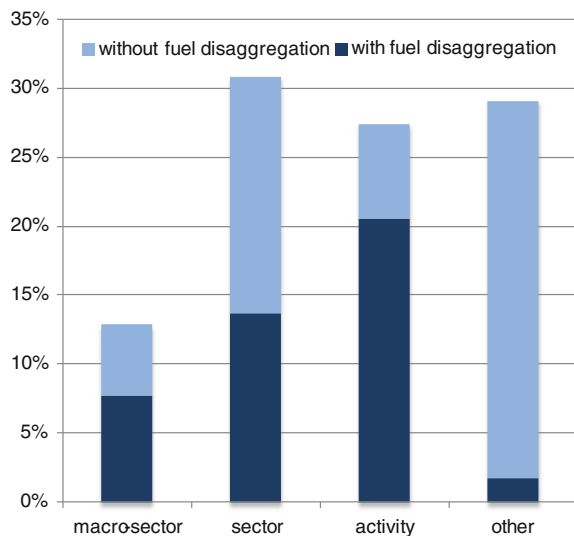
- Macro-sectors (SNAP level 1, e.g. “energy transformation sector”); it exists 11 different macro-sectors,
- Sectors activity (SNAP level 2, e.g.” public power”) which are a disaggregation of macro-sectors level,
- Activity levels (SNAP level 3, e.g. “combustion plants ≥ 300 MW (boilers)”) which are a further disaggregation of sectors levels.

For each disaggregation level, more details can be added with definition of fuel specification.

Emission inventories with disaggregation to the sector activity and activity levels are most commonly used (Fig. 3.2). Together they cover one half of the questionnaires. Only 10 % of the studies use a macro-sector disaggregation level. A combination of different levels of disaggregation is often used. Fuels specification is used in more than 50 % of the cases. According to the database, there is no relation between the category disaggregation level and the spatial scale of the study.

Concerning the approach used to set up the inventory, a combined approach using both a bottom-up and top down methodology is most common (58 %). This is not surprising as official national and regional inventories are usually constructed using this complementary approach. A top-down approach alone is used in few cases (8 %), while bottom-up approaches alone represent about 22 % of the cases. For the studies using a bottom-up approach, a majority of them have created a project specific emission inventory over a small area. Urban, local and street level studies represent more than 80 % of the studies using a bottom-up approach.

Fig. 3.2 Disaggregation level used in AQP and RP as reported in the APPRAISAL database



3.2.2 *State*

STATE, in the DPSIR approach, is defined as the environmental conditions of a natural system; in the current case, it represents the concentrations of targeted pollutant in atmosphere.

Air quality state can be described as gridded concentrations over the studied area, or as local concentrations at receptor sites. The AQ state has also a temporal dimension, considering that a pollutant can be monitored or modelled with different temporal resolutions.

A large variety of chemical transport models exist, implementing from simpler to more complex approaches and covering different scales, going from global/regional scales to urban and street level scales. State can be also described by source-/receptor models that directly link the emission to an AQ index calculated from targeted pollutant concentrations.

The APPRAISAL database indicates that national, regional and local authorities use a large variety of air quality models to design their AQPs and assess their impacts on air quality.

If we analyze the responses in terms of model types, Eulerian models are the most used with 32 and 59 % for AQP and RP, respectively (Fig. 3.3) which is not surprising since Eulerian modelling can be applied from the regional down to the local scale. In the case of AQPs, Gaussian plume and puff approaches represent about 20 %, in total while in RPs they represent only 6 % of use cases.

In total 33 different model names are mentioned. The most popular are the Eulerian models CAMx with 8 citations and CHIMERE with 11. CALPUFF is cited 6 times in the sample, but also traffic models are included (IMMIS, PROKAS and OSPM) with more than 5 citations. The many different models that are used today are a clear indication that no standard reference model currently exists. It is also interesting to note that in many AQPs, more than one model is used: three or more are used in 33 % of the cases, while about 27 % of the AQPs refer the use of two models and about 44 % of a single model. Regarding research projects, a unique model is used in 44 % of the cases, two in 17 % and three or more in 39 % of the cases sampled. In these projects, CHIMERE is the most often used chemical transport model. It is important to stress however that in one reported case, no air quality model is used. Information about modelling methodologies is in general available since approximately 70 and 85 % of the models referred to by the APPRAISAL database contributors are included in the EEA Model Documentation System, for AQPs and RPs, respectively.

It is interesting to note that street canyon models are not so frequently used (12 % in AQP). This is probably due to the lack of proper input data at the adequate resolution, or to the limited spatial coverage these models generally have. One can also note that CFD models are rarely used in Europe even in research projects, probably due to their current limitation to idealized, stationary and very fine scale applications. Calculation of annual statistics therefore still remains a very

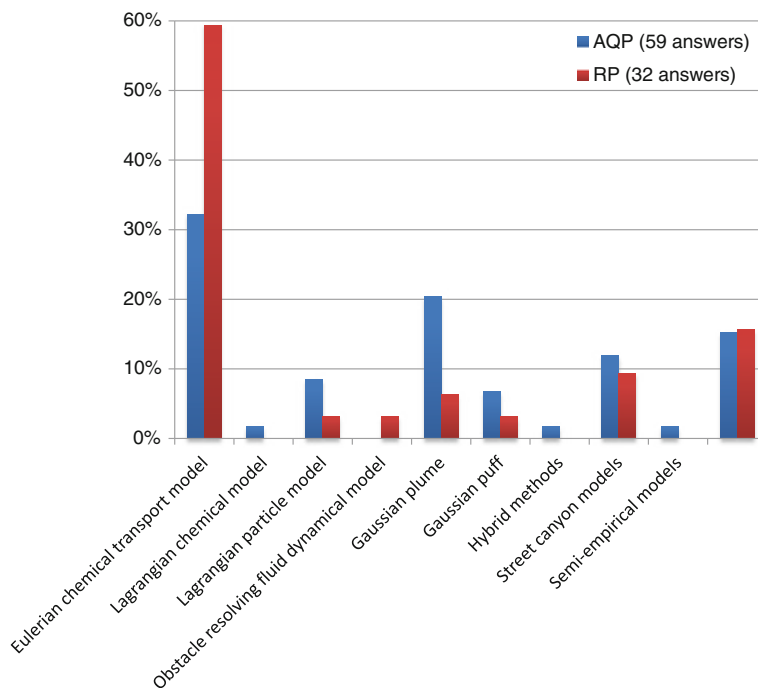


Fig. 3.3 Model types as used in AQP (blue) and RP (red)

challenging task for this type of models as shown in Parra et al. (2010), who attempted to estimate the concentration evolution from a series of steady state simulations for long time periods. With increasing computer power their importance might however increase in the future as they could progressively take on the role of the current generation of empirical or Gaussian models for local and street level modelling. The “hybrid” models in Fig. 3.4 refer to the application of a method based on numerical and statistical models.

The spatial scale of the AQ models was analyzed. Since at least 3–4 grid points are needed to resolve a flow structure, models with a resolution coarser than 3 km were classified as “regional scale” (5–50 km) while models with a resolution coarser than 500 m were considered as “urban scale” (1–5 km). The “local scale” (up to 1 km) models were those with a resolution between 500 and 10 m and finally “street scale” models are those with a resolution in the order of meters.

In total, the 59 air quality studies with up to 3 AQ models each, lead to a total of 177 different model setups (Fig. 3.4). Among RP studies, 40 % of AQ models were for the regional scale, 30 % at the urban scale, 13 % at the local scale, and 11 % at street scale. For the remaining 6 % model setups no information was given on resolution or range of scales.

Although the majority of the AQP applications regard regional and urban scales, exceedances of air quality limit values occur at traffic-induced hot spots to a large

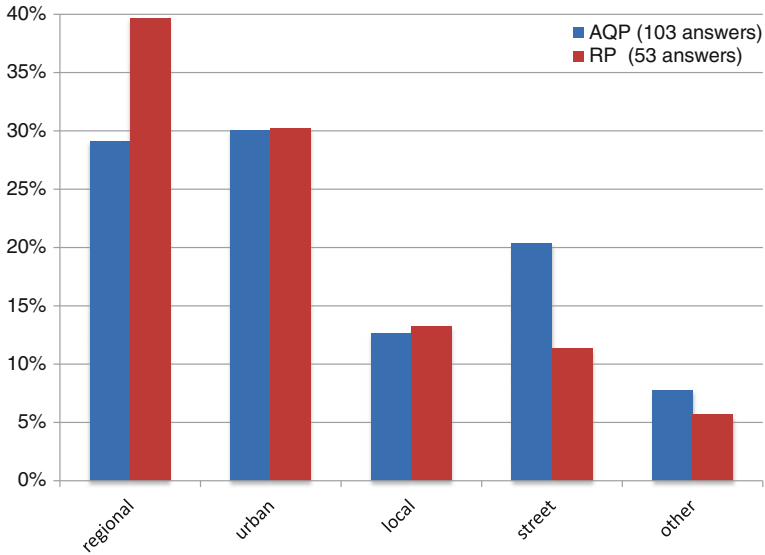


Fig. 3.4 Main scope for air quality assessment with respect to spatial scale for AQP (blue) and RP (red). Regional ranges from 10 to 50 km; urban from 1 to 5 km and local below 1 km

extent. Consequently, some of the AQPs adopt street level (20 %) and/or local scale modelling (13 %).

Only 12 % of the AQPs report on the use of highly resolved street canyon models. Even if alternatives to explicit street canyon modelling exist and consist in extending regional/local scale model capabilities to account for sub-grid scale effects, in the majority of the cases (more than 80 %) reported in the APPRAISAL survey, no additional model feature is included in the modelling approach to capture street effects, although these are keys to reproduce the concentrations and frequent exceedances at street locations.

More complex IAM methodologies, in which optimization algorithms are implemented, cannot embed full 3D deterministic multi-phase modelling systems for describing the nonlinear dynamics linking precursor emissions to air pollutant concentrations because of their computational requirements. They therefore rely on simplified relationships for describing the link between emissions and air quality, which are called source/receptor models (S/R).

In terms of the Design of Experiment required to identify these S/R, the majority of approaches apply the OaT (Once at a Time) approach (11 studies), in which one varies one emission at a time, and measures the variation in the concentration or effects at one site. In few cases “factor analysis” (2 studies) in which the impact of an emission and its interactions with another factor are considered simultaneously or a “statistical based” approach (3 studies), based on global sensitivity indexes, are used. The number of scenarios considered in the Design of Experiment is more than 50 (Fig. 3.5) only in the case of more complex research projects. The number of

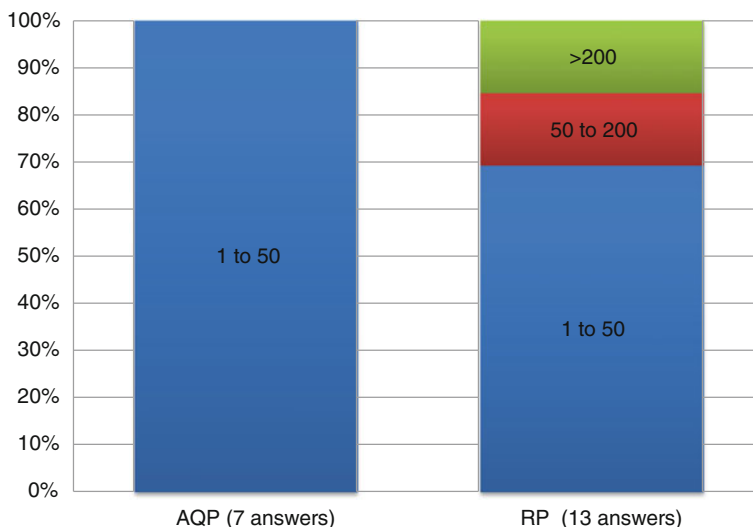


Fig. 3.5 Number of AQ modelling simulations (runs) used to identify S/R considered for AQPs and RPs

meteorological years considered is limited to a single year in 70 % of both the AQPs and RPs.

3.2.3 Impact

The block on IMPACT describes the consequences of modifications of environmental conditions related to the STATE of air quality, being either beneficial or adverse.

Only 34 studies included the assessment of Health Impact (HI): 21 Air Quality Action Plans, 11 Research Projects and 2 other activities. But, only 5 questionnaires have specifically expressed HIA as the main objective, respectively 4 for research projects and 1 for another activity. This reflects the fact that Integrated Assessment Models do not all necessarily include the health aspects and the AQPs are designed not with the main scope to assess HI.

The most common approaches used for HIA are the predictive approach (11 times) and the retrospective approach (7 times), while the counterfactual approach had been answered 2 times and other methods 14 times.

Among all the activities, 11 (6 of which were AQPs) HIAs focused on both short-time and long-term exposure to pollutants, 10 focused on long term exposure and 1 on short-term exposure.

The most frequent air pollutants included in the health impact assessments are related to the urban pollutants, such as particles (PM₁₀ and PM_{2.5}) followed by

ozone (O₃) and nitrogen oxides (NO_x). Other pollutants such heavy metals (arsenic, nickel, cadmium and lead) are mainly considered in RPs (Figs. 3.6 and 3.7).

The exposure indicators, for both AQPs and RPs, were estimated based on intake fraction (emissions), air quality monitored data and air quality modelled data (Figs. 3.8 and 3.9). Additionally, exposure indicators based on individual exposure data were also used in the scope of one research project.

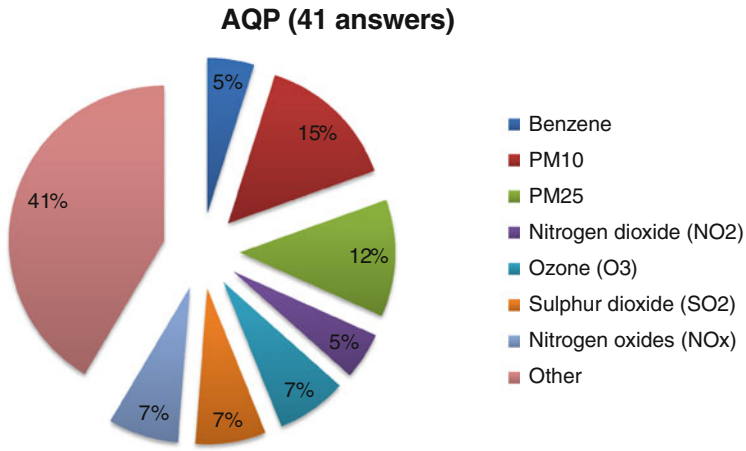


Fig. 3.6 Air pollutants assessed in HIA for AQPs

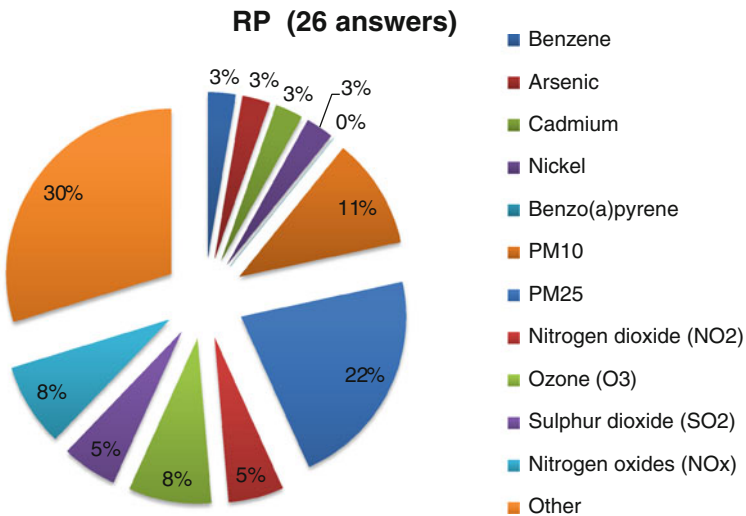


Fig. 3.7 Air pollutants assessed in HIA for RPs

AQP (10 answers)

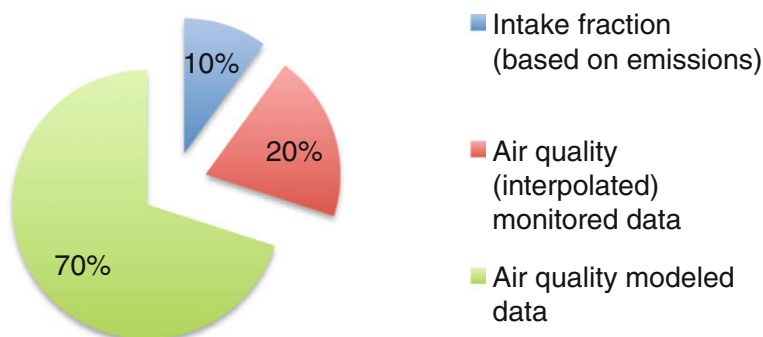


Fig. 3.8 Distribution of the calculation for exposure indicators in AQPs

RP (12 answers)

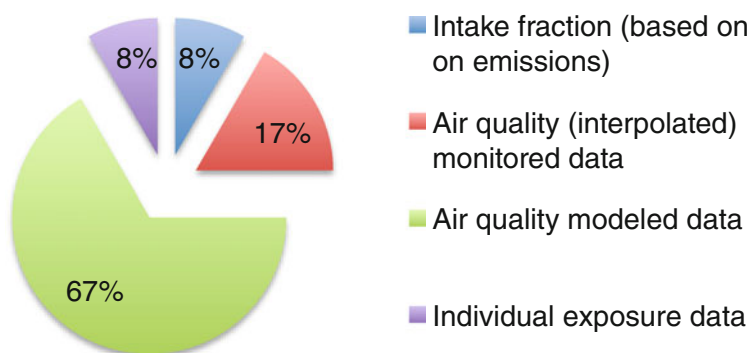


Fig. 3.9 Distribution of the calculation for exposure indicators in RPs

The spatial resolution considered for population and concentration estimation is usually the same. The temporal resolution used for concentration data differs between the two types of activities: 5 of the assessed AQPs use daily temporal resolution, 2 hourly and 2 annual. Six RPs utilize daily resolution, 2 are based on annual data and 2 on hourly data.

In the case where monitored concentration levels were used for the assessment of exposure, 2 studies processed data recorded at traffic station sites, 5 studies used data from urban background stations, 4 from sub-urban background sites and only one from rural background station.

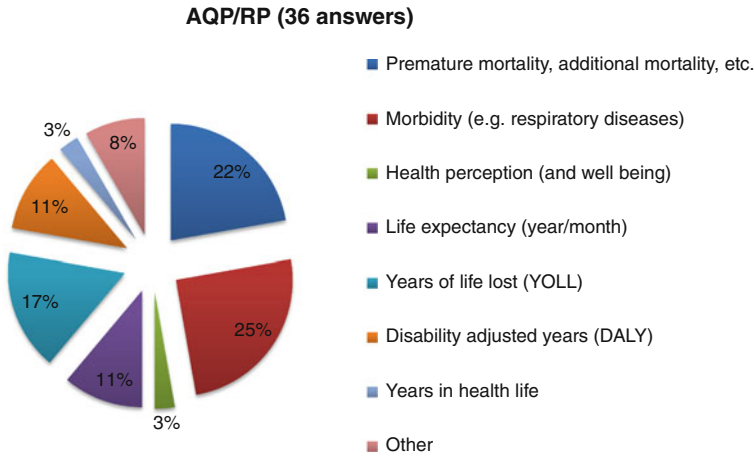


Fig. 3.10 Health indicators in the AQPs and RPs

Approximately 20 % of the AQPs that undertook a HIA considered a sub-group based on the age of the population. RPs also focused on the sub-groups gender and on other variables, beside age.

The considered HI indicators were related to premature mortality and morbidity (Fig. 3.10). Only two studies did not consider mortality impact.

3.2.4 Responses

This block represents the set of techniques/approaches that can be used to take decisions on emission reduction measures to be applied or on changes in activity levels (drivers). The DPSIR framework helps to visualize the difference between the possible approaches (Fig. 3.11).

All the items stored in the database implemented modelling systems to define mitigation measures and planning (Fig. 3.12). RPs are more oriented than AQPs to planning and source apportionment.

The Scenario analysis is the most frequently used methodology (Fig. 3.13), both in AQPs (more than 60 % of the cases) and RPs (roughly 30 % of the cases) implementation.

In the scenario analysis approach, source-apportionment can be used to identify the main emission sources that contribute to air pollution concentrations. Emission reduction measures are selected and/or established taking into consideration synergies at different scales. The effect of these measures on the air quality improvement is quantified using air quality modelling systems and afterwards translated to

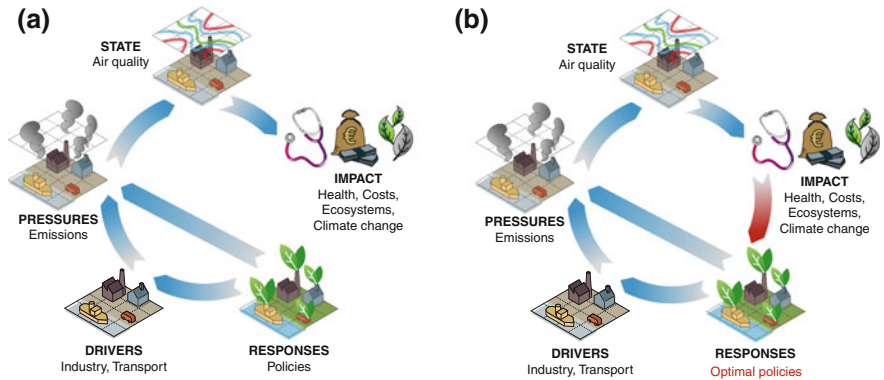


Fig. 3.11 IAM approaches within the DPSIR scheme: scenario analysis (left) and optimization approach (right)

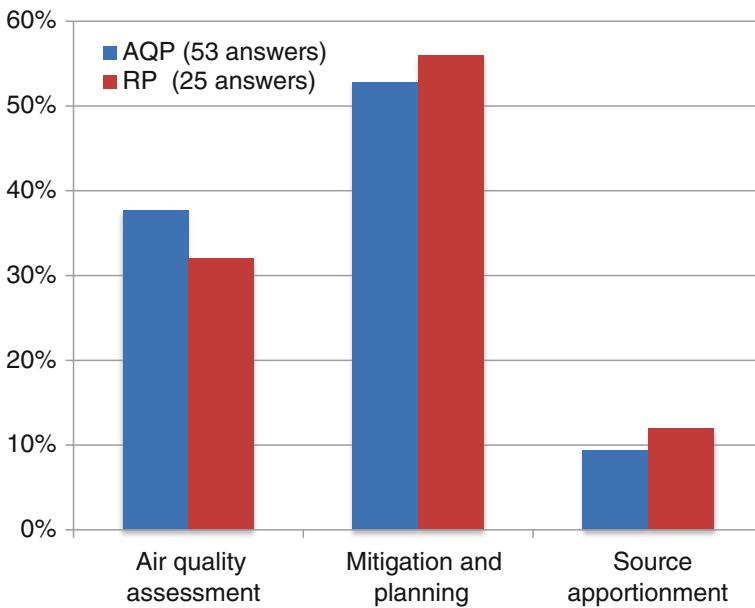


Fig. 3.12 Modelling purpose of AQPs (blue) and RPs (red)

health effects. Moreover source apportionment analysis within the framework of IA studies is applied to comply with the obligations deriving from the AQD, to design air quality plans or action plans, to identify the causes of exceedances, and to identify the transboundary pollution contribution from other countries (Fig. 3.14).

Receptor models and dispersion models (Lagrangian models, Eulerian models and Gaussian models) are used for the identification of sources. Objective

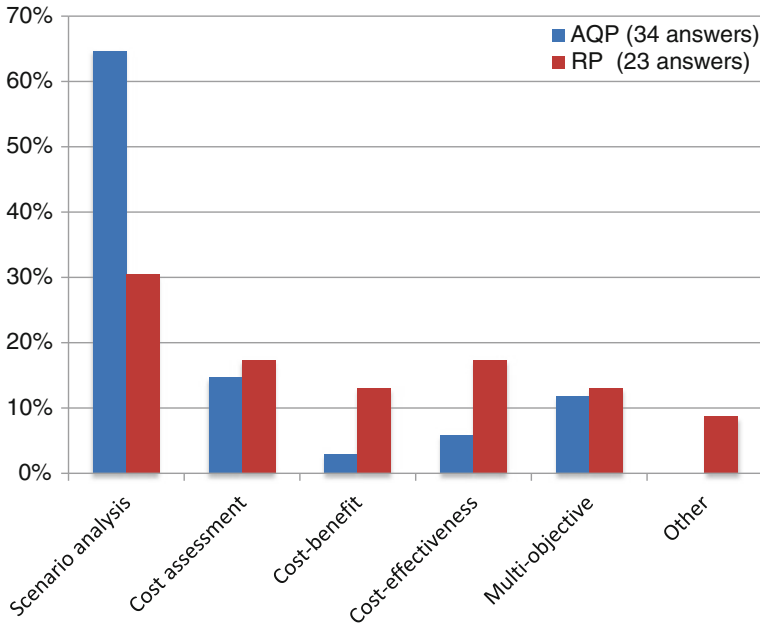


Fig. 3.13 IA methodologies in AQPs (blue) and RPs (red)

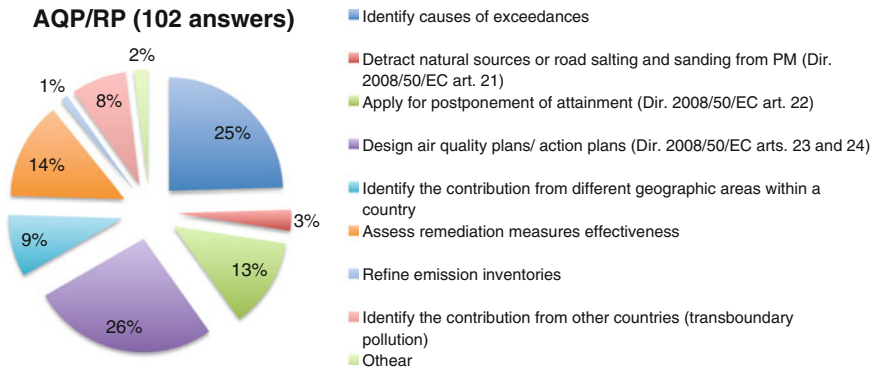


Fig. 3.14 Source apportionment purposes

estimation and inverse models are used marginally for this task (Fig. 3.15). It is worth to mention that one third of the answers report the combined use of more than one methodology.

The most frequent activity sectors/source categories identified in the studies are combustion in the energy sector and road transport (more than 70 % of the studies), followed by combustion in industry, non-industrial combustion and agriculture. Interestingly, many of the studies (40 %) focus only on one single activity

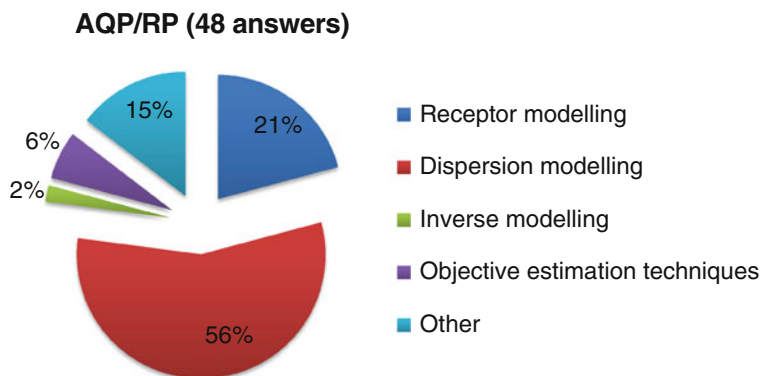


Fig. 3.15 Methodologies used for source apportionment

sector/source category. The frequency of such categories reflects the most commonly encountered pollution sources. Nevertheless, this is also influenced by the availability of source characterization studies and the existence of mandatory emission registers.

The most important pollutants considered in source apportionment studies are PM₁₀ (84 %) and nitrogen dioxide (63 %) followed by two pollutants associated to them: PM_{2.5} (63 %) and nitrogen oxides (28 %), respectively. All the other pollutants are treated in less than 10 % of the studies.

The great majority of the studies focus on the city level (35 %) while local (lower than city) and regional scales represent a 32 and 22 % respectively. The country scale is marginally assessed (7 %).

The types of input data strongly depend on the adopted methodology. Monitoring networks and emission inventories are the most frequent sources of information (20 % each). Meteorological fields are input in 36 % of the answers while dedicated field campaigns represent the 16 %.

In the optimization approach, the emission reduction measures are selected by an optimization algorithm assessing their impact on air quality, health exposure, and implementation costs. Such optimization algorithms requires thousands of air quality assessments; in these cases, AQ systems cannot directly be used because of the computing time demand, so they provide tens to hundreds simulations processed to identify ‘simple’ emissions-AQ links (source/receptor relationships).

IAM approaches based on cost-benefit, cost-effectiveness or on multi-objective (i.e. optimization) approaches are used more often in research projects (61 %) than in AQPs (35 %). One explanation for this low proportion in the AQPs might be the fact that optimization approaches generally require extensive work to derive relationships to link emissions to air quality (source/receptor relationships) and to collect data related to emission reduction measures and costs and to externalities. Indeed these approaches cannot embed full 3D deterministic multi-phase modelling systems because of their prohibitive computational requirements.

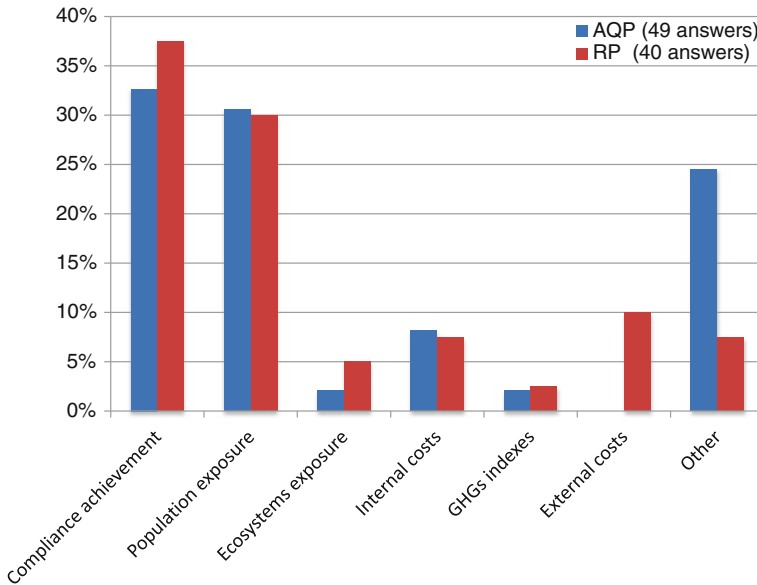


Fig. 3.16 Main indicators on which IAM tools focus

It is also interesting to assess which priorities were identified when designing air quality plans and running research activities. The reported priorities are focused on compliance achievement and population exposure followed by emission reduction costs (internal costs) and costs mainly related to the negative impact of air pollution on human health (external costs) (Fig. 3.16).

3.2.5 Scale and Resolution Issues

The synergies among national, regional and local approaches, including emission abatement policies, were analysed for the following aspects:

1. Contribution to decision level: 37 studies support the decision at the regional scale, 11 at the national scale and 31 at the local scale.
2. Emission sectors addressed with the AQ mitigation measures: Fig. 3.17 highlights the significance of SNAP 7 (Road traffic) and SNAP 2 (Non-industrial combustion) and the low involvement of SNAP 10 (agriculture) in defining policies. The traffic related emissions (SNAP 7, 94 %) were the focus of most AQPs with less prominent roles for non-industrial combustion (SNAP 2, 68 %). This is of course related to the pollutants targeted: most plans target nitrogen oxides for which traffic and combustion in general is the main source. For the

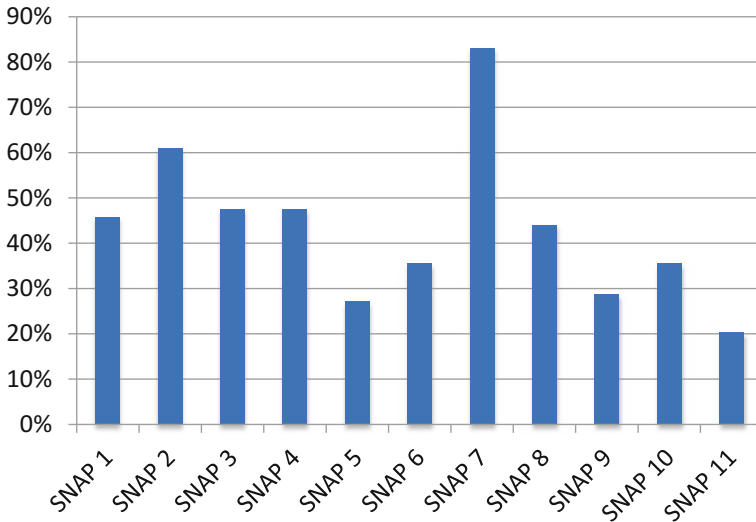


Fig. 3.17 Analysis of SNAP (SNAP1-combustion in energy and transformation industries; SNAP2-non-industrial combustion plants; SNAP3-combustion in manufacturing industry; SNAP4-production processes; SNAP5-extraction and distribution of fossil fuels and geothermal energy; SNAP6-solvent and other product use; SNAP7-road transport; SNAP8-other mobile sources and machinery; SNAP9-waste treatment and disposal; SNAP10-agriculture; SNAP11-other sources and sinks) sectors being addressed by air pollution measures

RPs, the attention to the different sectors is more equilibrated albeit also in this case SNAP 7 remains the most important sector.

3. Type of emission reduction measures: the number of non-technical and technical measures considered is very similar (41 and 39 % respectively).

3.2.6 Sensitivity and Uncertainty

Understanding the factors that contribute to the uncertainty in IA studies is quite complex. Out of the APPRAISAL database, 28 studies included responses to the topic on “uncertainty and robustness”. The responses reported the current practise in quality control procedures when applying IAM for air quality related studies and AQPs. Out of these 28 responses, 14 were regarding to AQPs (41 % of the total AQPs) while 11 were RPs (61 % of RPs) and 3 represented other purposes.

In particular, the majority of model users rely on the operational evaluation technique (comparison with measurements) to assess the quality of the model results both in AQPs and RPs (Fig. 3.18). The other evaluation methods were also

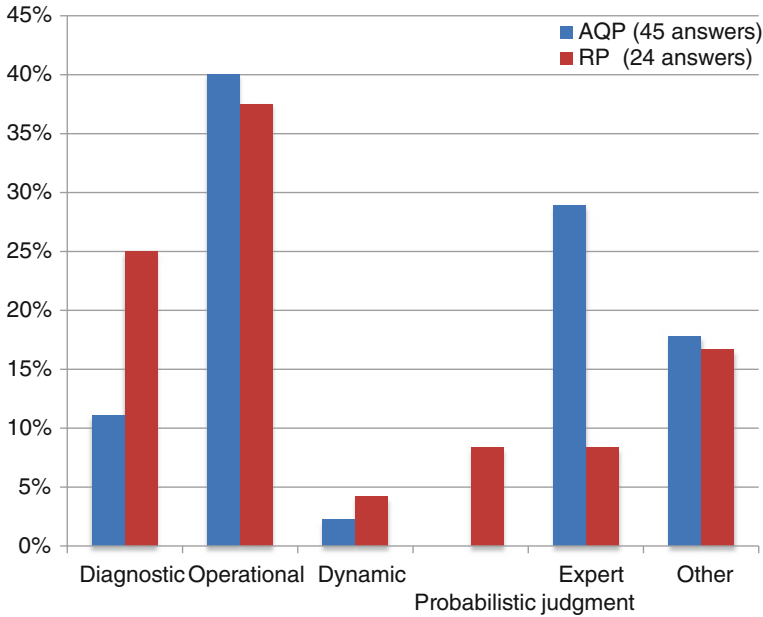


Fig. 3.18 Overview of evaluation methodologies used for the assessment of AQPs and RPs

represented in the returned questionnaires, although not so commonly applied. In the case of RPs, the percentage of responses indicating the use of a probabilistic or diagnostic method increases, whereas the number relying on expert judgement is relatively low. It can be therefore concluded, that a more comprehensive model evaluation process is performed in European member states in the frame of RPs than for AQP, with the operational evaluation dominating but complemented by other techniques. This can be attributed to the fact that these additional evaluation techniques require intensive personnel, infrastructure and time resources.

AQ modelling is the IAM component for which uncertainty analysis is most commonly considered in the questionnaire responses, both in the case of AQPs as well as for RPs (Fig. 3.19).

Nine of the responses reported that uncertainty estimation was performed for AQ modelling, one for source apportionment and 3 for health impact assessment, while uncertainty quantification for the IA system as a whole was represented only in 2 of the responses.

Global uncertainty analysis methods (e.g. Monte Carlo analysis) have been used in more studies compared to local uncertainty analysis methods more significantly, in RPs (Fig. 3.20). In some of the questionnaires, no answer was provided for the methodology used (local or global), particularly in the case of AQPs.

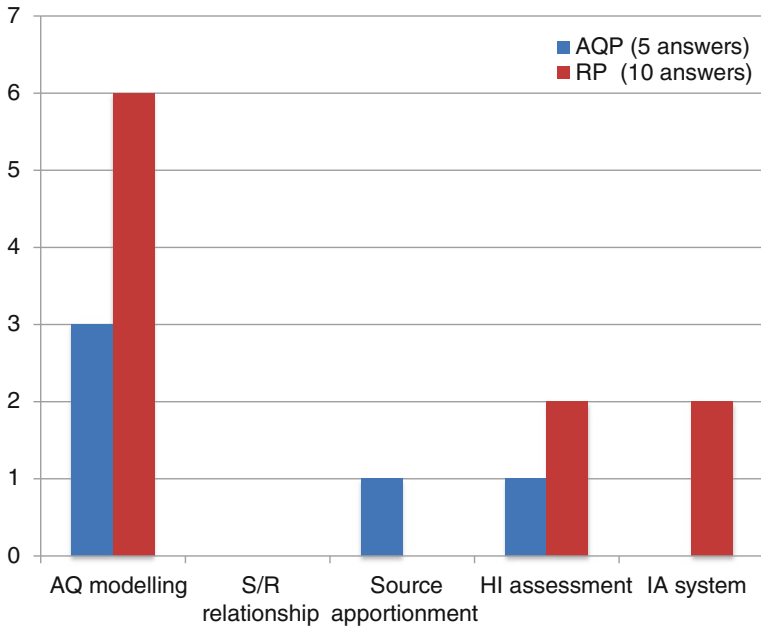


Fig. 3.19 Uncertainty estimation in different IAM components in AQPs and RPs

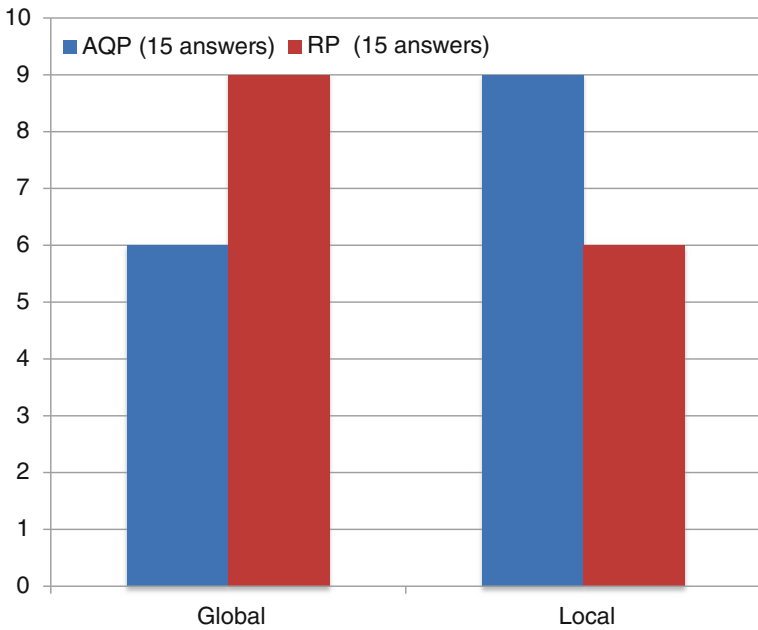


Fig. 3.20 Uncertainty analysis approaches in AQPs and RPs

Variance-based uncertainty estimation methods are the most commonly used among the global uncertainty assessment approaches. However, local uncertainty analysis methods (sensitivity methods, OaT) are also significantly represented in the responses, particularly in the case of RPs (Fig. 3.21).

The following Fig. 3.22 provides information on the AQ modelling elements for which uncertainty estimation was specifically carried out. As expected, model formulation was not one of the priority aspects examined in the case of AQPs; it was however considered in a significant number of RPs. Within AQPs, uncertainties were mostly analysed for meteorology, emissions and boundary conditions. Regarding RPs, it is interesting to note that uncertainties related to boundary conditions received less attention. For both AQPs and RPs, emissions related uncertainties are identified to significantly contribute to the total AQ modelling uncertainties.

In terms of quality control of model results for planning applications, most of the studies assumed that the AQ model is adequate when it behaves correctly for assessment applications (82 %) while in the 18 % of the cases the reliability of the model is based on model intercomparison and ensemble approaches.

It is interesting to note, that no reference technique is adopted so far to check the quality of the models used to quantify the impact of emission reduction scenarios in AQPs.

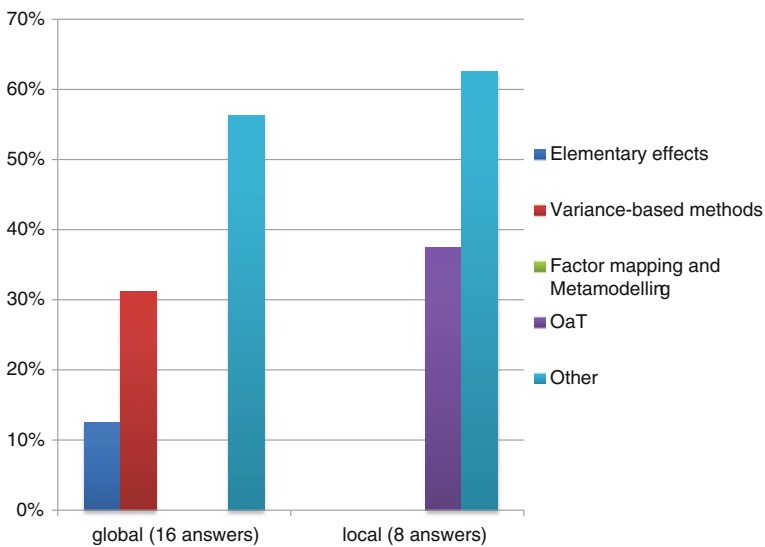


Fig. 3.21 Local and Global analysis methods

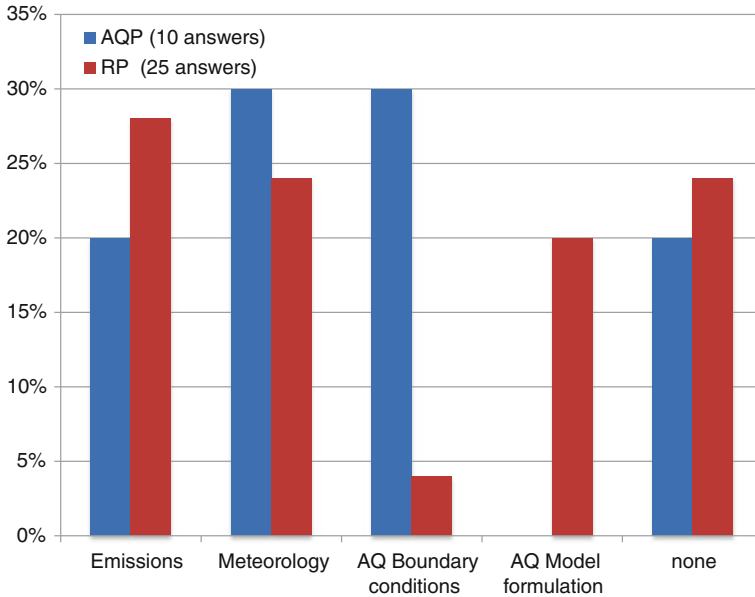


Fig. 3.22 Uncertainty estimation of different components of AQ modelling

3.3 Classifying the AQ Plans in Europe

The questionnaire responses have been classified trying to evaluate the level of detail at which each block of the DPSIR scheme has been treated. Though this classification is qualitative and partially subjective, it may serve a double purpose: within each plan, it highlights where more work has been invested and where, on the contrary, less attention was given; in comparison with other plans, it may indicate how a certain aspect has been dealt with in similar cases.

It must be noted that dealing with an aspect with a higher level of detail does not necessarily mean that the plan is more accurate or efficient in that field. Though the two things are hopefully correlated, there may be cases in which a more detailed approach was not supported by corresponding data or was not balanced with the corresponding costs or benefits.

The analysis of individual AQPs has been summarized using radar charts. This chart graphically represents the level of detail for each of the DPSIR blocks based on the answers to the questionnaire. For each of the five blocks, five levels of detail have been defined: Level 0—impossible to evaluate based on input from questionnaire (the topic is not even mentioned); Level 1—the block is considered in the AQP, but not investigated; Level 2—low level of detail in the implementation; Level 3—medium level of detail; and Level 4—high level of detail.

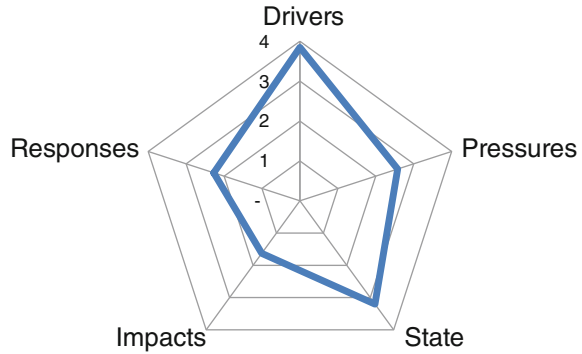
For the Driver block the complexity depends on whether the different levels (national, regional and local) are included as well as potential synergies between these different levels. For Pressure blocks the distinction is based on whether the activities and emissions were derived using a top down or a bottom-up approach or a combination of these two. The level of complexity for the state block (concentration/deposition) is determined by how the state is derived (using a model?) and whether the different scales ranging from the regional to the local scale were considered. Detail in the spatial and temporal resolution for the exposure and population data is what matters for the complexity of the Impact block. For the RESPONSES block, finally, the degree to which an objective, quantitative choice of the abatement measure(s) is made will distinguish a simple from a more complex methodology (Table 3.1).

The radar chart in Fig. 3.23 represents the “average graph” computed considering all the plans available in the database. Some main observations can be

Table 3.1 Levels of complexity distinguished for the different DPSIR blocks

DPSIR block	Level	Description
DRIVERS	1	not implemented
	2	top-down approach, using coarse spatial and temporal allocation schemes
	3	bottom-up approach with generic (i.e. national/aggregated) assumptions
	4	bottom-up approach with specific (i.e. local/detailed) assumptions
PRESSURES	1	not implemented
	2	emissions estimated for rough sectors on a coarse grid using a top-down methodology
	3	combination of bottom-up and top-down methodology
	4	emissions calculated with the finest resolution in space and time available (fine grid), using a bottom-up method and the highest level of detail in the SNAP sectors
STATE	1	not implemented
	2	measurements and geo-statistic interpolation are used
	3	one single deterministic model is used
	4	a downscaling nested models chain is used
IMPACT	1	not implemented
	2	coarse description of exposure provided either by measurement or modelling of AQ (e.g. average mean annual exposure for a city), simple population description
	3	similar to level 1, but with spatial detail in the STATE description
	4	detailed temporal and spatial resolution for exposure and population data
RESPONSE	1	not implemented
	2	expert judgment and scenario analysis
	3	source apportionment and scenario analysis
	4	Optimization

Fig. 3.23 “Average graph” computed considering all air quality plans available in the APPRAISAL database



derived. Most effort was put into quantifying the drivers and the state (concentration) in all the studies that were considered. The degree of detail used to evaluate emissions (PRESSURES) or to determine the consequent actions (RESPONSE) has been generally lower. Only rarely, actual plans and studies try to reach a quantification of the impacts on human health and ecosystems.

Following this approach, some examples of AQP classification are detailed in the next sections.

3.3.1 AQP for Athens

Description of the AQP

Athens AQP was developed as part of a wider effort of the Greek Ministry of Environment, Physical Planning and Public Works to comply to the EU legislation 1996/62/EC regarding ambient air quality levels. In this framework, the Ministry has funded the preparation of development plans for the abatement of air pollution in urban areas in Greece. For the urban area of Athens, the plan was jointly undertaken by two consulting companies, namely ENVECO S.A. and EPPEM, with the official title: “Development of an Operational Plan for the Abatement of Atmospheric Pollution in the City of Athens”.

The city of Athens is located in a basin of approximately 450 km². It is surrounded on three sides by fairly high mountains (Mt. Parnis, Mt. Pendeli, Mt. Hymettus and Mt. Aegaleon), while to the SW it is open to the sea. Industrial activities take place both in the Athens basin and in the neighboring Thriasion plain. The Athens basin is characterized by a high concentration of population (about 40 % of the Greek population), accumulation of industry (about 50 % of the Greek industrial activities) and high motorization (about 50 % of the registered Greek cars). Anthropogenic emissions in conjunction with unfavorable topographical and meteorological conditions are responsible for the high air pollution levels in the area.

The program for the abatement of air pollution in the urban area of Athens was divided into three phases:

Phase 1: This included the collection of emission data from all contributing sources (transport, industry, central heating) and the application of a dispersion model for the reference year 2002, in order to assess the spatial distribution of pollutants, complementarily to the measured concentration data from the monitoring network.

Phase 2: It included the application of an air quality dispersion model for predicting the air pollutant levels for the years 2005, 2008 and 2010.

Phase 3: In this final phase, a Decision Making System was developed in order to evaluate the efficiency of abatement measures in terms of compliance with the EU Directive.

Drivers/Pressures

The main drivers identified included industry, central heating and transport. However, in terms of PM₁₀, an additional source apportionment study was performed which included sources particularly linked to PM₁₀ emissions, such as long-range transport and resuspension.

Within the development of the AQP, the Greek Ministry of Environment funded the compilation of an emission inventory which was compiled for the Greater Athens Area, for the reference year 2002, taking into account emissions from:

1. Stationary air pollution sources like, industry, domestic heating and oil stations,
2. Mobile sources, such as, road traffic and emissions from ship, airplane and train lines.

Pollutants included were CO, NO₂, NO_x, O₃, SO₂, Benzene, PM₁₀ and Pb, for most of which EU legislation sets up specific air quality limit values that had to be met within 2005 and 2010. Regarding stationary air pollution sources, an on-site measurement campaign was undertaken including 1000 industrial units from 48 industrial sectors. An emission factor database adapted for Greece was also prepared. Concerning the emission inventory for road traffic emissions, the CORINAIR methodology (EEA 2013) and the COPERT software (COPERT4 2007) were applied. A detailed bottom-up emission inventory was the result of this effort.

Emission rates for pollutants from transport and industry were derived from the National Emission Inventory (Ministry of Environment), while biogenic emissions were based on existing published results. The emission rates for tire wear, brake wear and road abrasion were calculated based on the CEPMEIP database (<http://www.air.sk/tno/cepmeip/>), while the construction activity was approached from satellite images and traffic resuspension emissions from literature data.

State

In this AQP, both air quality assessment as well as a source apportionment methodology for PM₁₀ were applied.

Regarding the urban air quality assessment, it can be concluded that this was addressed at an advanced complexity level. The Eulerian OFIS urban scale dispersion model (Moussiopoulos and Sahn 2000) was used for the spatial assessment of pollutant levels in the study area and for the development of maps allowing the identification of heavily polluted areas within the study domain. OFIS simulates concentration changes due to the advection of species and chemical reactions in each cell of the computational domain. In order to account for the contribution from local emission sources, the OSPM combined plume and box model (Berkowicz et al. 2008) was used for simulations of air pollution from traffic in urban streets.

The influence of meteorological patterns on PM₁₀ concentrations was analyzed, particularly in regard to long-range PM₁₀ transport from other areas (e.g. the Saharan desert). The contribution of natural sources was assessed using a combined methodology of satellite images, LIDAR measurements, measurements from the national monitoring network and modelling results using the SKIRON/Eta transport and deposition model (Kallos et al. 1997)

Concentrations of pollutants were assessed using a chain of models adapted to different scales from the regional to the local scale. The Eulerian model OFIS takes into account regional background pollutant levels to evaluate the transfer of pollutants towards and away from the urban area. Furthermore, all main chemical transformation mechanisms are represented in the OFIS model, which is a pre-requisite for studying reactive pollutants such as ozone and particles. The OSPM street scale model accounts for increased concentrations at the local (hot-spot) scale due to local emissions. Both models have an appropriate spatial and temporal resolution to realistically describe pollutant dispersion at the scales of interest. Furthermore, both a sensitivity analysis in terms of emissions was conducted (emission reduction scenarios and sensitivity to natural background contributions) as well as an operational model validation against measurement data from the monitoring network. In conclusion: an advanced (Level 3) complexity level was used for concentration assessment.

Impact

The impact of the assessed pollutant concentration levels on health was not specifically addressed in the development of this AQP. This parameter was only indirectly considered, on the basis of exceedances of limit values for the protection of human health, according to the EU Directive.

Response

The simulations were performed for the urban scale as well as for the street scale model for several emission scenarios, for the years 2005, 2008 and 2010, in order to examine compliance with standards.

The results indicated that natural emission sources play a very important role in the calculation of PM concentrations and that their contribution leads to significant increase in the number of current and future exceedances. This could suggest that stricter policies regarding the anthropogenic part of PM emission need to be applied.

A source apportionment study was conducted for PM₁₀. The spatial and temporal distribution of PM₁₀ in the Greater Athens Area was assessed with the use of

the Eulerian photochemical model REMSAD (S.A.I. 1998) and sensitivity simulations were performed with the same modelling tool to identify and quantify source contribution.

An interesting point in the AQP for Athens was that different emission reduction scenarios were evaluated both for the urban scale (using the OFIS model) as well as for particular hot spots due to local traffic emissions (using the OSPM model). In this way it was shown that a further emission reduction is required in order to comply with standards at the local scale (i.e. to reduce number of exceedances), on top of the emission reduction that is necessary to comply with annual limit values.

An optimization procedure was not performed. A thorough Multiple Criteria Analysis using the ELECTRE III method (Roy 1968) was applied in order to identify the most suitable set of abatement measures. Parameters such as the public cost, public acceptance and socio-economic impacts were considered.

The overall plan may thus be represented by the chart in Fig. 3.24.

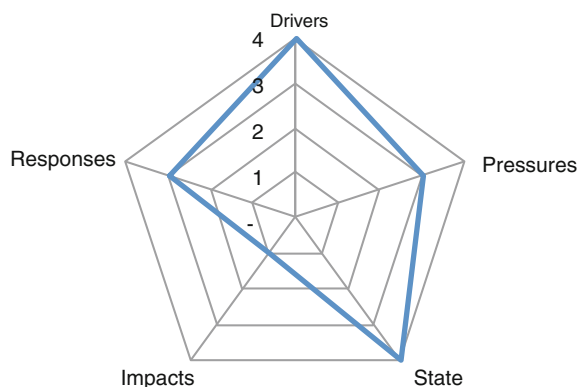
3.3.2 AQP for Emilia Romagna

Description of the AQP

This study was concerned with the Po Valley area and in particular with the Emilia-Romagna region. The aim of the study was mainly to assess the benefits of different sets of measures to improve air quality.

The Emilia-Romagna region is located in the south-western part of the Po Valley basin, a densely populated and heavily industrialized area, where meteorological conditions, due to the low wind intensity, cause the stagnation of the air masses, associated with peak pollution episodes of PM during winter time and high levels of ozone during the summer time. The daily Limit Value (LV) for PM10 was exceeded every year since the enforcement of the EU directive (2008) with a slow decreasing trend of the PM10 annual mean during 2001–2012. The NO₂ annual limit value shows some exceedances mainly at the traffic stations and a decreasing

Fig. 3.24 Radar chart for the AQP of Athens (levels: 4 = high; 3 = medium; 2 = low; 1 = not considered; 0 = N/A)



trend. Ozone health and vegetation protection limit values are systematically exceeded in all the stations with a stationary trend during 2001–2012. The data show also that the annual LV for PM_{2.5} (obligation from 2015) can be exceeded with adverse meteorological conditions.

Drivers/Pressures

Sources of PM and ozone precursors, such as NO_x and VOCs, are mainly related to road transport and combustion. Almost 60–65 % of particulate matter is of secondary origin and a large part of particulate matter and ozone pollution is due to regional background that is influenced by the transport of pollutants from the neighboring regions of the Po Valley basin. NO₂ exceedances are mainly due to local pollution, nevertheless the background concentration of NO_x plays an important role in the production of the secondary aerosols. Ammonia (which is mainly emitted by agriculture) is an important precursor of PM in the Po Valley. Diesel trucks are responsible for a large part of NO_x emissions. Emissions from wood burning and motor vehicles (exhaust and non-exhaust) are the main sources of PM₁₀.

The emission scenarios and the resulting air pollution simulations have been produced on a domain grid covering the Emilia-Romagna region and the surrounding areas, which influence the regional air pollution. The regional inventory of atmospheric emissions has been undertaken by regional environmental agency (ARPA-ER) on behalf of the Emilia-Romagna Region, with reference to the year 2010 using INEMAR (INventario EMissioni in ARia—Air Emission Inventory, <http://www.inemar.eu/xwiki/bin/view/Inemar/WebHome>): a data collection and processing system developed to guide the development of a regional bottom-up atmospheric emission inventory for different activities (heating, road transport, agriculture, industry, etc.). The gridded emissions and proxy variables were prepared using the tool eFESTo, which is part of the NINFA Regional Air Quality Modeling System (Stortini et al. 2007). This input allows the RIAT+ tool (Carnevale et al. 2012) to produce a spatial and seasonal disaggregation of the emissions inside the region.

The regional emission inventory details emissions by macro sector-sector-activity and fuel (inside the Region); the point source emissions also have stack details.

State

To determine NO₂, PM and O₃ related AQIs a nested chain of Eulerian models was used. Air pollution concentrations have been simulated for the year 2010 using NINFA, which includes CHIMERE (version 2008c), a Eulerian chemical transport model. The range of scale was regional and urban; the spatial resolution was 5 km by 5 km, with 40 vertical levels; the output consists of hourly concentrations. The meteorological model used is COSMO17 (<http://www.cosmo-model.org>), with a prognostic approach. The background contribution was determined as hourly concentrations using the Prev'air model (<http://www.prevoir.org/en/modele.php>). The concentrations due to the local traffic/industry emissions were then further refined to street level.

Emission data (for NO_x, VOC, NH₃, PM₁₀, PM_{2.5}, SO₂) and AQI computed values (mean PM₁₀, mean PM_{2.5}, AOT40, SOMO35, mean NO₂, mean MAX8H O₃) have been then used to train the Artificial Neural Networks (ANNs), which describe the relationship between emissions of the precursors and the AQI for each temporal period (year, winter and summer). The results confirmed that the neural network surrogate model is capable of reproducing the non-linear relationship between emissions and precursors.

To train the ANNs, 12 emission scenarios on the Emilia-Romagna domain were designed and used.

Impact

For the health impact assessment, the high-resolution concentration maps were combined with a detailed population map. The approach used was retrospective. The health impact relationship used dealt with the reference values associated to the relative risks, without thresholds. Population data used for the health impact functions originated from a cohort study. The air pollutants used in the estimation were: PM_{2.5}, Arsenic, Cadmium, Nickel and other. The exposure indicators were calculated based on interpolated monitored data and modeled values. For population, the same spatial and temporal resolution of concentration were used. The indicator used was the morbidity (e.g. pneumonia cases, cardiovascular and respiratory diseases).

Response

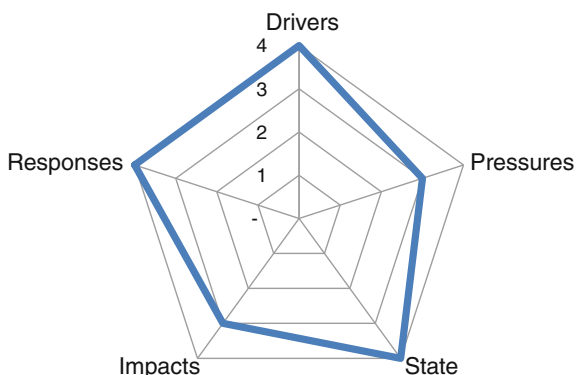
In this preliminary phase of the Regional AQP, the RIAT+ tool has been used to assess measures and costs to improve air quality. Both technological and efficiency measure are taken into account in the optimization process. Analyzing the yearly average PM₁₀ concentration on the whole Emilia-Romagna, a Pareto curve was obtained, the points of which represents different optimal combinations of reduction measures. The analysis of the Pareto curve shows that a significant reduction of NH₃ should be reached acting on agriculture macro sector, while NO_x reduction should be obtained through transport and other mobile sources macro-sectors. Actions on residential heating should be promoted to reduce a large part of primary PM₁₀ component.

RIAT+ gave also a detailed list of measures to obtain these reductions. The combination of different runs with single or multi-pollutant optimization objectives leads to the following list of priority measures to be implemented:

- Energy efficiency measures in the residential sector including improved fireplaces;
- High efficiency oil and gas industrial boilers and furnaces in manufacturing industry;
- Significant replacement of old heavy and light duty diesel vehicles with newer Euro5 and Euro6 compliant), as well as an increase of the limited traffic zones and cycling paths;
- Replacement of oldest construction and agriculture vehicles.

The overall plan may thus be represented by the chart in Fig. 3.25.

Fig. 3.25 Radar chart for Emilia-Romagna preliminary AQP (levels: 4 = high; 3 = medium; 2 = low; 1 = not considered; 0 = N/A)



3.3.3 AQP for the Warsaw Agglomeration

Description of the AQP

Warsaw has about 1.7 million inhabitants and is the largest and one of the most congested cities in Poland. This is mainly due to the lack of a real bypass road, so most of the traffic is routed through city streets, which are quite narrow in many areas. The Warsaw metro is one of the newest subway systems in Europe, however it has only one line so far. Building activities for the second line—which is being currently realized—constitutes an additional disruption in city traffic. In general, bicycle routes are scarce, being well organized only in a few districts. As a result, according to the latest assessment (Deloitte 2014) each Warsaw's dweller loses on average a month of salary a year, due to time spent in traffic congestion.

The first Air Quality Plan for Warsaw was issued due to the exceedances of PM10 and NO₂ limit values in 2004. The road transport sector (SNAP07) has the biggest share in all pollutants concentrations, but there are a few districts with a significant share of residential heating. In general, the contribution of transport emissions to PM concentrations is constantly growing. Beyond the exceedance zones, the pollutants inflow from outside of the agglomeration has an important share, at times being the prevailing one.

This AQP study was performed for the years 2004–2007. Furthermore, plans concerning B(a)P (2007) and PM2.5 (2010) were also established. Warsaw agglomeration zone is considered as a hot spot with problems in terms of exceedances of the NO₂ and PM guidelines of the EC Directive. A new AQP is currently being implemented (up to the end of 2016).

Drivers/Pressures

The Air Quality Plan (AQP) for Warsaw takes into account national, regional and local strategies and applies bottom-up approach, therefore the complexity of the DRIVERS block is high (level 4). The main local activities are: road transport, residential heating, energy production and industry.

The emission database was generated by EKOMETRIA Agency. For traffic, hourly emissions for a road network were calculated as a function of traffic volume, road characteristics and fleet composition, based on the data from the Warsaw's Boards of Urban Roads and of Public Transport (250 m × 250 m resolution). Residential emissions were calculated based on the local information on residential units not connected to the city central heating system, their furnace type and fuel used (coal, coke, gas, oil, wood) (250 m × 250 m resolution, as well). For the industrial emissions a detailed emission inventory (compiled by the Regional Inspectorate of Environmental Protection in Warsaw) with stack level data was used. The complexity of the PRESSURES block is thus also high (level 4) as emissions were calculated with a fine resolution in space and time, using a bottom-up method.

State

To determine the NO₂ and PM₁₀ concentrations a chain of models was used. The concentrations for the study area (covering the agglomeration and its 30 km diameter surroundings) were calculated with a CALPUFF (<http://www.src.com>) Gaussian puff model setup (discrete receptors were used) with decreasing resolution from 1 km (for city surroundings) to a very high 250 m resolution (for the agglomeration itself). Regional (Voivodeship) background concentrations were calculated at a resolution of 7 km using the CAMx Eulerian chemical transport model (Environ 2006) and included monthly varying boundary conditions also for aerosols derived from the EMEP Unified model (50 km resolution, monthly averages).

Operational model evaluation was carried out with the set of statistical metrics proposed by Juda-Rezler et al. (2012).

The features of CALPUFF model also allowed to compute the contribution of different source categories to the air pollution in the study area (source-apportionment).

In summary, the level of complexity of the STATE block can be considered high (level 4).

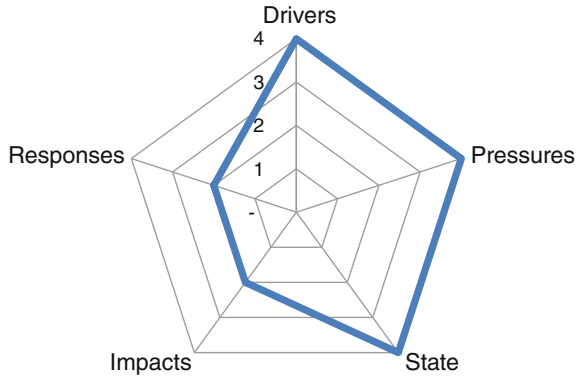
Impact

In the AQP for Warsaw, the human health effects were not directly considered, and indirectly measured, as determined by the exceedances of limit values for the protection of human health, according to the EU Directive. The analysis was based on yearly average concentrations for NO₂ and both yearly and daily averages for PM₁₀ concentrations. Thus, the IMPACT assessment block level is 1.

Response

In this study a preliminary list of economically and/or socially and politically feasible measures was drafted and subsequently extended and screened based on expert opinion and previous experience with respect to the effectiveness of the individual measures. Besides the measures, also a map of hot spots was provided for which the measures should be applied. The finally proposed measures were split into two groups:

Fig. 3.26 Radar chart for the AQP for Warsaw
 Agglomeration (levels:
 4 = high; 3 = medium;
 2 = low; 1 = not considered;
 0 = N/A)



1. Measures to be implemented to the residential emission:
2. Connection of individually heated houses to the municipal heating network: This measure is proposed for 4 districts, covering approximately 1 % of the agglomeration area, with approximately 13,000 inhabitants.
3. Measures to be implemented to the road transport emission: Improvement of public transport network by building of 2 ring roads: City Centre Ring Road & City Ring Road (up to 2020) and establishment of a low emission zone in the City Centre.

Implementation of the first measure alone will reduce total PM10 emission in the zone by as much as 21 %, while implementation of the second will reduce total PM10 and NO₂ emissions in the zone by 30 and 53 %, respectively.

For each of proposed measures differences in concentration were calculated (scenario analyses).

The study did not use either source apportionment or an optimization procedure to derive the set of abatement measures Given that the RESPONSES block is based on expert judgment and scenario analyses, its complexity appears to be relatively low (level 2) and the overall AQP chart may be represented as in Fig. 3.26.

Acknowledgments This chapter is partly taken from APPRAISAL Deliverables D2.2, D2.3, D2.4, D2.5, D2.6, D2.7, D4.2 (downloadable from the project website <http://www.appraisal-fp7.eu/site/documentation/deliverables.html>).

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