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foR Assessment
of Integrated Strategies
At regional and Local scales

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Summary

This document synthetizes the results of the first year project activities. Starting from the background expertise of the partners and partly from the plans collected in the WP2 (through the IAM database), the main project finding is the proposal of an Integrated Assessment Modelling (IAM). The proposed IAM framework (designed also to describe the different approaches gathered in the WP2 database) is structured in interconnected modules, and considers as additional dimensions of the problem the “synergies among scales” (from regional, to national and European) and the “uncertainty analysis” (to evaluate and propagate uncertainty in the various modules composing the framework).
With the definition of different “levels of implementation complexity” for each of the DPSIR modules, the framework suggests, to policy makers using IAMs, in which direction to develop and extend their IAM implementations, and how to better design Air Quality “Plans and Programmes”.

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1. Background and motivation

The recent reports on the Thematic Strategy on Air Pollution ([1], [3]) show the evolution of compliance from a base year of 2010 to 2025 (assuming current legislation only), the improvement for the optimised A5 so-called 'Central Policy Scenario' by 2025 and the further compliance achieved in 2030, by implementing all technical measures (MTFR). Their assessment of compliance with the annual mean NO2 limit value and the daily PM10 exceedances limit value are both shown in Figure 1 and Figure 2. In each case, the limit values used for assessing compliance are those of the current Ambient Air Quality Directive, which will potentially undergo major revision as part of the current AQPR process.

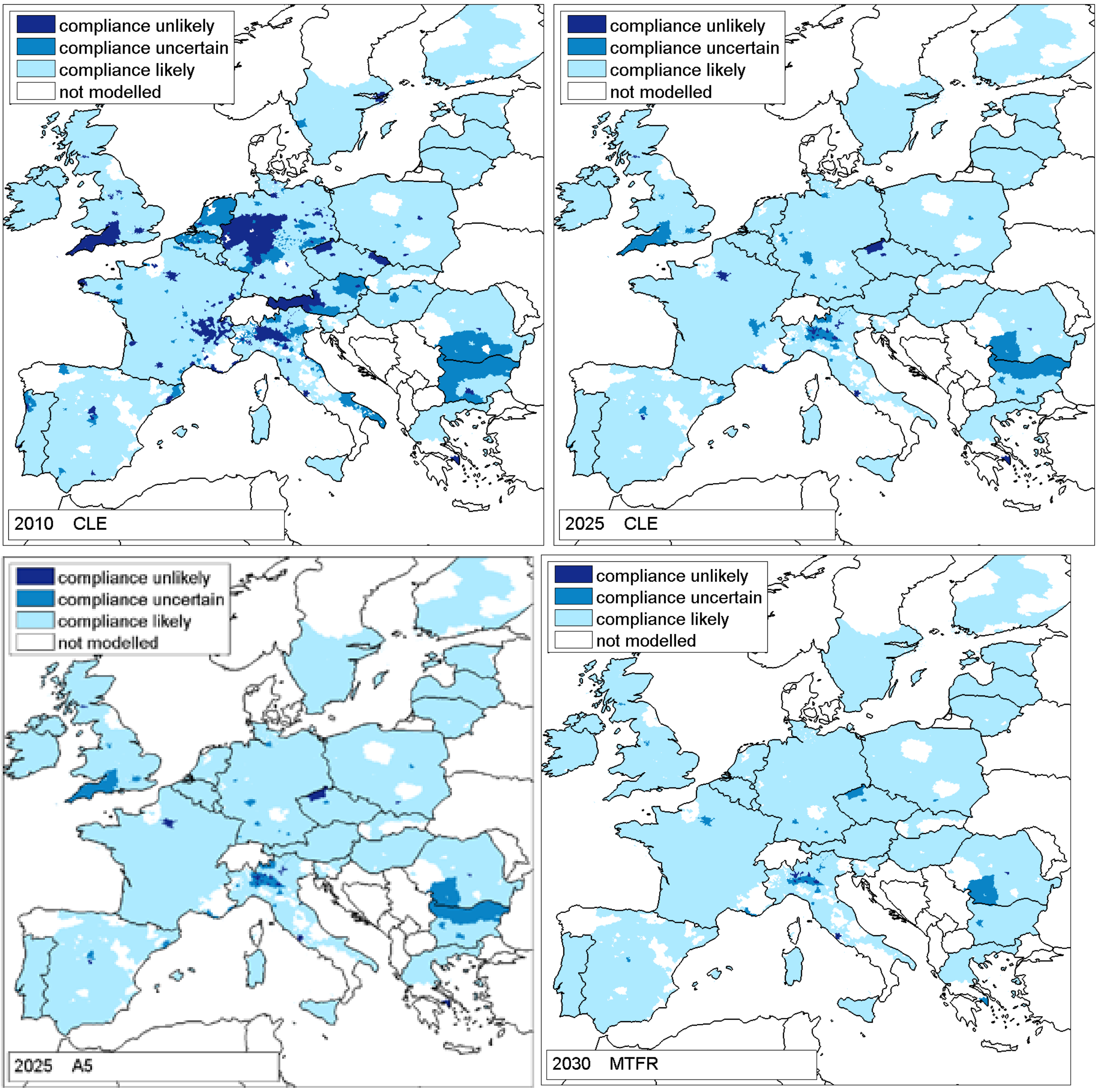

Figure 1. NO2 Annual Mean Compliance Assessment via GAINS 2013.

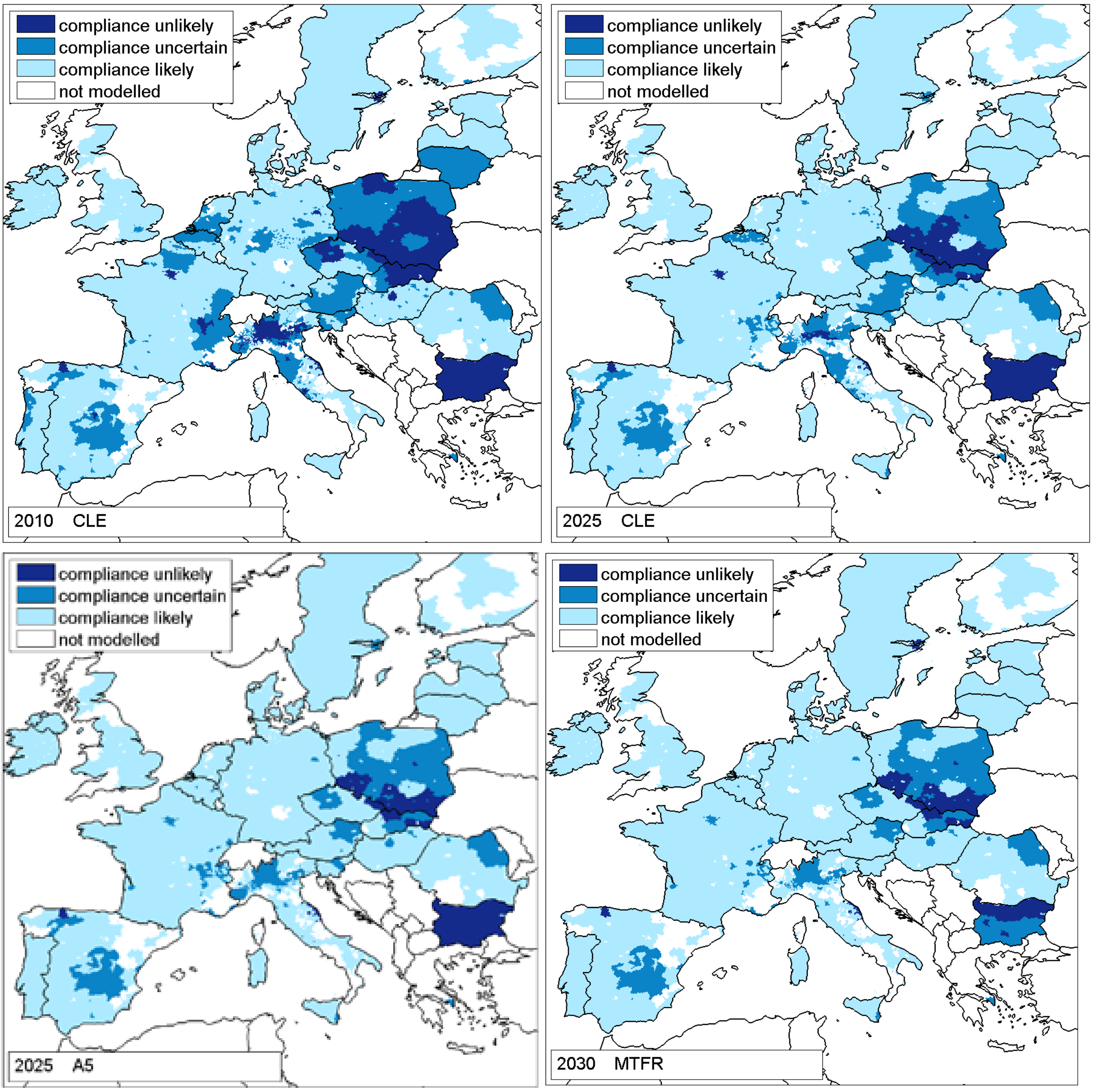

Figure 2. PM10 Compliance Assessment via GAINS 2013.

Some important observations can be made from these two series:

(i) The first observation in comparing the 2010 map with the 2025 CLE case is the clear move away from a general picture of non-compliance (2010) to more geographically **discrete remaining areas of non-compliance**. Further European wide measures (already mandated) here bring about a significant improvements in compliance especially in the EU-15 Member States. What is also clear by comparing the 2025 CLE with the 2025 A5 (designated 'central policy scenario' in Report #10) is the limited potential of further EU-Wide measures to improve compliance; this is further underlined by comparing the 2025 A5 scenario with the 2030 MTFR scenario.

(ii) Introducing tougher European-wide measures to address residual non-compliance confined to 10% of the urban zones in Europe (the extent of NO2 non-compliance according to IIASA in the 2025 CLE scenario) would likely **be significantly more costly than directly addressing the non-compliance areas with specifically designed measures based on bottom-up Integrated Assessment** using regional/local data. This has significant implications for the role of regional/local 'bottom up' approaches to develop effective Air Quality Management Plans to efficiently achieving compliance.

(iii) In this regard, some regional Integrated Assessment tools (such as RIAT, OPERA, LEAQ) with their ability to identify cost-optimised local strategies are already quantifying the cost-effective split between further European wide measures and regional/local measures. They will inevitably need to find wider application and play an increasing role in this emerging 'discrete islands of non-compliance' EU. Even at this early stage of the APPRAISAL project, the pilot questionnaire responses, as seen in what follows, highlight the timeliness of these recent developments.

(iv) A further observation comes from comparing the 2025 CLE cases with the 2025 A5 scenario. A5 is a high ambition scenario (delivering 75% of the further health benefits of MTFR for the EU as a whole). At this high ambition level for the EU as a whole, a number of individual Member States are already driven to MTFR. Yet, from an AQ compliance perspective it does not substantially change the picture from 2025 CLE. This points to an **increasing role for targeted technical and non-technical measures in order to achieve compliance. As already noted, such measures (low emission zones, special fuels for captive fleets, captive fleet retrofitting etc.) can only be appropriately designed using 'bottom up' tools**.

These observations motivate the growing interest in IA models and tools to local and regional scale.

Such interest is also due to the European and national directive requirements.
As is apparent from recitals 1 and especially 2 in the preamble to Air Quality Directive 2008/50/EC (AQD), European air quality legislation puts the main emphasis on protecting human health and the environment as a whole and stresses that "it is particularly important to combat emissions of pollutants at source and to identify and implement the most effective emission reduction measures at local, national and Community level." The basic principles have already been formulated in the former so called air quality framework directive (96/62/EC) and its daughter directives (1999/30/EC, 2000/69/EC, 2002/3/EC, 2004/1007/EC). The concept of model based air quality management is now still more in the focus of air quality management with the AQD from 2008. Thus, "Air quality plans" according to AQD's Art. 23 (formerly "Plans and Programmes") are the strategic element, to be developed with the aim to reliably meet ambient air quality standards considering not only the effect of emission reduction measure on ambient air quality but considering aspects of cost-effectiveness as well. The importance of model based approaches for air management becomes apparent again in connection with Article 22 "Postponement of attainment deadlines and exemption from the obligation to apply certain limit values" commonly called "notification for time extension". For both, air quality plans and time extension, more elaborated requirements are formulated in Annex XV compared to former regulations. The implementing decision from 12 December 2011 (2011/850/EU) reflects this clearly looking at the reporting obligations laid down there ((Article 13, Annex II, Section H, I, J and especially

K) and looking at the amount of information that has to be provided regularly. This important step forward will become real when e-reporting is entering full operation mode starting from 1 January 2014.

Neither the Directive nor the implementing decision indicates what methodology is required to devise efficient measures.

2. Review and gaps identification in air quality and health assessment methodologies at regional and local scale

The European Commission is currently reviewing the air quality legislation aiming to update health and environmental standards, to establish new actions to reduce emissions for meeting interim objectives and to take into consideration costs and benefits of these actions (http://ec.europa.eu/environment/air/review_air_policy.htm). Diagnosing the methods that are available and applied in practice to carry out a quantitative integrated assessment of the effects of emission abatement policy options on the reduction of atmospheric pollutants and on human health is an essential part of this review process.
The APPRAISAL Project addresses this need to consolidate and assess air pollution and health integrated assessment (IAM&HA) research and current practices in order to support the coming revision of EU air quality policy. One of its main purposes is to perform an overall review of the methodologies, from simple (e.g. scenario approach) to more comprehensive ones (e.g. full cost-benefit analysis), used in different countries to evaluate the impact of local and regional air quality plans and their health implications. Identifying which relevant research activities on air pollution and its health implications, especially EU funded, have been utilized is also part of APPRAISAL's main objectives.
To this end in work package 2 activities were established aiming to address this reviewing objective, more in particular focusing on:

- monitoring data and complementary methodologies to identify sources, e.g. source apportionment, in a general integrated assessment frame;
- emission abatement policies and measures planned at regional and local scales and their synergies/trade-offs with the measures implemented at the national scales;
- modelling methodologies in place across member states to assess the effectiveness of emission reduction measures at all scales; integrated assessment models to select effective air quality policies;
- methodologies to assess the effects of local and regional emission abatement measures on human health;
- techniques used to assess the robustness and uncertainties of the assessment and of the selected policies.

The diagnosing process started by defining a common and structured online database (http://test.terraria.com/appraisal/; deliverable D2.1) in which strengths and weaknesses of the different methodologies were classified and organised around the five previously identified main areas.
Thereafter this structured database was open to APPRAISAL partners and stakeholders to collect and classify methodologies and systems from member states current practices and from research funded projects. The questionnaires were specifically addressed to national contact points in EU member states and stakeholders involved in the development of air quality plans, but also to model users applying models in the frame of research projects. This database which currently contains 63 contributions from 12 member states, concerning air quality plans and research projects, was used as a key stone for the review work that resulted in the production of 5 deliverables: (i) synergies among national, regional and local approaches, including emission abatement policies (deliverable D2.2); (ii) air quality assessment, including modelling and measurements (deliverable D2.3); (iii) health impact assessment approaches (deliverable D2.4); (iv) source apportionment (deliverable D2.5);

and (v) uncertainty and robustness, including Quality Assurance / Quality Control (QA/QC) (deliverable D2.6). The analysis differentiated between the answers that were given for “air quality plans” (AQP) and those that related to “research projects” (RP). The rationale for this is that the AQP will be representative of current practice while the RP might have a broader scope since they are not necessarily aimed at drafting an air quality plan and thus may go beyond what is state of practice. Moreover, APPRAISAL reviewing relied on the expertise and knowledge of its partners and stakeholders joining all major activities on air quality and health assessment in the EU.

3. Contribution to the Air Quality Directive Review

In general the European Directive 2008/50 and more recently the Commission Implementing Decision 2011/850 do not specify what methodology is required to devise efficient measures to improve the quality of the air. The contents of the template provided for reporting however indicate that a scenario approach supported by source apportionment can be useful addressing the following:

1. Source apportionment: Which are the main emission sources responsible for the pollution, distinguishing local and regional (transboundary) contributions? With which accuracy is the emission source base case known?
2. Air quality assessment for the current situation: In which zones (location, type) are exceedances of the limit values of a pollutant observed and how large is the population that is exposed?
3. Air quality assessment for future years or emission scenario's:
   - What is the baseline level i.e. the concentration to be expected in the year when the limit value comes into force without any measures beyond those already agreed or implied by existing legislation.
   - Which measures are currently in place beyond those required by current legislation and what is their effect on the air quality?
   - Which additional measures are planned and what is their effect on the air quality?

With respect to emissions, the Directive 2008/50/EC requires an air quality plan reporting the origin of pollution (Annex XV) by providing a list of the main emission sources responsible for pollution (map) and the total quantity of emissions from these sources (tonnes/year). The Commission Implementing Decision of 12 December 2011 requires the AQP to report on the emission scenario and the total emission for both the baseline and for the projection as well as the reduction in annual emissions due to the applied measures.
In fact, the Directive acknowledges the importance "to identify and implement the most effective emission reduction measures at local, national and Community level" (article 2). This presumes that:

1. the emission inventory used for the AQP is sufficiently detailed to allow mapping measures to the specific emissions managed at the different administrative levels that have to be considered.
2. the costs of emission reduction technologies are available.
3. a suitable optimization approach to select effective policies can be implemented.

Emission inventories and projections as needed for the assessment and planning at the local scale are currently developed ad-hoc. It is recommendable to take an initiative to harmonize the criteria and the procedures for developing such local emission inventories. Further fixing and specifying these procedures might improve emission data necessarily needed for air quality modelling and in consequence will improve modelling results for this part.

Moreover, the effectiveness of any type of remediation measure strongly depends on the reliability of the pollution source identification and quantification process. Hence, the use of methodologies with minimum biases and uncertainties certainly contributes to focusing valuable resources and time on the most contributing sources in the area of interest.

Article 25 of the Directive deals with the problem of transboundary air pollution. To be effective an air quality plan should appropriately take into account the contribution of sources outside the zone considered in the plan. This is especially true for long lived and secondary pollutants and where the zone that is modelled is small as in local and street level models. In those cases larger scale modelling is needed to properly incorporate the effect of the boundary conditions or at least a sensitivity analysis should be required to quantify the importance of the boundary conditions. If results at different scales are combined, the consistency of the inputs used should be checked and care should be taken to account for differences between the models.
On the other hand the problem of transboundary air pollution can be read as the issue to assess the impact of regional-local emissions, in other words, to quantify the effective potential of regional-local policies in a specific domain. Methodologies should be formalized and developed to fill this gap.

Integrated Assessment Modelling (IAM) should support the air quality authorities in selecting efficient mitigation strategies by providing tools for assessing and solving air quality planning problems at different spatial scales. AQ modelling is the IAM component explicitly mentioned in EU legislation. The Directive recognizes that modelling can be used in combination with measurements to obtain a better representation of the spatial distribution: “Where possible modelling techniques should be applied to enable point data to be interpreted in terms of geographical distribution of concentration” (Article 6). As population density is not necessarily homogeneous within a zone, the air quality plan report could be improved by replacing the single values for the concentration and population within the zone in the report by a map showing the spatial distributions for the concentration and the population.

As the role of modelling in understanding the influence of physical and chemical processes on the dispersion and transformation of pollutants is increasingly being recognised, and MS are already using models in their current assessment techniques it is recommended to further promote the use of modelling tools in the scope of the nowadays AQD revision. Moreover, there is no alternative to modelling for assessing the effectiveness of emission reduction measures in future years. Thus, modelling should become an essential part of air quality planning and any such modelling based report should include a complete description of the model and inputs used as well as an evaluation to quantify the reliability of the AQ assessment.

Today many different modelling tools exist that are being used for AQ assessment and planning so that there is currently no obvious standard model that could be imposed as a ‘preferred’ model for each of the different scales and pollutants considered. Preferably however the model as a whole or at least its subcomponents should have undergone a scientific peer review or a report should exist in which the model has been submitted to a diagnostic analysis.

The need to incorporate uncertainty estimation in air quality modelling, health and air quality plan impact assessment is also recognised by policy makers.

Another important issue for a proper model application when developing an AQP, which is currently not covered by the AQD, concerns the representativeness of the simulation period for air quality planning.

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 or proximity measures does not seem to reflect the personal exposure. Estimating detailed personal exposure to air pollutants should be addressed more. Indeed, individual exposure studies should include parameters affecting their exposure (cultural, socioeconomic, ethnic, etc.). Although most health outcomes are not confined to a single pollutant, studies typically focus on the risks of single pollutants and do not consider the mixture of pollutants. There is a clear need to develop methods for evaluating and managing the effect of the air pollution with a multi-pollutant approach.

The main contribution is the formalization of an Integrated Assessment Framework to design (see the following section and for more details the deliverable D3.1) and to implement Air Quality Plans (guidelines provided by WP4).

4. Integrated Assessment Framework Design

Limitations of the currently available assessment methods identified in the IAM&HA review, as well as key areas to be addressed by research and innovation, are the inputs to the design of the decision framework defined in WP3 (deliverable D3.1)
In particular, the **WP3 provides a methodological approach** following a the DPSIR framework classifying (in broad terms) two possible decision pathways:

- **open-loop, or scenario analysis.** This is the approach mainly used at the moment to design “Plans and Programmes” at regional/local scale, selecting emission reduction measures based on expert judgment or Source Apportionment (see Deliverable D2.6), and testing the measures effect through scenario analysis (see Deliverable D2.3). It is clear that this approach does not guarantee that cost-effective measures are going to be selected, and only allows for “ex-post evaluation” of costs and other impacts. This approach goes in the directions of providing Air Quality improvements with “measures not entailing disproportionate costs” (as said in the 2008/50 Directive), since this is implicitly considered when selecting the set of measures under consideration.
- **closed loop, or optimization.** This approach allows for the selection of cost-effective measures for air quality improvement, through the solution of an optimization problem. In this frame it is clear how (during optimization) a “feedback” is provided on the effectiveness/efficiency of the measures, in terms both of costs and of effects; this allows for the selection of the set of measures that should be applied to improve air quality in an effective way. The concept of cost-effectiveness of measures is a key one, and was already addressed in [4], in which the authors proposed the “Establishment of a framework to identify (cost)-effective measures” as an option to improve the AQ planning process. Cost-effectiveness of measures is also cited e.g. in the Italian transposition (D.Lgs 155/2010) of 2008/50 Directive.

THE DPSIR FRAMEWORK CONCEPT

Starting from the need to provide a methodological support for the implementation of “air quality plans” at regional/local scale, and using both background knowledge and the data gathered in the WP2 (in which a Database of IAM approaches at regional and local scale has been compiled) the aim is to define the key elements of an Integrated Assessment Modelling framework. These elements are created considering the EEA DPSIR ([1]) and a holistic approach, that should:

- Be structured in a modular way, with data flows connecting each framework building block;
- Be interconnected to higher decision levels (i.e. national and European scales);
- Consider the approaches available to evaluate IAM variability (taking into account both the concept of “uncertainty”, that is related to “variables/model results” that can be compared with real data, and the concept of “indefiniteness”, related to the impacts of future policy decisions)
- Be sufficiently general to include the experiences/approaches gathered in WP2

database
- Show, for each module of the framework, different "levels of implementation complexity".

The last two points of the previous list are quite important. The idea is that, looking at the different "levels of complexity" defined for each DPSIR block, one should be able to grasp in which "direction" to move to improve the quality of his own IAM implementation. This should translate into the possibility to assess the pros and cons for enhancing the level of detail of the description of each block in a given IAM implementation, and thus compare possible improvement with the related effort. The final idea is to be able to classify each plan contained in the WP2 database, with the aim not to provide an assessment value of the plans themselves, but to show possible "directions" of improvement, for each building block of each plan.

The DPSIR scheme helps "to structure thinking about the interplay between the environment and socioeconomic activities", and "support in designing assessments, identifying indicators, and communicating results" ([1]). Furthermore, a set of DPSIR indicators has been proposed, that helps to reduce efforts for collecting data and information by focusing on a few elements, and to make data comparable between institutions and countries [1].
Starting from these definitions and features, in the frame of the APPRAISAL project, it has been decided to adapt the DPSIR scheme to Integrated Assessment Modelling (IAM) at regional (considering regional as a domain of few hundreds of kilometres) scale. So the DPSIR scheme has been translated into the framework illustrated in Figure 3.

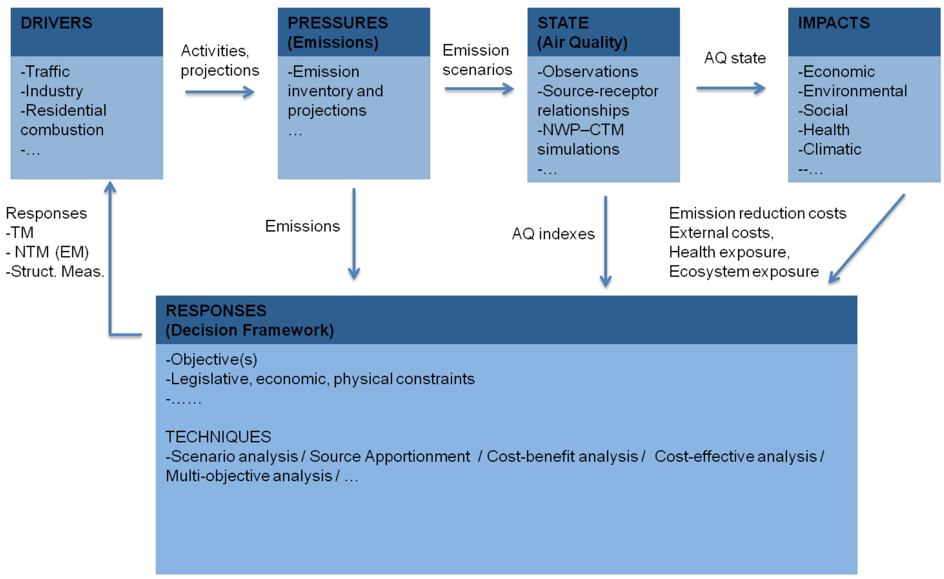

Figure 3: the DPSIR scheme adapted to IAM at regional/local scale. "Synergies among scales" and "uncertainties" are additional dimensions of the scheme.

In particular, in the scheme in Figure 3, the meaning of each block is as follows (quoting from EEA glossary):

- DRIVERS: this block describes the "action resulting from or influenced by human/natural activity or intervention". Here we refer to variables (often called "activity levels") describing traffic, industries, residential heating, etc…

- PRESSURES (Emissions): this block describes the "discharge of pollutants into the atmosphere from stationary sources such as smokestacks, and from surface areas of commercial or industrial facilities and mobile sources, for example, motor vehicles, locomotives and aircrafts." PRESSURES depend on DRIVERS, and are computed as function of the activity levels and the quantity of pollution emitted per activity.

- STATE (Air Quality): this block describes the "condition of different environmental compartments and systems". Here we refer to STATE as the concentrations of air pollutants resulting from the PRESSURES defined in the previous block. In IAM implementations, STATE can sometimes be directly measured, but more often it is computed using some kind of air quality model.

- IMPACT: this block describes "any alteration of environmental conditions or creation of a new set of environmental conditions, adverse or beneficial, caused or induced by the action or set of actions under consideration". In the proposed framework, we refer to IMPACT on human health, vegetation, ecosystem, etc… derived by a modification of the STATE. Again the calculation of the IMPACT may be based on some measure, but normally requires a set of models (e.g. health impacts are often evaluated using dose-response functions).

- RESPONSES: this block describes the "attempts to prevent, compensate, ameliorate or adapt to changes in the state of the environment". In our framework, this block describes all the measures that could be applied (to Drivers = structural and energy measures and to Emissions = end-of-pipe measures), at a regional/local scale, to improve the STATE and reduce IMPACTS.

It is worthwhile to note that Figure 3 scheme is integrated with "higher" decision levels. This means that for each block some information is provided by "external" (not described in the scheme) components. For instance, the variables under DRIVERS may depend on GDP growth, population dynamics, etc…; the STATE may also depend on pollution coming from other regions/states; or the RESPONSES may be constrained by economic factors. Each block can thus be seen as receiving external forcing inputs since they cannot be influenced (or just marginally) by the actions under consideration. More specifically, all regional and local plans are to be compatible with national and international policies.

5. Key areas to be addressed by research and innovation

1.1 Drivers

There were considerable uncertainties identified for the DRIVERS block assessment framework for all the main emission source sectors contributing to local level, especially for road traffic, non-road traffic and machinery and residential combustion.
Of these, most severe uncertainties were estimated for residential combustion sector, more specifically residential wood combustion. Furthermore, residential wood combustion has been recently found as one of the major contributors to fine particle and other organic air pollution in many urban areas in Europe. Future research needs for residential wood combustion DRIVERS block assessment concern mainly:

- Activity amount assessment
- Combustion appliance and user's practice information
- Spatial assessment (i.e. gridding)

A more general new future research line related to DRIVERS should be devoted to the integration of bottom-up and top-down inventories. In fact at the moment there are inconsistencies between bottom-up (local/regional) and top-down (EU level) approaches and tool, and this can prevent the implementation of a fully integrated approach connecting various governance scales. Also, while activity levels (DRIVERS) are usually available at international/national level, this is not the case at regional/local scales, where only emission inventories (PRESSURES) are compiled; this aspect can also cause inconsistencies among data provided at different levels of governance.

A further key issue for future research is related to the estimation of how the economic sectors will develop and adapt in the future, also taking into account the current downturn.

1.2 Pressures

About emissions, key areas to be investigated by research and innovation concern various topics.

General methodology of emission inventories: there is the need for

- harmonization of bottom-up and top-down approaches, used at different scales, o create emission inventories;
- approaches to improve the quality of the emission inventories (inverse modeling for emissions improvement, new model chains to describe projections, …) ;
- disaggregation coefficients (spatial and time ones) to be adapted to regional and local scales, especially for CO, PM and NH_3 emissions.

Input data related to the calculation of emission projections, with the need for

- Bottom-up and top-down emission inventories integration and consistency, to allow "seamless" integration of measures from local to EU level, and vice versa;
- consistency of all data has to be improved; transport sector has still some missing

data concerning the composition of the real vehicle fleet, especially concerning the split between the different categories of age of vehicles and the type of engines (gasoline/ diesel);
- for biogenic emissions, the landuse, the meteorological data and the topography (slopes and orientation) need finer description according to the species which can effectively be taken into account mostly in mountainous and coastal areas.
- distributions of the different species of forest trees and plants adapted to the areas of study;

Emissions factors, that need to be more specific to the effective sources, as for
- PM components (e.g. BC, metal, UFP, wildfires)
- Other gaseous pollutants (VOC, SLCP, reactive nitrogen)
- HFC emissions from refrigeration and air conditioning equipment and the NO2 emissions from cars equipped with catalytic converters;
- NO2 from agricultural soils due to the use of fertilizers;
- totally unknown sources, as peatlands CH_4, and very little known as swamps and wet zones;
- aggregated emission factors used for road traffic: it has to be constantly improved because of the constant changes and evolutions of the real vehicle fleets at local, regional and higher levels. Measurements have to be performed in situ to fit real traffic situations;

1.3 State

Key areas to be addressed by research and innovation, in the STATE module, are:
- Refinements of air quality assessment and exposure. Research directions could be devoted to better represents local scale in AQ modelling for IAM. This could be done through the use of CFD in AQ study for local and street level modeling or by developing the use of sub-grid scale model and sub-grid parameterization in CTM. One of the challenging issue in local scale modelling is related to local scale emissions. Concerning meteorological models, a better use of urban module in meso-scale model would benefit to regional and more local studies, and help to link model at different scales.

- Monitoring based on the joint use of ground-based and remote-sensing methods, to assess the “current” AQ situation

- Better understanding of sources of various fraction of PM

- Climate change considerations. Long-term study integrated assessment should take into account both air quality and climate change issues. In this framework, it is important to develop the use of future meteorological simulation for running AQ models. More extensively, a challenge is the development in IAM of online chemical transport model, which allow the study of feedback interactions between meteorological/chemical processes within the atmosphere, and to take into account AQ/climate change interactions.

- Validation of AQ simulation for future policy scenarios. It is important to work to develop a common methodology to combine measurement data in a reference year with modelling results for future policy scenarios.

- Surrogate modelling. Issues are related to extend surrogate model approaches, to properly describe nonlinearities in secondary pollution concentrations and improve the "Design of Experiments" (that is to say, the phase that allows for the choice of set of Chemical Transport Models simulations required to train surrogate models).

1.4 Impacts

Key areas to be addressed by research and innovation, in the IMPACTS module, are related to:

- Refinements of air pollution impact on health and exposure
- The detailed reconstruction of the population patterns in the domains under study; in particular it is important to study how to correctly reconstruct spatial and temporal patterns of the population, to compute the real exposure of the population (i.e., reconstructing how population is moving during the day to go to work, school, etc.. and not using "average" population patterns). At the moment, "static" population maps are often used to perform HIA studies.
- Detailed and localized dose-response functions, at the moment often related to average values at EU level, and not properly describing local features.
- Mortality and morbidity factors of long term NO_2 and O_3 exposure
- Effects of NO_2 exposure in particularly polluted environments (i.e. busy roads) and short-term exposure to extreme levels
- Environmental impacts of reactive nitrogen and interlinks with climate/global change

1.5 Responses

Key areas to be addressed by research and innovation, in the RESPONSES module, are:

- Refinements of mitigation and adaptation options and measures.
- Development of methodologies to assess the impact of regional-local emissions and to quantify the effective potential of regional-local policies in a specific domain.
- Inclusion of socio-economic aspects.
- Integration of AQ aspects into other policy areas.
- "Efficiency measures". The use of these measures is now limited to scenario analysis, because it is very difficult to estimate the costs of such measures, particularly, because they impact many other sectors beside air quality. For instance, car sharing has the potential to reduce not only exhaust emissions, but also accidents and noise. How can the overall cost be associated to the benefits in such diverse sectors? It will be necessary to further investigate such actions. Also, an additional complexity is related to the use of these measures in an optimization frameworks; from this point of

view, new formal approaches should be devised.

- IAM nesting. As it is already done with CTMs, a research direction could be devoted to developing IAMs nesting capabilities (both one-way and two-way nesting) to easily manage EU/national constraints at regional level, and at the same time to provide feedbacks from the regional to the EU/national scale.
- IAM approaches harmonization and guidelines. It is important to work to develop guidelines and harmonize approaches to implement IAMs. This work will partly be done in the frame of APPRAISAL, but it is necessary to continue these activities in order to guarantee that local/regional plans can be compared and integrated, when necessary.
- Air Quality and Climate Change issues. At the moment, national climate change policies simply dictate some constraint to local air quality plans, but it is well known that also local air quality policies (e.g. the reduction of aerosols) can have consequences in terms of climate change. In a “resource limited” world, the aspect of maximizing the efficiency of the actions (to get win-win solutions for AQ and CC) will become of extreme importance and this requires a guideline to integrate climate change policies (normally established at national or even international levels) with air quality plans developed at regional/local level.
- Dynamics. All current approaches are static, in the sense that they devise a solution to be reached at a given time horizon (say, for instance, in 2020). However, the system we would like to control is non-stationary (see the effect of the current economic crisis) and thus it may be more supportive for decision maker to know where to currently invest with the highest priority in order to follow a certain path to the target condition, but with the ability of modifying the decisions in case of system evolution differing from the projected one. This involves the necessity of flexibly adding into the plans the advent of new technologies and the ability to determine the cost of scrapping old plants to substitute them with newer ones. This essentially means designing a new generation of Decision Support Systems to be intended more as control dashboards, than planning tools.
- Benefit evaluation. Related to the dynamic problem is the issue of how to evaluate future benefits of air quality investments. If economy has defined since long how to account for investment costs lasting for a period in the future, this is more difficult for benefits that are not monetizable or last in the future for an unknown period. How can we account for a 20% improvement of an AQI ten years from now? What is the benefit from a reduction of PM_{10} today that will decrease cardiovascular problems in a population sometime in the future?

Moreover some ideas of the issues that should be further investigated are:

- How does the decision model approach impacts on effective planning design?
- How does the choice of a given optimization algorithm biases the determination of effective policies?
- How do different sets of indexes (AQIs for human, ecosystems and materials exposure) impact policy design?
- Which is the sensitivity of the solutions to a decision problem to different assumptions and uncertainties on emission and emission reduction strategy?
- Which are the approaches most suitable for different scales?

- How can the uncertainty (or robustness) of the proposed solutions be evaluated and be transferred to decision-makers to effectively support their decisions?

6. References

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